2015 International Congress on Ultrasonics

Metz, France,
May 11-14, 2015

hosted by

Georgia Tech EUROPE | Lorraine Georgia Institute of Technology

in collaboration with

Sfa

Abstract Book 2015 ICU - Metz, France

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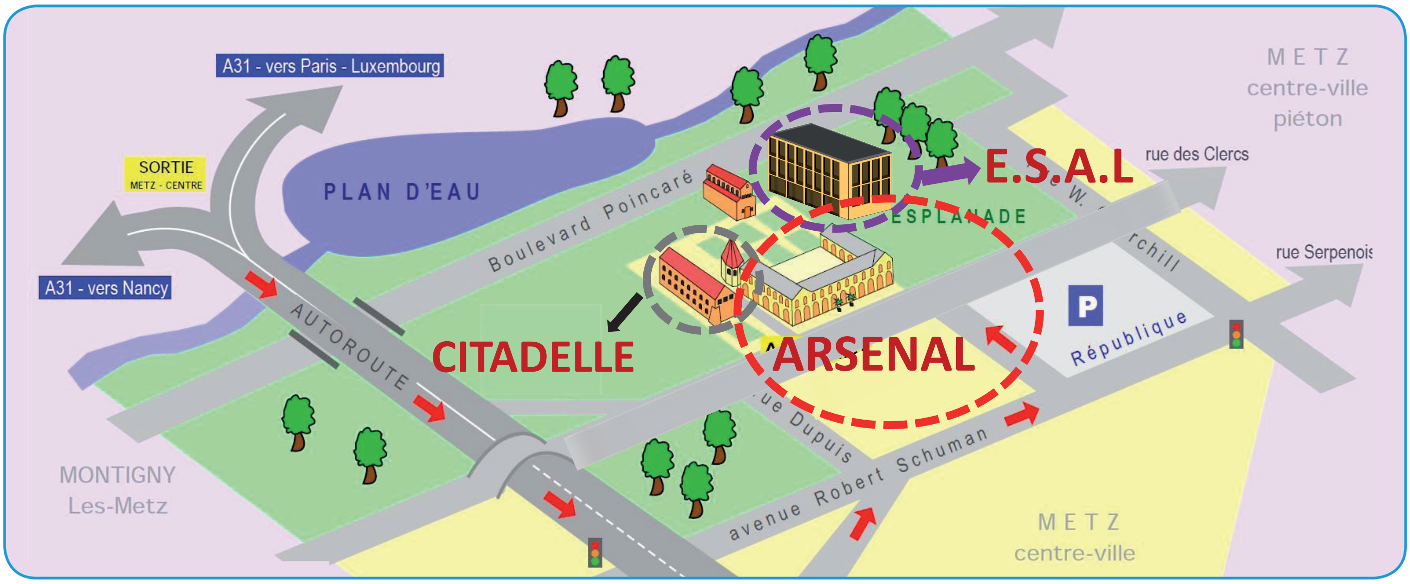
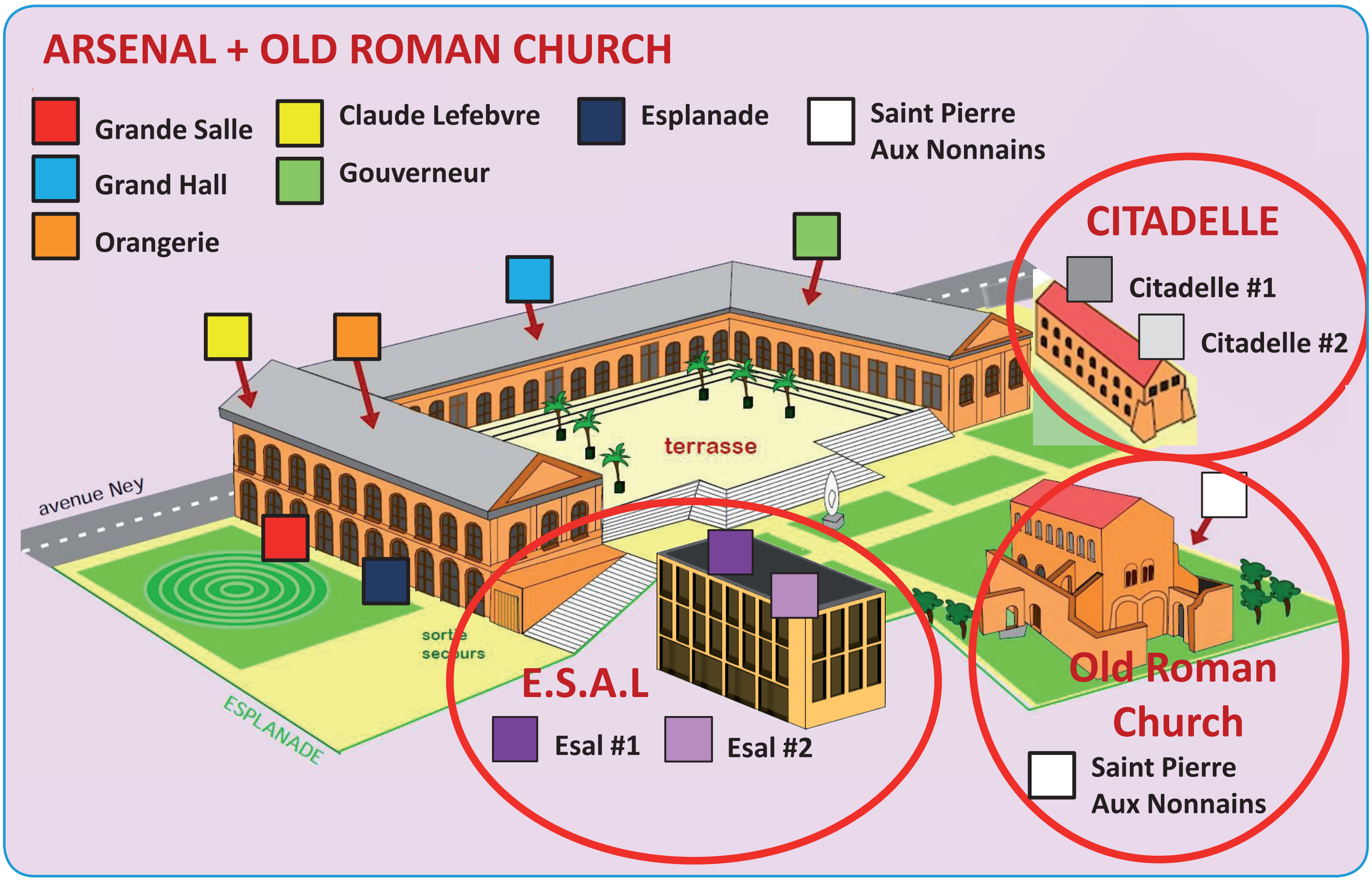
Metz, France, May 11-14, 2015
www.2015icu.fr

Meeting facilities at: Arsenal - E.S.A.L. - La Citadelle





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2015 International Congress on Ultrasonics

11-14 May 2015 - Metz, France

www.2015icu.fr

Word from the 2015 ICU President

Dear Participants,

Welcome to the 2015 International Congress on Ultrasonics (2015 ICU), hosted by Georgia Tech Lorraine in collaboration with the French Acoustical Society. It is with thankfulness to everyone at all levels who have been involved in the realization of the scientific and social program that we are offering you a congress program book for the coming week. It is equally with sincere gratitude that we welcome all participants and sponsors without whom this week would not be possible.

The 2015 International Congress on Ultrasonics is part of a long tradition and sequence of congresses, dating back to 1993, including the WCU (the World Congress on Ultrasonics), UI (Ultrasonics International) and "UI+WCU" later renamed as ICU. The event takes place every two years. For 2015 ICU we are welcoming **over 650 participants from 53 countries**. More than **30% are students**. During the congress, we are expecting **almost 600 presentations**, i.e. 410 oral presentations and more than 170 poster presentations. In total we have **95 scientific sessions** with a maximum of **9 parallel sessions**. The congress has invited 9 Plenary and Keynote Speakers. During the ICU congress we also welcome the 12th AcoustoFluidics Congress organized as an integral part of ICU by USWNet, the Ultrasonic Standing Wave Network. In addition a special session on Acousto-Optics is devoted to the career of Oswald Leroy. Congress proceedings will be published online in Elsevier's Physics Procedia.
The location of the congress is the Arsenal of Metz, France. The Arsenal is a cultural venue dedicated specially to Classical and Erudite music and is located near the Esplanade garden in Metz, capital of the Lorraine region, France. In September 2010, Classica magazine listed the venue among the 20 most beautiful concert halls in the world, qualifying the Arsenal as an 'acoustic diamond'. The Arsenal is part of a cultural complex along with the chapel of the Knight Templars, constructed in the 13th century; the ancient Saint-Pierre-aux-Nonnains basilica, a Roman basilica of the 4th century, refurbished as showroom and concert hall for the Gregorian chant, respectively.

Our social program consists of an opening ceremony with a musical performance by Françoise Vanhecke on Monday morning, a Welcome Reception on Monday evening, a Musical Concert on Tuesday evening, a Gala Dinner on Wednesday evening and a Closing Ceremony on Thursday afternoon.
Special thanks to our sponsors : ARCELOR MITTAL, INSPECTION TECHNOLOGY EUROPE BV, KIBERO GmbH, MISTRAS Products & Systems, OLYMPUS Corporation, POLYTEC, PVA Tepla, S-SHARP, XARION Laser Acoustics with the financial support of FEDER, Conseil Régional de Lorraine, Le Conseil Général de Moselle, Metz Métropole.

Last but not least I would personally like to express my appreciation for the help and the technical support offered by Didier Cassereau in handling registration, abstract submission and session organization.
On behalf of the International Board of ICU, the French Acoustical Society and Georgia Tech Lorraine represented as members of the Executive Committee, the Scientific and Technical Committee, the Local Operations Committee and everyone else who has in one way or another helped with the organization.

Nico F. Declercq
2015 ICU President

ABOUT THE HOSTING ORGANIZATIONS

Georgia Tech Lorraine

Georgia Tech-Lorraine (GTL) is the European Campus of the Georgia Institute of Technology (G.I.T). Georgia Tech is a public university, worldwide renowned for creating tomorrow's leaders in engineering, science and technology. Georgia Tech is consistently ranked among the best universities in the United States and the world, ranked #6 on Shanghai world ranking. Georgia Tech-Lorraine (GTL) was established as Georgia Tech's first international campus in 1990 in Metz, France, a city recently named by the New York Times as one of the top 44 places to see in the world. Centrally located in eastern France along the Luxembourg and German borders, GTL is less than 90 minutes by train from Paris. Being a highly innovative institution offering year-round undergraduate, Masters and PhD programs, GTL is also home to a strong sponsored research program in key technological areas. GTL fosters the flow of new ideas, creates new opportunities, and develops valuable qualities in our students, such as global leadership and innovative thinking. In today's global economy, Georgia Tech-Lorraine plays a determining role in fulfilling the goals of the Georgia Institute of Technology as stated in its strategic plan. Over 3000 undergraduate and MS students (CS, ECE, and ME) have spent a semester or more on the Metz campus, enriching their education with a global perspective.

Unité Mixte Internationale (UMI) is an international joint laboratory between Georgia Tech and the French 'Centre National de la Recherche Scientifique' (CNRS). Research activities are primarily focused on Non-linear Optics and Dynamics, Smart Materials, Computer Science. Research activities entail: 55 researches, around 40 PhDs, ANR programs, industrial contracts, European Contracts. An open Lab on "Material & process" had been created in 2011 with the largest car manufacturer in France: PSA Peugeot Citroên.

The "Institut Lafayette": is an innovation platform created to develop applications and products in optoelectronics and advanced semiconductor materials within a complete innovation chain starting with a concept, passing through the elaboration of a material, the qualification of prototypes and components, to the validation of the up-scaling of its manufacturing. The new technologies as developed are put on the market by an array of technology transfer services and commercialization tools, serving as a catalyst for economic development in the region, based either on the involvement of the industry groups and entrepreneurship . The *Institut Lafayette* is a third major development of Georgia Tech Lorraine growth in Metz. It is developed with the contribution of two significant institutes in Atlanta *Entreprise Innovation Institute* and *Georgia Tech Global*; and supported by *FEDER, État Français, Conseil Régional de Lorraine, Conseil Général de la Moselle* and *Metz Métropole, Georgia Institute of Technology, Georgia Tech Lorraine*.

SFA The French Acoustical Society

The French Acoustical Society (La Société Française d'Acoustique - SFA) gathers French acousticians from public research and industry. Created in 1948 by Yves Rocard, it includes more than 800 individual members (researchers, teachers, engineers, musicians, audiologists, architects...), as well as institutional members (industrial companies and specialized research laboratories). Its vocation is to facilitate the circulation and any scientific and technical information as well as the contacts between research laboratories and industrial R&D Centers. The activities of the SFA include:

- Organization of CFA congresses and workshops. These events can be regular (the French Congress of Acoustics takes place every even year) or be more specifically organized to deal with novel subjects ;
- Promotion of acoustics. The SFA is a natural interlocutor of numerous national authorities (for example, the

National Noise Council or various standardization committees). It promotes the education in acoustics, notably by providing the list of all existing training courses on its Web site. It supports students' participation at international congresses through scholarships ;

- Diffusion of information through its periodic bulletin or through the magazine "Acoustique & Technique", published by the Noise Documentation and Information Center and in which the SFA participates actively ;
- Relations with other national scientific societies, because acoustics is in the crossroads of numerous disciplines (solid or fluid mechanics, signal processing, cognitive psychology, speech...)
- Relations with the equivalent societies of foreign countries. The SFA is a founding member of the European Acoustics Association (www.euracoustics.org), which gathers thirty European societies. This association edits one of the major world scientific reviews of acoustics (Acta Acustica united with Acustica - http://www.acta-acustica-united-with-acustica.com).

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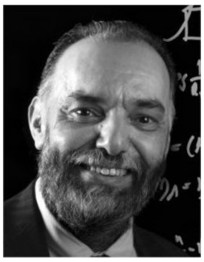
2015 ICU President



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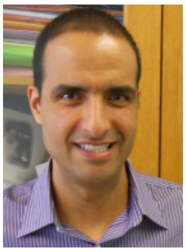

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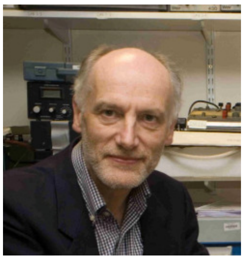
Other Committees

The congress organization has also been supported by other local organizing committee members specialized on non-scientific matters. Their names can be found on the Congress Website and in the Congress Proceedings.

PLENARY SPEAKERS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Jose Sanchez-Dehesa - Spain


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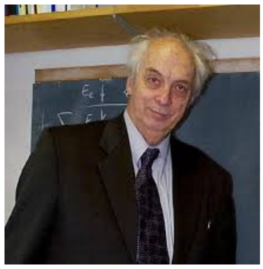
Vitaly Voloshinov - Russia


Victor Georgievich Veselago – Russia

HIGHLIGHTS

USWNet
Ultrasonic Standing Wave Network

The Ultrasonic Standing Wave Network holds its 12th AcoustoFluidics Congress during the 2015 ICU event. Participation is possible by subscribing to 2015 ICU.


A special session is organized on Acousto-Optics in honor and in the presence of Oswald Leroy.

R.W.B. STEPHENS STUDENT AWARD

Elsevier, the publisher of the journal **Ultrasonics** , is sponsoring the **RWB Stephens Prizes**. This competition honors the memory of Professor RWB Stephens (1902-1990) who was active in starting the Ultrasonics International (UI) conferences and who contributed greatly to their success. During his lifetime he was recognized as a great teacher who taught and inspired generations of students in acoustics and ultrasonics. Cash prizes will be awarded to the presenters of the most outstanding papers (oral or poster) presented at the 2015 ICU by a student or recent graduate as determined by a panel of distinguished judges covering a broad diversity of ultrasonics topics. The chair of the Prize Committee is Wolfgang Sachse of Cornell University who is actively engaged with the ICU conferences as well as the journal Ultrasonics.

2015 ICU: A UNIQUE APPROACH TO MUSIC & INNOVATION

In 2014, as part of a collaborative project between Georgia Tech School of Music, Georgia Tech Lorraine, Arsenal and Orchestre National de Lorraine (O.N.L), a series of concerts were performed on Georgia Tech's Campus in Atlanta and Metz. As a follow up to this initiative, "Music Tech Metz", a music festival comprised of 7 different events will be organized in parallel to the 2015 ICU congress. As part of this program, expect a full symphony concert as well as the presentation of the finalists of the Margaret Guthman's innovative instrumental design competition:

Margaret Guthman: is an annual event to find the world's best new ideas in musical instrument design, engineering, and performance, is held at the Georgia Institute of Technology. Sponsored by the Georgia Tech Center for Music Technology, the School of Music, and the College of Architecture, the competition selects 20-25 semi-finalists from all over the world each year. Presentation of finalist projects of this prestigious award will take place.

A unique full symphony concert dedicated to all 2015 ICU participants: "Surchauffe", a piece of music from O.N.L, directed by Jacques Mercier.

Invent and share: this is the dual goal of the "Overheating" project, whose culmination is the creation of a piece specially written for the Orchestre National de Lorraine. This project brings the Orchestra into an unexpected area of research and innovation with the creation of a new metallic percussion instrument - the Veme® - which will make its first appearance in the world of music.

To create "Overheating", Dominique Delahoche took the difficult moments of adolescence as a starting point. Through a palette of new sounds, he puts the contradictory energies of this phase of life into motion in his music. At the core of the piece, planned interludes leave open space for expression by local youth.

Nicolas Chatenet, solo trumpeter for the Orchestra, will introduce them to DJing. Texts written by young people from CMSEA, a local association for child and youth welfare, during a nature workshop led by writer Jérémie Lefebvre will echo the music and express the feelings experienced by the young authors.

MUSIC PERFORMANCE: Françoise VANHECKE

Soprano Françoise Vanhecke is a contemporary, daring, power performing and creative artist. She works closely with composers from around the world. She developed a new extended technique, ISFV® Inhaling Singing, which is part of her doctoral research at the University College, School of Arts; IPEM - Dept. of musicology, Ghent University.

She appears on the show bills of the world's leading music festivals and theatres and received different international awards. Françoise Vanhecke will perform music by Händel, Mozart, Puccini, Satie and Irma Bilbao and will play the ocean-drum and the Theremin.

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Chair Person (s): D. Ciplys, N. Polikarpova

Monday 11 may 2015

Bio-medical ultrasound for therapy I

Room: Saint Pierre
Start time: 16:00
Chair Person (s): L. Crum, C. Lafon

Monday 11 may 2015

Nonlinear Ultrasonic NDE/NDT I

Room: Grande Salle
Start time: 16:00
Chair Person (s): I. Solodov, S. Delrue

Monday 11 may 2015

Picosecond laser ultrasonics I

Room: ESAL 1
Start time: 16:15
Chair Person (s): V.E. Gusev, O. Wright

Monday 11 may 2015

Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" I

Room: Esplanade
Start time: 16:45
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Monday 11 may 2015

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Room: Orangerie
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Monday 11 may 2015

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Chair Person (s):

Monday 11 may 2015

Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics (Special Session in Honour of Professor Emeritus Oswald Leroy) (poster)

Room: Main Hall
Start time: 15:00
Chair Person (s):

Monday 11 may 2015

Bio-medical ultrasound for therapy (poster)

Room: Main Hall
Start time: 15:00
Chair Person (s):

Monday 11 may 2015

Device technology (poster)

Room: Main Hall
Start time: 15:00
Chair Person (s):

Monday 11 may 2015

Nonlinear Ultrasonic NDE/NDT (poster)

Room: Main Hall
Start time: 15:00
Chair Person (s):

Monday 11 may 2015

Physical acoustics (poster)

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Start time: 15:00
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Room: Grande Salle
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Tuesday 12 may 2015

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Tuesday 12 may 2015

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Room: Saint Pierre
Start time: 10:30
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Tuesday 12 may 2015

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Room: Gouv
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Tuesday 12 may 2015

Nonlinear Ultrasonic NDE/NDT II

Room: Grande Salle
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Chair Person (s): I. Solodov, S. Delrue

Tuesday 12 may 2015

Picosecond laser ultrasonics II

Room: ESAL 1
Start time: 10:30
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Tuesday 12 may 2015

Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" II

Room: Esplanade
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Tuesday 12 may 2015

High power ultrasound in materials engineering

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Nonlinear Ultrasonic NDE/NDT III

Room: Gouv
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Chair Person (s): I. Solodov, S. Delrue

Tuesday 12 may 2015

Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" III

Room: Esplanade
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Tuesday 12 may 2015

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Room: Saint Pierre
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Tuesday 12 may 2015

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Start time: 14:15
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Tuesday 12 may 2015

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Start time: 15:45
Chair Person (s): A. Neild, S. Radel

Tuesday 12 may 2015

Cardiovascular ultrasound image and signal analysis: a powerful tool toward valid, non-invasive and low-cost disease diagnosis

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Start time: 16:00
Chair Person (s): S. Golemati, M. Tanter

Tuesday 12 may 2015

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Tuesday 12 may 2015

Physical acoustics: Inverse problem

Room: ESAL 2
Start time: 10:30
Chair Person (s): A. Maurel, M.V. Predoi

Tuesday 12 may 2015

Device technology: energy harvesting, micro-devices and multiphysics

Room: Citadelle 1
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Physical acoustics: Inverse problem

Room: ESAL 2
Start time: 13:45
Chair Person (s): V. Gibiat, W. Pereira

Tuesday 12 may 2015

Nanoacoustics and phonons: General

Room: ESAL 1
Start time: 14:15
Chair Person (s): B. Perrin

Tuesday 12 may 2015

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Room: ESAL 2
Start time: 16:00
Chair Person (s): M. Castaings, M. Lowe

Tuesday 12 may 2015

Bio-medical: Imaging process, beamforming and tomography

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Tuesday 12 may 2015

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Room: ESAL 1
Start time: 16:15
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Tuesday 12 may 2015

Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics (Special Session in Honour of Professor Emeritus Oswald Leroy) (poster)

Room: Main Hall

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Tuesday 12 may 2015

Bio-medical ultrasound for therapy (poster)

Room: Main Hall
Start time: 9:30
Chair Person (s):

Tuesday 12 may 2015

Bulk wave NDT/E: modelling and simulation (poster)

Room: Main Hall
Start time: 9:30
Chair Person (s):

Tuesday 12 may 2015

Device technology (poster)

Room: Main Hall
Start time: 9:30
Chair Person (s):

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Physical acoustics (poster)

Room: Main Hall
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Picosecond laser ultrasonics (poster)

Room: Main Hall
Start time: 9:30
Chair Person (s):

Tuesday 12 may 2015

Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" (poster)

Room: Main Hall
Start time: 9:30
Chair Person (s):

Tuesday 12 may 2015

Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics (Special Session in Honour of Professor Emeritus Oswald Leroy) (poster)

Room: Main Hall
Start time: 15:00
Chair Person (s):

Tuesday 12 may 2015

Cardiovascular ultrasound image and signal analysis: a powerful tool toward valid, non-invasive and low-cost disease diagnosis (Poster)

Room: Main Hall
Start time: 15:00
Chair Person (s):

Tuesday 12 may 2015

Device technology (poster)

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Start time: 15:00
Chair Person (s):

Tuesday 12 may 2015

High power ultrasound in materials engineering (poster)

Room: Main Hall
Start time: 15:00
Chair Person (s):

Tuesday 12 may 2015

Physical acoustics (poster)

Room: Main Hall
Start time: 15:00
Chair Person (s):

Tuesday 12 may 2015

Structural Health Monitoring (poster)

Room: Main Hall
Start time: 15:00
Chair Person (s):

Tuesday 12 may 2015

Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" (poster)

Room: Main Hall
Start time: 15:00
Chair Person (s):

Tuesday 12 may 2015

Ultrasound in Food science, Pharmaceutical and Cosmetics (poster)

Room: Main Hall
Start time: 15:00
Chair Person (s):

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Start time: 8:30
Chair Person (s): M. Deschamps

Wednesday 13 may 2015

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Wednesday 13 may 2015

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Room: Esplanade
Start time: 13:30
Chair Person (s): E. Benes, S. Hirsekorn

Wednesday 13 may 2015

Keynote lecture III

Room: Gouv
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Chair Person (s): V. Laude

Wednesday 13 may 2015

Biomedical Imaging and Therapy through the Interaction of Light and Sound

Room: Saint Pierre
Start time: 10:30
Chair Person (s): E. Bossy, R. Roy, R. Cleveland

Wednesday 13 may 2015

Guided wave NDT/E: modelling and simulation I

Room: Grande Salle
Start time: 10:30
Chair Person (s): M. Lowe, A. Lhémery

Wednesday 13 may 2015

Sonic and phononic crystals

Room: Claude Lefebvre
Start time: 10:30
Chair Person (s): Y. Pennec, M. Caleap

Wednesday 13 may 2015

Ultrasonic transducers in harsh environments

Room: Gouv
Start time: 10:30
Chair Person (s): L. Bond, A. Sinclair

Wednesday 13 may 2015

Guided wave NDT/E: modelling and simulation II

Room: Grande Salle
Start time: 15:30
Chair Person (s): A. Lhémery, M. Lowe

Wednesday 13 may 2015

Acoustic Metamaterials: fundamentals, applications and emerging topics I

Room: Claude Lefebvre
Start time: 16:15
Chair Person (s): B. Assouar

Wednesday 13 may 2015

Chemical and molecular ultrasonics: General

Room: Citadelle 2
Start time: 10:30
Chair Person (s): J.-Y. Hihn

Wednesday 13 may 2015

Physical acoustics: nonlinear

Room: ESAL 2
Start time: 10:30
Chair Person (s): M. Bentahar, A. Mayer

Wednesday 13 may 2015

Standing waves, resonating and actuating ultrasonics I

Room: Esplanade
Start time: 10:30
Chair Person (s): S. Radel, J. Friend

Wednesday 13 may 2015

Bio-medical: Bones

Room: Citadelle 1
Start time: 10:45
Chair Person (s): L. Le, P. Laugier

Wednesday 13 may 2015

NDE / NDT: Guided waves

Room: ESAL 1
Start time: 10:45
Chair Person (s): F. Luppé, E. Moulin

Wednesday 13 may 2015

Physical acoustics: physics

Room: ESAL 2
Start time: 15:30
Chair Person (s): B. Perrin, A. Every

Wednesday 13 may 2015

Standing waves, resonating and actuating ultrasonics II

Room: Esplanade
Start time: 15:30
Chair Person (s): J. Friend, S. Radel

Wednesday 13 may 2015

Bio-medical (poster)

Room: Main Hall
Start time: 9:30
Chair Person (s):

Wednesday 13 may 2015

Chemical and molecular ultrasonics (poster)

Room: Main Hall
Start time: 9:30
Chair Person (s):

Wednesday 13 may 2015

NDE / NDT (poster)

Room: Main Hall
Start time: 9:30
Chair Person (s):

Wednesday 13 may 2015

Physical acoustics (poster)

Room: Main Hall
Start time: 9:30
Chair Person (s):

Wednesday 13 may 2015

Standing waves, resonating and actuating ultrasonics (poster)

Room: Main Hall
Start time: 9:30
Chair Person (s):

Wednesday 13 may 2015

Bio-medical (poster)

Room: Main Hall
Start time: 14:30
Chair Person (s):

Wednesday 13 may 2015

Guided wave NDT/E: modelling and simulation (poster)

Room: Main Hall
Start time: 14:30
Chair Person (s):

Wednesday 13 may 2015

NDE / NDT (poster)

Room: Main Hall
Start time: 14:30
Chair Person (s):

Wednesday 13 may 2015

Physical acoustics (poster)

Room: Main Hall
Start time: 14:30
Chair Person (s):

000448 **Ultrasonics in an Atomic Force Microscope** 226
M. S. Skilbeck, R. S. Edwards and N. R. Wilson

000632 **Optimization of Surface Acoustic Wave Streaming in PDMS microfluidic channels, effect of frequency** 226
B. Tiller

Wednesday 13 may 2015

Sonic and phononic crystals (poster)

Room: Main Hall
Start time: 14:30
Chair Person (s):

000059 **Quaternion Formalism for the Intrinsic Transfer Matrix** 227
N. Cretu, M.I. Pop and A. Boer

000233 **Phononic Crystal of Surface Acoustic Wave based on Gold Pillar Array on LiNbO3 Substrate** 227
F.-L. Hsiao

000258 **Near-Field Coupling of Resonators in Locally-Resonant Sonic Crystals** 228
Y.-F. Wang, Y.-S. Wang and V. Laude

000556 **Analysis of a phononic crystal constituted of piezoelectric layers using electrical impedance measurement** 228
S.A. Mansoura, P. Marechal, B. Morvan and B. Dubus

Thursday 14 may 2015

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Room: Grande Salle
Start time: 8:30
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9:00 **Phase and Group Velocities of Bulk Optic and Acoustic Waves in Crystals and Artificial Periodically Structured Media** 229
V. B. Voloshinov and N. V. Polikarpova

Thursday 14 may 2015

Acoustic Emission

Room: Grande Salle
Start time: 10:30
Chair Person (s): S. Yaacoubi, C. Di Fratta

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11:00 **AT on Buried LPG Tanks Over 13 m3: An Innovative and Practical Solution** 230
C. Di Fratta, A. Ferraro, P. Tscheliesnig, G. Lackner, V. Correggia and N. Altamura

11:15 **Acoustic Emission technique: italian experience on the requalification of underground LPG vessels** 230
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Thursday 14 may 2015

Acoustic Metamaterials: fundamentals, applications and emerging topics II

Room: Claude Lefebvre
Start time: 10:30
Chair Person (s): V. Sanchez-Morcillo, J. Christensen

Thursday 14 may 2015

Micro/nano technology-based transducers, acoustic microsystems, and applications

Room: Esplanade
Start time: 10:30
Chair Person (s): D. Certon, L. Degertekin

Thursday 14 may 2015

Soft Tissue Quantitative Ultrasound

Room: Saint Pierre
Start time: 10:30

Chair Person (s): E. Franceschini, J. Mamou

Thursday 14 may 2015

Waves in granular media and structures

Room: Gouv
Start time: 10:30
Chair Person (s): V. Tournat, C. Daraio

Thursday 14 may 2015

Instrumentation and signal in acoustics

Room: Grande Salle
Start time: 13:30
Chair Person (s): J.-M. Girault

Thursday 14 may 2015

NDE / NDT: General I

Room: Citadelle 2
Start time: 10:30
Chair Person (s): V. Gibiat

Thursday 14 may 2015

Physical acoustics: inhomogeneous media

Room: ESAL 2
Start time: 10:30
Chair Person (s): F. Luppé

Thursday 14 may 2015

Bio-medical: Imaging methods

Room: Citadelle 1
Start time: 10:45
Chair Person (s): N. Ruiter

Thursday 14 may 2015

NDE / NDT: material characterization

Room: ESAL 1
Start time: 10:45
Chair Person (s): P. Nagy, E. Le Clézio

Thursday 14 may 2015

Bio-medical: Microbubbles and contrast agents

Room: Citadelle 1
Start time: 13:45
Chair Person (s): L. Crum

Thursday 14 may 2015

Naval, marine and underwater ultrasonics

Room: ESAL 2
Start time: 13:45
Chair Person (s): B. Dubus

Thursday 14 may 2015

Phononic crystals and metamaterials

Room: Claude Lefebvre
Start time: 15:30
Chair Person (s): V. Laude

Thursday 14 may 2015

Granular and inhomogeneous media: General

Room: Gouv
Start time: 16:00
Chair Person (s): A. Tourin

Thursday 14 may 2015

NDE / NDT: General II

Room: Saint Pierre
Start time: 16:00
Chair Person (s): M. Castaings

Thursday 14 may 2015

Acoustic Metamaterials: fundamentals, applications and emerging topics (poster)

Room: Main Hall
Start time: 9:30
Chair Person (s):

Thursday 14 may 2015

Instrumentation and signal in acoustics (poster)

Room: Main Hall
Start time: 9:30
Chair Person (s):

Thursday 14 may 2015

Micro/nano technology-based transducers, acoustic microsystems, and applications (poster)

Room: Main Hall
Start time: 9:30
Chair Person (s):

Thursday 14 may 2015

NDE / NDT (poster)

Room: Main Hall
Start time: 9:30
Chair Person (s):

Thursday 14 may 2015

Phononic crystals and metamaterials (poster)

Room: Main Hall
Start time: 9:30
Chair Person (s):

Thursday 14 may 2015

Soft Tissue Quantitative Ultrasound (poster)

Room: Main Hall
Start time: 9:30
Chair Person (s):

Thursday 14 may 2015

Waves in granular media and structures (poster)

Room: Main Hall
Start time: 9:30
Chair Person (s):

Abstracts

Mon 11:30 Grande Salle Plenary lecture I

Intramembrane cavitation – (000631)

E. Kimmel
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The Bilayer Sonophore (BLS) model for intramembrane cavitation is a non-thermal mechanism through which ultrasound pressure waves are transformed at specific locations - the bilayer membranes - into strain energy, when the two leaflets are pulled apart cyclically. We investigate the response of a whole cell, presented by an ellipsoid capsule, with sonophores equally distributed on its surface. The simulated cell deforms under ultrasound into a more spherical shape, while the tension in the surrounding membrane increases, inducing intracellular stresses and strains. We claim that this mechanism is responsible for various bioeffects observed in cells, when exposed to ultrasound in vivo and in vitro. Moreover, we believe that a similar mechanism of intramembrane cavitation and cell distortion affect cells during a too rapid decompression maneuver, or develop after substantial mechanical impacts. Two mechano-electric models for excitable tissue combine the BLS model with models of membrane biophysics; both models predict closely in-vivo experimental results. The first, the NICE (Neuronal Intramembrane Cavitation Excitation) model accounts for ultrasound induced cell-dependent selective stimulation or inhibition in the cortex and thalamus. The second model describes the activation of cardiomyocytes in the heart's left ventricle, and succeeds in predicting the protocol for effective extracorporeal acute cardiac pacing by high intensity focused ultrasound. Many questions are still open. How to validate the BLS model explicitly? How do the sonophores work in tissue? Does the BLS enable a new method of ultrasound (membrane) elastography? Does the BLS initiate the formation of extracellular bubbles at high intensities?

Mon 14:00 Grande Salle Plenary lecture II

Time-Reversal: from acoustics to optics – (000638)

M. Fink
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Time-reversal invariance is a very fundamental concept in physics. It was first in the field of acoustics, later for microwaves and more recently in optics, that "time-reversal mirrors" have been built. Such mirrors allow to refocuses in space and time an incident wave field at the original source location regardless of the complexity of the propagation medium. They also allow to revisit the concept of imaging through complex medium. Contrary to intuition, a remarkable property was shown: the more complex the propagation medium, the sharper the focus. Such results have been recently extended to focus on spots much smaller than the wavelength using sub-wavelength structured media, opening new avenues toward super-resolution imaging and high rate telecommunications. An important concept has emerged from this research: the spatio-temporal degrees of freedom of a wave-field that can be control differently in acoustics or in optics. Recently, new tools available in optics such as spatial light modulators and fast megapixel digital sensors open the field of time-reversal to optical waves with many new perspectives in imaging through turbid medium. We will present in this paper an overview of these fields.

Mon 16:00 Esplanade Keynote Acoustofluidics 2015

Challenges and opportunities in translating acoustofluidics in to clinical applications – (000640)

T. Laurell
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Microchip based acoustic cell manipulation holds a promising outlook towards medical applications where modalities such as separation and enrichment are key features that may impact the way cell processing and cell analysis is done in the future. Key aspects in this respect are that sample processing can be done in a time span that meets clinical requirements or is competitive with current practice. This implies that acoustofluidic so-

lutions should address system throughput as an important parameter. In many applications it is equally important that the processing conditions are such that cells are unperturbed after passing the microfluidic chip and display unchanged phenotype and unimpaired proliferation capacity. Furthermore, the ability of microchip acoustophoresis to separate different cell types based on species specific acoustophoretic mobility opens the route to e.g. differentiation of white blood cell subpopulations and rare cell separation. Examples of how all these aspects have been addressed and what still may be challenges for a rapid penetration of acoustofluidics into the clinical domain will be discussed.

Mon 16:00 Gouv Acoustic waveguide applications

Exploitation of guided waves for applications in NDE and material property monitoring – (Invited, 000087)

M. J. Lowe
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Corresponding author E-mail: m.lowe@imperial.ac.uk

Guided waves are now well established in industry for the detection of cracks and corrosion in structures including pipelines, heat exchanger tubing and railway lines. Guided waves technology has also been developed for many other applications in Non Destructive Evaluation (NDE) and as sensors, such as for the monitoring of the properties of materials that are adjacent to a waveguide.
The design of measurement systems for chosen applications requires a careful and specific focus in each case because of the complexity and multi-modal nature of the guided waves. This involves the choice of the wave mode to be used, and then specific transduction and signal processing to make use of it selectively. In the case of NDE, the challenge is to use waves which are sensitive to defects in the waveguide and insensitive to materials with which it is in contact. On the other hand, in the case of material property measurement the challenge is the other way round: to use waves that are particularly sensitive to the material adjacent to the waveguide. The paper will discuss example applications of guided waves for NDE and for the measurement of material properties such as elastic modulus, viscosity and density. This will illustrate the different choices of mode and instrumentation according to these different purposes.

Mon 16:30 Gouv Acoustic waveguide applications

Piezoelectric Fiber Composite Transducers for Transverse Horizontal Guided Plate Waves – (Contributed, 000424)

C.-C. Yin and W.-C. Tsai
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The dispersive characteristics of a piezoelectric fiber composite guided ultrasonic transducer system depend not only on the transducer itself but also on the host plate, on the surface of which the transducer is adhered. The piezoelectric fibers are used to generate and detect the transverse horizontal (TH) waves polarized parallel to the fibers via thickness-shear mode vibration. TH modes have less attenuation in guided wave structural health monitoring for the host media comprising porous cores or covered by layered insulation with weak-adhesives. A periodic finite-element approach has been used to determine dynamic characteristics of the lowest several symmetric and anti-symmetric TH plate waves with coupling of a single- or two-layer piezoelectric fiber composite. The two-layer piezoelectric fiber composite can be used to actuate and sense TH guided modes by series or parallel connection. The dispersions of layered piezoelectric fiber composite adhered on a host plate can be classified into two categories, PFC modes and plate modes. The PFC modes redistribute after layered PFC being adhered on the host plate. They split off from their original values into the plate modes asymptotically in the vicinity of the intersections of both modes. Larger mechanical responses can be induced in the plate modes of longer wavelengths. On the other hand, the transducers have better sensitivity for the PFC modes in thickness-shear deformation. Two prototype transducers made of 250 μm diameter piezoelectric fibers were fabricated to assess the above-mentioned characteristics. The experimental results are in very good agreement with simulation in a broad frequency range up to 5 MHz. The presented conformal TH wave transducers have potential applications in guided wave structural health monitoring.

Mon 16:45 Gouv Acoustic waveguide applications

Characterization of the spatio-temporal response of optical fiber sensors to incident spherical waves – (Contributed, 000206)

I. A. Veres[a], A. Rosenthal[b], P. Burgholzer[a], G. Wissmeyer[b], V. Ntziachristos[b] and T. Berer[a]
[a]Research Center for Non-Destructive Testing GmbH, Altenberger Str. 69, 4040 Linz, Austria; [b]Institute for Biological and Medical Imaging, Ingoldstädter Landstraße 1, 85764 Neuherberg, Germany
Corresponding author E-mail: istvan.veres@recendt.at

Optical fiber-based sensing of ultrasound is regularly used to detect waves up to tens of megahertz. The measurement principle is based on the changes of the refractive index in the optical fiber core due to mechanical stresses. Recently, optical fibers found their application in photoacoustic imaging in tissue where the imaged object is naturally represented by a finite sum of point-like acoustic sources, and the resulting wavefront may be described by a finite sum of spherical waves. Therefore, knowledge of the response of the sensor to point sources allows enhancing the reconstruction process by incorporation of this information, e.g., in a model-based inversion algorithm.
The aim of the presented work is to evaluate the frequency response of a coated optical fiber to an incident spherical wave. To this end, first a fundamental solution to the scattering of plane waves from a layered cylinder is obtained by using the transfer matrix method for cylindrical geometries. Then the incident spherical wave is described in cylindrical coordinates by using an integral representation which allows the evaluation of the acoustically induced strains using the fundamental solution.
Experimentally measured responses of a double layered optical fiber are compared to theoretically calculated acoustic responses. A pi-shifted fiber Bragg grating sensor with spatially varying sensitivity was used to detect acoustic waves from a photo-acoustic source. The results show that the response of the fiber is a combination of the change in the length of the sensor and the variation of the refractive index in the core. Longitudinal guided waves are responsible for the first effect which leads to two major peaks at frequencies below 10MHz; for higher frequencies the second effect dominates the response as the result of transverse resonances of the fiber. The experimental and analytical results show a reasonable agreement.

Mon 17:00 Gouv Acoustic waveguide applications

Concentration Measurement in Bubbly Liquids - a Matter of Times – (Invited, 000199)

J. Rautenberg and M. Münch
SensAction AG, Rosenauer Straße 27, 96450 Coburg, Germany
Corresponding author E-mail: jens.rautenberg@sensaction.de

Leaky Lamb waves in an acoustic cavity can be utilized for the measurement of temperature, density and sound velocity of an enclosed liquid. If the sensitivity of these variables to a change of predefined components in a liquid mixture is high enough, a robust online concentration measurement can be utilized as well. The robustness is due to the large aperture of the emitted Leaky wave in comparison to conventional focusing transducer setups. Therewith parts of the sound wave reach the receiver, even if the liquid is interspersed with gas bubbles. But these bubbles interact with the acoustic wave and change the signals and therewith the measurable times-of-flight. This effect depends on the resonance frequency of the bubbles as well as the operating frequency of the acoustic sensor and can be misinterpreted as a change of concentration if not noticed.

This contribution will show how group and phase velocity measurements can be used to calculate the sound velocity of the pure liquid, even if gas bubbles are interspersed. Apart from that it will be theoretically shown that for a given bubble size and operation frequency of the ultrasonic sensor only a certain volume fraction of gas is tolerable if a given uncertainty in the sound velocity measurement should be reached. To demonstrate the advantage of the new method, the different sound velocities of a bubbly liquid (group, phase and compensated velocity) will be compared over time in a typical industrial process.

Mon 17:30 Gouv Acoustic waveguide applications

Model based sensitivity analysis in the determination of viscoelastic material properties using transmission measurements through circular waveguides – (Contributed, 000333)

F. Bause[a], H. Gravenkamp[b], J. Rautenberg[a] and B. Henning[a]
[a]University of Paderborn, Warburger Str. 100, 33098 Paderborn, Germany; [b]Federal Institute for Materials Research and Testing, Unter den Eichen 87, 12200 Berlin, Germany
Corresponding author E-mail: bause@emt.uni-paderborn.de

In the context of reliable simulation of wave phenomena in complex structures it is crucial to determine material properties. For polymeric materials viscoelastic material models have to be considered to account for their relaxation and retardation behavior. One of the most complex material models is the fractional Zener model which relies on four independent parameters for a single degree of freedom. Expansion into three dimensions and assuming transversly isotropic material symmetries reveals 14 unknowns, i.e. five independent parameters to account for the matrix of elasticity and three times three parameters for anelasticity of each eigen-motion of the material. In this contribution we consider the measurement setup as proposed by Rautenberg (PhD-thesis, Paderborn, 2012) in which a transmission measurement through a circular waveguide is used to determine the material parameters of the waveguide. Rautenberg has shown that the setup can be used to determine quasi-isotropic elastic material-symmetries and two Rayleigh damping parameters. However, considering complex viscoelastic models the number of unknowns increases and therefore the question about sensitivity to these parameters and approaches for an appropriate reduction of unknowns arises. Using a numerical model of the wave propagation based on SBFEM (Gravenkamp, PhD-Thesis, 2014) several simulations with differing material parameters can be performed. Utilizing a derivative kernel (Farid and Simocelli, 1997), the sensitivity of the material change as a function of time can be computed. The sensitivity curves are discussed and appropriate approaches for the reduction of independent parameters based on empirical studies are derived.

Mon 17:45 Gouv Acoustic waveguide applications

Estimation of the Area of a Reverberant Plate Using Average Reverberation Properties – (Contributed, 000182)

H. Achdjian, E. Moulin, F. Benmeddour and J. Assaad
IEMN UMR CNRS 8520, University of Valenciennes and Hainaut-Cambrésis, Mont Houy, 59313 Valenciennes, France
Corresponding author E-mail: hossep.achdjian@univ-valenciennes.fr

This paper aims to present an original method for the estimation of the area of thin plates of arbitrary geometrical shapes. This method relies on the acquisition and ensemble processing of reverberated elastic signals on few sensors. The acoustical Green's function in a reverberant solid medium is modelled by a nonstationary random process based on the image-sources method. In that way, mathematical expectations of the signal envelopes can be analytically related to reverberation properties and structural parameters such as plate area, group velocity, or source-receiver distance. Then, a simple curve fitting applied to an ensemble average over N realisations of the late envelopes allows to estimate a global term involving the values of structural parameters. From simple statistical modal arguments, it is shown that the obtained relation depends on the plate area and not the plate shape. Finally, by considering an additional relation obtained from the early characteristics (treated in a deterministic way) of the reverberation signals, it is possible to deduce the area value. This estimation is performed without geometrical measurements and requires an access to only a small portion of the plate. Furthermore, this method does not require any time measurement nor trigger synchronisation between the input channels of instrumentation (between measured signals), thus implying low hardware constraints. Experimental results obtained on metallic plates with free boundary conditions and embedded window glasses will be presented. Areas of up to several meter-squares are correctly estimated with a relative error of a few percents.

Mon 16:00 Claude Lefebvre Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics I (Special Session in Honour of Professor Emeritus Oswald Leroy)

Research cooperation between Catholic University Leuven Campus Kortrijkand University of Gdansk in acousto-optics - a historical recollection – (Invited, 000462)

A. Sliwinski
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Corresponding author E-mail: fizas@univ.gda.pl

Summary A short review of results achieved during many years of cooperation between the Belgian group of KULAK and the Polish group of Gdansk University is presented as a tribute to Oswald Leroy for his significant contribution. The scientific research in examination of ultrasonic light interaction phenomena was the area of this fruitful joint collaboration since 1970. Oswald Leroy's crucial role in the cooperation is emphasized and some historical events are recalled. His original theoretical papers predicted new theoretical phenomena which were successfully experimentally verified in the A.O. laboratory at the University of Gdansk. Later on, they have become inspiration for further fundamental search in acousto-optics. The mutual cooperation was being continued and many common papers appeared confirming the predicted results. Members of Gdansk AO group many times visited Kortrijk to work

together on ULD phenomena or attending seminars and symposia organized in Belgium and the Belgian group took part in the International Spring Schools and Applications systematically organized by Gdansk University as the three-annual meetings since 1980. Leroy's contribution to the mutual co-operation has been recognized as so imported and significant that in 1991 he was honored with the Doctorate Honoris Causa of the University of Gdansk.

Mon 16:30 Claude Lefebvre Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics I (Special Session in Honour of Professor Emeritus Oswald Leroy)

Ultrasound-Driven Megahertz Faraday Waves for Generation of Monodisperse Micro Droplets and Applications* – (Invited, 000551)

C. S. Tsai, S. C. Tsai and R. W. Mao
University of California, Campus Dr., Room S2224, Eng.Gateway Bldg., Irvine, 92697, USA
Corresponding author E-mail: cstsai@uci.edu

Faraday waves has continuously been a subject of scientific pursuit since Lord Faraday's classical experiment with a water layer on a vibrating elastic surface at the very low drive frequency of 5 hertz (Hz) in 1983 [1]. However, all of the subsequent theoretical and experimental studies were limited to relatively low drive frequencies ranging from tens to thousands hertz and, thus, no micron-size monodisperse droplets were observed. Our recent theoretical findings on Faraday waves at the much higher drive frequency of megahertz (MHz) [2,3] and realization of silicon-based multiple-Fourier horn ultrasonic nozzle together have facilitated generation of mono-disperse droplets of micron diameter (2-5μm) at low electrical drive power (<1.0 Watt) from the liquid layer on the end face of the distal horn [4]. The resulting miniaturized droplet generator may find a variety of applications such as pulmonary (inhalation) drug delivery, nanoparticle synthesis, and fabrication for electronic and photonic nano-structures. In this paper the theoretical findings on temporal instability of Faraday waves at MHz drive frequency and experimental verification and production of mono– disperse micro droplets, and the specific application to inhalation drug delivery [4] are presented.

*Supported by the National Institute of Health (NIH), USA (NIBIB Grant #5R21EB006366, Counter ACT Program U54-NS063718 and AMRMC W81XWH-12-2-0114). #Corresponding author.

[1] M. Faraday, Phil. Trans. Roy. Society, London, A52, 299-340 (1831). [2] S.C. Tsai, S.K. Lin, R.W. Mao and C.S. Tsai, Phys. Rev. Lett., 108, 154501- 154501 to -154505 (2012). [3] S.C. Tsai and C.S. Tsai, IEEE Trans. Ultrason. Ferroelect. Freq. Control, 60, 1746-1754 (2013). [4] C.S. Tsai, R.W. Mao, S.K. Lin, Y. Zhu, and S.C. Tsai, "Faraday instability- based micro droplet ejection for inhalation drug delivery," TECHNOLOGY, 2, 75- 81, 2014. http://www.worldscientific.com/worldscinet/technology.

Mon 17:00 Claude Lefebvre Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics I (Special Session in Honour of Professor Emeritus Oswald Leroy)

Matched Pair of AOTFs with Net Zero Frequency-Shift – (Contributed, 000166)

J. D. Ward[a] and C. Pannell[b]
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Acousto-Optic Tunable Filters are used in many applications where their fast agile tuning characteristics can be used to advantage. In addition, their ability to conserve spatial-coherence is useful in specialist applications, for example with single-mode optical fibres. Since, as is common with most AO devices, AOTFs generally use a travelling acoustic wave, the diffracted beam is frequency-shifted by an amount that is essentially equal to the RF drive frequency. This can be inconvenient, especially in applications where the AOTF is deployed in a multi pass configuration such as a recirculating-ring or laser-cavity. Often in such configurations a second AO device (usually similar to the first) is deployed in such a way so as to compensate for the frequency- shift. For an AO device using the isotropic AO interaction this is relatively straightforward since there is a symmetry about the device and interaction. However, an AOTF uses the anisotropic interaction which is asymmetric, and this is frequently further complicated by the inclusion of pointing-stability compensation. We describe and characterise a pair of matched AOTFs operating in opposite quadrants of the "K-space" diagram that when combined have true reciprocity and give a net zero frequency shift whilst maintaining excellent pointing- stability. Any minor deviations in manufacture are self-compensated making these components ideal for use within a single-mode fibre network, or laser cavity. Furthermore, small controlled frequency-shifts (up to about 10kHz) may be introduced with little or no detriment to the alignment of the system.

Mon 17:15 Claude Lefebvre Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics I (Special Session in Honour of Professor Emeritus Oswald Leroy)

Visualization of Acoustic Evanescent Waves by the Stroboscopic Photoelastic Method – (Contributed, 000092)

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It is well known that evanescent waves are produced when an incident wave strikes an interface at an angle larger than the critical angle and that they exhibit exponential decay within the refractive medium. Evanescent waves have been extensively studied and have attracted substantial attention for their applications in technology allowing expansion into the nano region. However, the propagation of evanescent waves is not well understood visually. We have achieved acoustic evanescent waves produced when the propagating incident wave impinges on the water/glass interface at a post-critical angle, using the Fresnel method in the water and the photoelastic method in the glass.

Mon 17:30 Claude Lefebvre Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics I (Special Session in Honour of Professor Emeritus Oswald Leroy)

Measuring Photoelastic Coefficients with Schaefer-Bergmann Diffraction – (Contributed, 000307)

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The photoelastic coefficients describe how the optical dielectric tenor of a material is changed by strain. Knowledge of the photoelastic coefficients allows for the optimization of acoustooptic devices, which utilize acoustic waves to diffract light.
We propose a novel method for measuring the photoelastic coefficients of a material using Schaefer-Bergmann diffraction patterns (SBDPs). In the SBDP experiment we create a diffuse acoustic field containing random amplitudes (due to different resonances) of nearly all plane wave acoustic modes in the transparent sample of interest. A collimated laser beam propagates through the sample and optical diffraction occurs for any acoustic plane wave components that satisfy the Bragg matching condition and the diffraction efficiency is determined by the photoelastic tensor. A Fourier transform lens maps the resulting SBDP onto a CCD camera. For our method, we measure SBDPs with different incident and diffracted optical polarizations. We compare the measured SBDPs to normalize out the unknown acoustic wave amplitudes and to determine the relative sign and magnitude of all independent photoelastic coefficients without requiring multiple or complicated cuts of the crystal.
We have measured the relative sign and magnitude of the photoelastic coefficients of fused silica to within a 1% error of the accepted values, and of the trigonal crystal α-barium borate with SBDPs and corroborated our results with the Dixon method.

Mon 16:00 Saint Pierre Bio-medical ultrasound for therapy I

Ultrasound phased arrays for therapy delivery and monitoring – (Invited, 000487)

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Focused ultrasound has been shown to be the only method that allows noninvasive thermal coagulation of tissues and recently this potential has been explored for noninvasive image-guided drug delivery. In this presentation, the advances in ultrasound phased array technology for well controlled energy delivery, exposure monitoring and control will be discussed. Experimental results from novel mulch-frequency transmit/receive arrays will be presented. In addition, some of the recent preclinical results for the treatments of brain tumors, stroke, and Alzheimer's disease will be reviewed. As conclusion, the advances in the image-guided focused ultrasound for the treatment of disease has been rapid and the future potential appears very promising.

Mon 16:30 Saint Pierre Bio-medical ultrasound for therapy I

The Twinkling Artifact in Medical Ultrasound – (Contributed, 000082)

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When Doppler ultrasound is used to as an imaging modality in renal stone detection, a multi-color image is often seen that have been variously described as the "Twinkling Artifact". We have investigated this artifact in some detail and have determined that it is likely due to microscopic gas bubbles that are somehow stabilized against diffusion on the stone itself. The incident Doppler ensemble pulses interact with the bubbles, and the resulting random decorrelation in the backscattered pulses is interpreted by the imaging machine as rapid changes in speed, Because this artifact is quite sensitive to the presence of gas bubbles, we have developed a Doppler technique to use this phenomenon as a means to spatially map the presence of transient gas bubbles, such as these induced by therapeutic ultrasound in tissue. A discussion of the artifact itself, methods to improve its sensitivity and specificity in stone detection, as well as its utilization in cavitation detection will be presented

Mon 16:45 Saint Pierre Bio-medical ultrasound for therapy I

New Methods and Transducer Designs for Ultrasonic Diagnostics and Therapy – (Contributed, 000248)

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Recent advances in the field of physical acoustics, imaging technologies, piezoelectric materials, and ultrasonic transducer design have led to emerging of novel methods and apparatus for ultrasonic diagnostics, therapy and body aesthetics. The paper presents the results on development and experimental study of different high intensity focused ultrasound (HIFU) transducers. Technological peculiarities of the HIFU transducer design as well as theoretical and numerical models of such transducers and the corresponding HIFU fields are discussed. Several HIFU transducers of different design have been fabricated using different advanced piezoelectric materials. Acoustic field measurements for those transducers have been performed using a calibrated fiber optic hydrophone and an ultrasonic measurement system (UMS). Novel approaches have been explored for dynamic focusing of HIFU, supersonic excitation and resonance amplification of shear waves, as well as use of standing waves in ultrasonic imaging and therapy. The results of *ex vivo* experiments with different tissues as well as *in vivo* experiments with blood vessels are presented that prove the efficacy, safety and selectivity of the developed HIFU transducers and methods. Work supported by the RSF grant no.14-15-00665.

Mon 17:00 Saint Pierre Bio-medical ultrasound for therapy I

Simulation of Transrib HIFU Propagation and the Strategy of Phased-Array Activation – (Contributed, 000157)

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High-intensity focused ultrasound (HIFU) has been emerged as an effective and noninvasive modality of solid tumor/cancer ablation with promising clinical results. However, liver ablation is challenging because of the presence of ribs. Partial rib dissection as the clinical solution decreases the advantage of HIFU, noninvasiveness. Acoustic burst focusing through multi-layer tissue with great inhomogeneity from arbitrary transducer geometry, especially asymmetrical one, is of importance in practical HIFU simulation, but difficult using Khokhlov-Zabozotskaya-Kuznetsov (KZK) equation. In this study, angular spectrum approach (ASA) has been used in the wave propagation from phased-array HIFU transducer, and diffraction, attenuation and the nonlinearity are accounted for by means of second order operator splitting method. Bioheat equation is used to simulate the subsequent temperature elevation and lesion formation with the formation of shifted focus and multiple foci. The effect of ribs on HIFU ablation using phased- array transducer was simulated. In addition, the strategies of elements ac-

tivation, acoustic ray projection and back-propagation using ASA, were compared with each other. In summary, our approach could simulate the performance of phased-array HIFU in the clinics, and an appropriate treatment plan could be developed for complicated situation, such as transcrib liver ablation.

Mon 17:15 Saint Pierre Bio-medical ultrasound for therapy I

Efficient and reproducible in vitro transfection using confocal ultrasound and inertial cavitation regulation – (Contributed, 000438)

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Acoustic cavitation can be used for in vitro and in vivo gene delivery as an alternative to viral-based transfection methods. In this study we present an ultrasonic device designed to generate and control cavitation in an in vitro sample. Transfection tests were performed on several types of cells in suspension. This device is based on two confocal ultrasonic transducers. This particular configuration is favorable for the initiation and control of cavitation activity. The crossing of the two beams forms an interference patterns that traps the bubbles in the focal zone. Moreover, numerical comparison shows that this configuration reduces the distortion of the pulse caused by nonlinear effects. The device also integrates a regulation process to control the cavitation activity by adjusting in real time the amplitude of the ultrasound signal as a function of the recorded acoustic response of the cavitation bubbles. With this control loop, the measured activity is within 5% of the desired value. peGFP-C1 transfection tests were done on Jurkat and K562 cell lines . The transfection efficiency and cell viability were evaluated 24h post sonication. Results show a proportional relation between transfection efficiency and cavitation activities for both cell lines. Transfection rates (Jurkat: 77%, K562: 49%) and viability (Jurkat: 42%, K562: 84%) were obtained with the optimal setup. These results are comparable to nucleofection method. On a third cell line, A549, this exposure condition gave 80% transfection efficiency for 75% of cell viability. Our results confirm that ultrasound can be an alternative to viral-based transfection methods to efficiently deliver genes in vitro. They support the consideration of ultrasound for in vivo gene therapy as an efficient and controlled method. Work supported by Caviskills SAS and Labex DevWeCan.

Mon 17:30 Saint Pierre Bio-medical ultrasound for therapy I

Intravital Fluorescence Imaging of the Effect of Ultrasound on the Extravasation and Intratumoral Diffusion of Phase-Shift Nanodroplets and Nanodroplet Encapsulated Drug – (Contributed, 000010)

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Motivation: Standard imaging techniques integrate data over the entire organ and measure together vascular and tissue signals. Intravital fluorescence microscopy allowed for the first time discriminating vascular and tissue compartments in the processes of extravasation and tumor tissue accumulation of phase-shift nanodroplets and nanodroplet-encapsulated drug, green-fluorescent paclitaxel. Methods: Intravital fluorescence microscopy was performed using a customized Nikon A1R system to monitor the effect of ultrasound on the carrier and drug extravasation rates and diffusion in tumor tissue upon intravenous injections to pancreatic tumor bearing mice. For image processing, masks were applied to select either blood vessels or tissue in the field of view. A suggested model allowed discriminating between various kinetic regimes of nanocarrier internalization in tumors of various sizes, cell density, and rigidity. Results: Initial portions of the blood vessel and tissue fluorescence time curves are controlled by the particle penetration through vascular wall, i.e. true extravasation. At later stages, nanoparticle diffusion and intracellular uptake play an important, possibly dominant, role in the nanoparticle accumulation and distribution in tumor tissue. Apparent extravasation coefficient E defined as initial slope of tissue fluorescence curve normalized to the maximal fluorescence of blood vessels was 3-fold lower for nanodroplets than for parent polymeric micelles; the overall tissue accumulation rate of nanodroplets was two orders of magnitude lower than that of micelles. Ultrasound application induced a 4.7-fold local enhancement of nanodroplet extravasation (to be compared to 1.5-fold enhancement for micelles) and resulted in higher nanodroplet concentration and more uniform distribution in tumor tissue.

Mon 16:00 Grande Salle Nonlinear Ultrasonic NDE/NDT I

Dynamic acousto-elastic testing – (Invited, 000569)

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Originally developed for ultrasound characterization of bone microdamage, dynamic acousto-elastic testing (DAET) was later applied to non-destructive testing of complex fluids, industrial materials and geomaterials, at the lab scale and recently in situ for characterization of soil nonlinear elasticity. DAET is the dynamic analog of conventional static acousto-elastic testing where the wavespeed is measured as a function of the applied static load. The purpose of DAET is to measure the wave amplitude-dependence (more generally strain- or stress-dependence) of the compressibility of a material. In DAET a material is probed simultaneously by two elastic waves, a low-frequency (LF) sine burst and a sequence of high-frequency (HF) pulses. A first source generates a LF wave to dynamically stress a large volume of the medium. A second source broadcasts the sequence of HF pulses in the studied area to determine the local changes of wavespeed that can be related to local changes of elasticity of the material. Contrary to methods like nonlinear resonant ultrasound spectroscopy and nonlinear wave mixing (or waveform distortion of a single wave due to nonlinear propagation) that measure the average nonlinear elastic behavior over multiple wave cycles, DAET allows one to capture the details of the nonlinear elasticity over a single wave cycle, including expansion-compression asymmetry and hysteresis. Experimental results obtained in different materials with different implementations of the method in the lab and in situ will be presented.

Mon 16:30 Grande Salle Nonlinear Ultrasonic NDE/NDT I

Coda Wave Interferometry (CWI) Applied to Dynamic Acousto-Elasticity (DAE) – (Contributed, 000349)

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Dynamic acousto-elasticity (DAE) technique is a unique method that can provide the entire full elastic behavior over a dynamic strain cycle. The technique consists of broadcasting a high frequency wave, from an ultrasonic (US) transducer source to an ultrasonic transducer receiver, to probe the elastic state modulated in the sample by a low frequency (LF) piezoelectric disk source. Experimentally, the modulus variation is evaluated by measuring the time of flight variation of the ballistic propagating wave into the sample. However, this requirement cannot be achieved in some cases, e.g. when the US pulse is strongly scattered or reflected in the medium. In such cases, the received signal contains a so-called coda resulting from the interaction of the pulse with multiple scatterers and/or with the boundaries of the sample. The objective of the study is to evaluate the potential of the Coda Wave Interferometry (CWI) to retrieve the velocity variation during DAE measurements. CWI is well-known in seismology for its ability to detect small variations of velocity in a perturbed medium. The CWI-based approach consists in cross-correlating US time signals measured at different dynamic LF strain in a moving time windows. Several small samples of metallic alloys, rocks and bones (thickness of few mm) having scatterers of different sizes and different nonlinear elasticity are investigated. US pulses of different frequencies (2.25MHz, 5MHz and 20MHz) are used. Results suggest that CWI is helpful to retrieve subtle velocity variations (<0.001%) in diffusive and weak nonlinear material such as bone.

Mon 16:45 Grande Salle Nonlinear Ultrasonic NDE/NDT I

Coda Wave Interferometry (CWI) and Acoustic Emission (AE) to detect and locate micro–cracks in linearly vibrating concrete – (Contributed, 000614)

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Nonlinear Resonance (NR) and Coda Wave Interferometry (CWI) have proved to be efficient to detect and follow the evolution of micro–cracks within a strongly scattering media (concrete, rocks, etc.). Nevertheless, the localization of the cracks using the same techniques is not straightforward. In order to avoid the conditioning and its subsequent relaxation effect related to NR, CWI is simultaneously applied when concrete samples are vibrating in the linear regime. Based on a comparative study of the coda signals contents (non ballistic part) in the absence and under the weak linear vibration, the localization of the mechanically induced scatterers was possible depending on the scatterers' main direction with respect to the vibration plane. The latter point raises the issue of the generated types of vibration at the scatterers. Therefore, investigations were performed using the acoustic emission (AE) technique, which has served to verify that the acoustic activity during the linear vibrations does change depending on the considered experimental configuration. The latter, has also a direct effect on the frequency content of the recorded AE hits showing the potential link existing between the quantitative analysis of AE hits and the generated vibration mechanisms of the existing micro–cracks.

Mon 17:00 Grande Salle Nonlinear Ultrasonic NDE/NDT I

Investigation of the Higher Harmonic Lamb Wave Generation in Hyperelastic Isotropic Material – (Contributed, 000032)

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Micro-structural damages, such as micro-cracks and voids, give locally rise to stresses and may initiate subsequent failure of structural components. Therefore, the development of methods for the detection of microstructural damage and the observation of their growth is an important and ongoing area of research, especially for thin-walled structures.

The proposed method for the detection is based on the nonlinearity caused by the micro-structural damages. Lamb waves are generated which induce imultaneously higher harmonic modes due the inherent nonlinearity. For detailed investigations, numerical simulations are essential.

In this work, the nonlinearity is modeled by the material law, which is based on the Neo-Hookean and Mooney-Rivlin material models. In contrast to previous studies, which used third order elastic coefficients, these hyperelastic material models are widely accepted, frequently used, and implemented in commonly available FEM software.

In the numerical investigations, Lamb waves are generated in a thin-walled aluminum plate with windowed sine burst signals. Due to the nonlinearity in the material law, the waves are not only observed at the excitation frequency, but also at higher harmonic frequencies. Excitation at especially selected frequencies evoke the cumulative effect, and thus gives rise to the amplitudes of the higher harmonics. Comparing the S_1- S_2 and S_2-S_4 mode pairs clearly show the higher sensitivity of the latter to the material nonlinearity. This matches with previous published experimental results. Finally, it is shown that the results obtained agree qualitatively well with numerical analyses, in which der micro-structural damages are modeled directly by a respective finite element discretization.

Mon 17:15 Grande Salle Nonlinear Ultrasonic NDE/NDT I

Acoustic Nonlinearity Evaluation for Thermal Aging of Aluminum Alloys by using Laser-generated Surface Acoustic Waves – (Contributed, 000316)

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A wave which travels on the solid material exhibiting elasticity is a surface acoustic wave (SAW). In the nondestructive evaluation (NDE) field, SAWs have been utilized for the assessment of material degradation by using acoustic nonlinearity measurement as well as investigation of near-surface features. The SAW can be produced not only by contact methods such as an instant impact or piezo-electric effect but also by non-contact ways such as electromagnetic mechanisms or laser- material interaction. Among them, using a laser-generated SAW is regarded as one of efficient and reliable NDE techniques since it is less affected by contact issues than using the SAWs created by contact methods.

In this study, a laser-generated SAW was used to assess the material degradation caused by thermal energy in aluminum alloys. The specimens were heat-treated of 220 °C for various times: 0, 20, 40, 60, 120, 600, 6000, 60000 minutes, respectively. For exciting a laser-generated SAW, Nd:YAG pulsed laser was employed as a source. To receive the SAW, a PZT transducer was used. After the acous-

tic nonlinearity of each specimen was measured, their relative ratios to the not-heated specimen were compared. To confirm the acoustic nonlinearity variation, the acoustic nonlinearity was additionally measured by using SAWs produced by PZT transducer excited by high power toneburst generator.
The result showed that a good agreement of acoustic nonlinearity variations according to thermal aging in both the cases of SAWs generated by PZT and LASER. This supports that the laser-generated SAW can be more effective and reliable tool for acoustic nonlinearity evaluation than the SAW produced by contact techniques because using laser as a source can resolve the contact issues at the excitation part and the acoustic nonlinearity evaluation of the SAW generated by the laser is equivalently to those from SAWs produced by contact methods.

Mon 17:30 Grande Salle Nonlinear Ultrasonic NDE/NDT I

Nonlinear elasticity and slow dynamics: physical and numerical modeling – (Contributed, 000503)

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Vibrational experiments in rocks or concrete reveal that two different dynamics coexist [2,3]. First, a "fast" elastic dynamics occurs with a time scale ruled by the frequency of the excitation. Second, a "slow" dynamics governs the relaxation of the elastic modulus. Here, a "soft-ratchet" model [4] is preferred to the phenomenological Preisach-Mayergoyz model commonly used. The softening/recovering is related to the concentration of defects that evolves dynamically with the stress. This relaxation mechanisms is coupled to nonlinear elasticity. Lastly, viscoelasticity is introduced.
Our contribution is two-fold [1]: Ï improvement of the physical model. A non-physical feature of the soft-ratchet model [4] is fixed. Moreover, the generalized Zener model introduced; Ï construction of a numerical scheme. Analytical tools used in [4] were unable to solve the full coupled system. On the contrary, we develop here a numerical strategy that enables to solve the whole equations.
First, we introduce the physical model and its basic features: evolution of defects, nonlinear elasticity, and attenuation. Second, the evolution equations are written as a first-order system of partial differential equations. Third, the numerical method is introduced, based on a splitting strategy. The hyperbolic step is solved by a Godunov scheme, whereas the relaxation step is solved exactly. Fourth and last, numerical experiments show that the experimental observations performed by DAET are qualitatively recovered.
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Mon 16:15 ESAL 1 Picosecond laser ultrasonics I

Acoustic Vibration of Nanoobjects: Ensemble and Single Metal Nanoparticles – (Invited, 000418)

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Nano-objects exhibit discrete low-frequency vibrations whose properties reflect their morphology and environment. They have been extensively investigated in single-material nanoobjects and the measured mode frequencies are well described in the framework of the classical continuous elacticity model, raising the question of the limit of its applicability. Using time-resolved nonlinear optical techniques we have investigated the acoustic breathing modes of small platinum and gold nanoparticle down to a one nanometer size, i.e., less than one hundred atoms. Even for these sizes, the results are in excellent agreement with the theoretical prediction of the elasticity model using the bulk material elastic constant, and are also well reproduced by atomistic calculation. In contrast, damping of the acoustic vibration, which can be addressed only in single particle measurements, are usually not correctly reproduced by this model. This suggests significant contributions either due to mechanical contact with the substrate or to material defects, that can be partly identified investigating the same individual nanoobject in different environments.

Mon 16:45 ESAL 1 Picosecond laser ultrasonics I

Direct Observation of Gigahertz Coherent Guided Acoustic Phonons in Free-Standing Single Copper Nanowires – (Contributed, 000023)

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Phonons confinement studies inside nanostructures shed light on the thermal behaviour at the nanoscale and generation and detection of nanoacoustic waves with nanoscale spot size is critical to design nanodevices for three-dimensional noninvasive imaging with nanometer resolutions. We report on the gigahertz acoustic phonon waveguiding in free standing single copper nanowires studied by femtosecond transient reflectivity measurements [1]. By considerably reducing the relaxation channel toward the substrate, the suspended nanowires provide a unique tool to observe the propagation of gigahertz coherent acoustic waves with spatial separations between generation and detection as large as 4 μm. The results are discussed on the basis of the semi-analytical resolution of the Pochhammer and Chree equation. The generated gaussian wave packet spreading of two different modes is derived analyticaly and compared with the observed oscillations of the sample reflectivity. These experiments provide a unique way to get independantly geometrical and material characterization. This direct observation of coherent guided acoustic phonons in a single nano-objet is also the first step towards nanolateral size acoustic transducer and comprehensive studies of thermal properties of nanowires.
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Mon 17:00 ESAL 1 Picosecond laser ultrasonics I

Brillouin scattering enhancement by the opto-acoustic excitation of a single nanorod – (Contributed, 000401)

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The understanding of physical and biological processes involved in various current researches requires the knowledge of elastic properties of solids or visco-elastic properties of soft matter at smaller and smaller length scales. For instance, recent experiments have highlighted the strong potential of laser induced GHz acoustic waves to monitor the mechanical properties of a single cell [1]. A promising way to probe elasticity at a nanometer scale is to consider a single nanoparticle as an opto-acoustic nanotransducer, with generated acoustic frequencies reaching tens of GHz, and thus acoustic wavelengths falling to a few tens of nanometers.
We demonstrate for the first time the detection in a transparent substrate of the GHz coherent longitudinal phonons generated by an optically excited single nanoparticle deposited on the free surface of the substrate. We use a picosecond ultrasonics setup relying on a common femtosecond pump-probe scheme [2]. We detect not only the known breathing mode of the nanoparticle [3] but also the coherent phonons propagating close to the nanoparticle. Indeed, the photo-elastic interaction between the optical probe pulse and the generated acoustic pulse leads to the so-called Brillouin scattering oscillations in the time domain [4]. Experiments have been performed on a single gold nanorod deposited on silica. The frequency of the Brillouin oscillations we observe is in perfect agreement with the frequency measured independently in bulk silica.
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Mon 17:15 ESAL 1 Picosecond laser ultrasonics I

Pushing the Limits of Acoustics at the Nanoscale Using Femtosecond Transient Interferometry – (Contributed, 000344)

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Picosecond acoustics is the perfect technique for measuring elastic properties at nanoscale. But there still are some limitations to reach in-plane properties of ultra-thin films related to optical detection of ultra-high frequency surface acoustic waves. Here we demonstrate that it is possible to push the limits of the technique using an interferometric detection instead of a usual reflectometry scheme. The experimental observations are supported by a simple model which explains from where comes the previous limitations and why it is possible to overcome it using the interferometric setup. Thanks to that results, it is possible to excite and detect very high frequency surface acoustic waves confined in ultra- thin layer using conventional femtosecond laser and optical setup.

Mon 17:30 ESAL 1 Picosecond laser ultrasonics I

Acoustically driven magnetization in ferromagnetic nanostructures – (Contributed, 000578)

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The magnetostriction, which couple lattice and magnetization in any ferromagnetic materials, is a basement for many everyday applications, which remain operating at relatively low frequencies. Picosecond ultrasonics extends the magnetostriction effects toward GHz frequencies and scales them down to nanometers. By injection of the picosecond strain pulses into a ferromagnetic structure, we may induce the coherent magnetization response, which is strong enough to be detected by conventional magneto-optical methods and considered for future nanoscale magneto-mechanical applications. In this talk, we demonstrate the wide abilities of picosecond ultrasonics to manipulate the magnetization of ferromagnetic nanostructures with high efficiency and precision [1-4].
The structures studied are ∼10-100 nanometer ferromagnetic layers of semiconductor (Ga,Mn)As and Galfenol (a metal Fe-Ga alloy) grown on GaAs substrates. An optically excited metal transducer deposited on the substrate backside serves to generate the picosecond strain pulses. Upon arrival to the ferromagnetic structure, the strain pulse modifies the magnetic anisotropy and launches coherent magnetization precession, which we monitor in time domain by the transient Kerr rotation. The magnetization response (its frequency, amplitude etc.) depends on applied magnetic field as well as on parameters of the strain pulse. By using the shear strain pulses, we significantly increase the efficiency of acoustic excitation achieving precession amplitudes of 10% of the saturation magnetization. By exploiting peculiar acoustic properties of the studied structures, such as the boundary conditions and the Eigen vibrational modes, we realize selective excitation of the standing spin waves and control of their lifetime.

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Mon 16:45 Esplanade Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" I

Stable Vortex Generation in Liquid Filled Wells by Mode Conversion of Surface Acoustic Waves – (Contributed, 000520)

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By mode conversion of surface acoustic waves stable vortexes were excited in water filled cylindrical wells made of aluminum. Lamb-type surface acoustic waves with a frequency of 1 MHz were excited by piezoelectric single-phase transducers attached to the outer surface of the bottom of the well. Resulting from mode conversion ultrasound waves were radiated into the water at an angle of 30 degrees with respect to the vertical direction (Rayleigh angle) causing Eckart streaming in the body of the liquid. Vortexes with different rotational orientations were generated depending on the location of the single-phase transducers at the bottom of the well including a symmetric double-vortex configuration with opposite rotational directions of both vortexes ("butterfly pattern"). The stability of the vortexes strongly depended on the liquid level within the well. Further investigations are aiming at the mixing of small amounts of liquids in multi-titer-plates for high-throughput screening without contact of the liquid with moving mechanical parts.

Mon 17:00 Esplanade Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" I

Modal Rayleigh-like streaming in layered acoustofluidic particle manipulation devices – (Contributed, 000052)

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Streaming in ultrasonic manipulation systems generates fluid flows that can potentially disrupt the ordering of particles with acoustic radiation forces. Eckhart streaming, caused by loses in the bulk of the fluid and Rayleigh streaming, driven by velocity gradients in the thermoviscous boundary layers are well known, and have been extensively studied. We have recently investigated streaming patterns in planar resonators whose mechanism had not previously been understood. These patterns which were in a plane normal to the axis of acoustic propagation were found to be closely related to the pattern of complex acoustic intensity. In this presentation we will describe another type of streaming pattern that we have observed experimentally. This pattern has similarities to classical Rayleigh streaming, however its vortex rolls have sizes related to cavity modes of the fluidic chamber, and can thus be larger than those of Rayleigh streaming. Modelling results confirm our hypothesis and give insight into the physical mechanisms involved.

Mon 17:15 Esplanade Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" I

Measurements of streams agitated by fluid loaded and unloaded SAW-devices using a volumetric 3-component measurement technique (V3V) – (Contributed, 000102)

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The excitation volume of a SAW-device and therefore the wave field of the acoustic wave depends strongly on the position of the device. For a loaded device the acoustic wave is approximately a rectangular function whereas the excitation decays exponentially for an unloaded device. According to the diffraction on a slit one can obtain a rough approximation about the wave field in the near and far field. The state of the art is using the model of the rectangular function for unloaded devices in the approcimation of a far field. To verify this assumption a 2D-PIV system was used by Dentry et al. [1]. But the assumption of a rectangular wave field should be more correct for the loaded device as for the unloaded.
To investigate this fact the position of the SAW-device was varied, so that the device was in one setup loaded and in another unloaded. This should result in a difference of the velocity field agitated by the loaded and unloaded SAW-device. We present for the first time, the unique V3V System from TSI which has been used to investigate the velocity field in a (20x50x50)mm cuvette. This measurement system features high spatially resolved 3-component velocity measurements inside the whole measurement volume of (20x50x50)mm. Therefore near and far field effects are can be observed simultanesously. The measurements showed differences between the velocity field of an unloaded and loaded device. This differeneces can be described by the sundry wave fields and the approximation of a near and far field.

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Mon 17:30 Esplanade Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" I

A Numerical Study of the Transient Build-up of Acoustic Streaming in Microchannels – (Contributed, 000359)

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Motivation
Handling of sub-micrometer bioparticles, such as bacteria, is important in biomedical, environmental, and food analysis applications. Typically, the streaming flow induced by standing acoustic waves prevents focusing of sub-micrometer particles as it counteracts the radiation force [1]. It has been shown experimentally that pulsed acoustic fields can lead to a reduction of the acoustic streaming [2]. To explain this reduction, we present a numerical study of the transient build-up of the acoustic

fields and the streaming in a microchannel.

Methods
Extending our previously developed numerical scheme describing steady-state time-averaged streaming [3], our present analysis takes into account the full time dependence of all fields involved. We switch on the acoustic actuation on a quiescent liquid, and study how the time-dependent acoustic resonance field and streaming flow are being established, and, also as a function of time, study how a steady component in the streaming builds up.

Results
Our results show a separation in timescales between the build-up time t_{res} of the acoustic resonance and the build-up time t_{str} of the steady component in the acoustic streaming flow. It may thus be possible to ensure a reduced streaming flow by operating the piezo transducer in pulsed mode with a pulse time t_{pls} fulfilling $t_{\mathrm{res}} < t_{\mathrm{pls}} < t_{\mathrm{str}}$, such that the resonance field and the associated radiation force act in full, before the otherwise detrimental streaming flow has reached any appreciable magnitude.

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Mon 17:45 Esplanade Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" I

Numerical analysis of the acoustic radiation force and acoustic streaming around a sphere in an acoustic standing wave – (Contributed, 000322)

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The main driving force in acoustophoretic applications is commonly attributed to the acoustic radiation force. This force can be obtained by integrating the time-averaged second-order stresses on the surface of the object under analysis. Calculation of acoustic radiation force has been investigated for the past few decades, and several formulae have been proposed, with the recent ones modified to add viscosity and thermal effects. Those closed-form formulae are only valid for a small sphere (compared to the wavelength). The acoustic streaming induced by the scattered waves is also neglected in their derivations.
The acoustic streaming is governed by equations similar to compressible Stokes flow where the volumetric body force is a quadratic function of the harmonic (first-order) velocity and pressure. By converting the equations to a set of Laplace equations of scalar and vector potentials, streaming velocity and pressure can be obtained numerically. Then, the total second-order stresses would be the sum of both the streaming-induced and the Reynolds stresses. We, hereby, propose a numerical scheme for calculation of acoustic streaming and, subsequently, radiation force on a sphere in a viscous fluid. Series expansion of eigen-functions of Helmholtz and Laplace equations were used for solving the first and second order (streaming) equations, respectively. The boundary conditions were imposed using the weighted residual technique. For small sizes of the sphere, the results match very well with Doinikov's solution (the relative error is less than 1%). For larger sizes, high-order eigen-functions are required for better accuracy. The proposed numerical scheme can be extended to the case of multiple spheres in a viscous fluid.

Mon 16:00 Orangerie Device technology: transducers

Application of PMN-32PT piezoelectric crystals for novel air-coupled ultrasonic transducers – (Contributed, 000078)

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Lead magnesium niobate-lead titanate [PbMg1/3Nb2/3O3-PbTiO3 (PMN-PT)] single crystals have excellent piezoelectric properties, what enables to exploit them in air-coupled ultrasonic transducers with enhanced performance. Objective of this research was development and experimental verification of novel effective air-coupled ultrasonic transducers with PMN-32PT piezoelectric crystals. For air-coupled applications the operation frequency usually is f $\leq$ 100 kHz. In order to obtain such low frequencies the main transverse length mode of piezoelectric crystal plates has been selected. For this purpose rectangular PMN-32PT single crystals with dimensions (15 x 5 x 1) mm and the [011] poled direction were investigated. The direction 2 gives a greater electromechanical coupling coefficient (k up to 0.97), therefore it was selected. For matching of acoustic impedances of piezoelectric elements and air various matching elements were investigated. An air-coupled ultrasonic array consisting of the 8 single piezoelectric bars was designed. Operation of the transducer was simulated by the finite element method using ANSYS Mechanical APDL Product Launcher software. Spatial distributions of displacements inside piezoelectric elements and matching layer were obtained. Experimental investigations were carried out by the laser Doppler vibrometer Polytec OFV-5000 and the Wayne Kerr electric impedance meter. The laser vibrometer was used to record mechanical displacements of the active surface of the transducer in continuous and transient modes. A good agreement between finite element simulation and measurement results was observed. It was found that performance of the array with PMN-32PT crystals was a few times better than PZT based array.

Mon 16:15 Orangerie Device technology: transducers

A Cylindrical Transducer with Piezo-Polymer Membrane: Analytical and Experimental Results – (Contributed, 000453)

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This work aims at providing a theoretical description of a cylindrical transducer composed of a Polyvinylidene fluoride (PVDF) membrane wrapped around a cylindrical structure, forming a rear toroidal air-filled cavity. Based on the fundamental equations of piezoelectricity and linear acoustics, an analytical model is presented. It intends for taking into account the resonances of the system, in both the radial and the axial directions, which result from the coupling between the displacement of the membrane and the pressure fields on both of its sides, and it accounts to some extend for the viscous and thermal boundary layer effects. Solutions are obtained using modal expansion theory for the displacement field of the membrane and for the acoustic pressure field in the rear cavity. A lumped elements network is also provided. It is derived from the solutions of the analytical model when considering both low frequency and lower order approximations. Comparisons between experimental results and theoretical ones for the pressure radiated as a function of frequency show a good agreement. Improvement of this transducer aiming at including directional receivers in view of application in ultrasonic ranging device is finally discussed.

Mon 16:30 Orangerie Device technology: transducers

MRI Compatible Ultrasound Transducers for Simultaneous Acquisition of Coregistered Ultrasound to MRI Data – (Contributed, 000584)

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Magnetic resonance imaging has become an important part of radiological diagnostics as it shows high resolution volumina of human tissue without any radiation exposure. Beside the high costs for MR imaging the greatest disadvantage of this technology is that it is not real-time capable which leads to possible motion artifacts.
Ultrasound is the most common diagnostic tool in radiology as it is real-time capable and cost effective. Therefore a combination of both modalities is obvious, not only to reduce motion artifacts in MR imaging but to save costs by reducing time in the MR system through coregistering ultrasound and MR images. This brings the possibility to do biopsies of tumors that are not visible in ultrasound with a virtual real time MR Image, based on consecutive acquisition of ultrasound, while relocating the patient to another room for biopsy.
We found that a MR tomograph has such a high sensitivity, that it is able to receive the harmonics of the ultrasound transmit signal around 125 MHz. To take this into account a special shielding concept has been developed and the transducer materials as well as all other components were chosen non ferromagnetic.
In this context we build several different transducers for motion compensation as well as a fully MR compatible 180° rotating phased array for registration of tissue deformation. This information is used to calculate the deformation in the MR image during biopsy. It has been shown that the acquisition of ultrasound and MRI can be done simultaneously without significant interferences of both modalities.

Mon 16:45 Orangerie Device technology: transducers

Modified BiFeO3-PbTiO3 MPB solid solutions for High temperature and High Power Transducers in Harsh Environment – (Contributed, 000321)

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Perovskite (1-x)BiFeO-xPbTiO (BF-PT) solid solutions with a morphotropic phase boundary (MPB) at about x=0.3, have received much attention due to their excellent piezoelectric properties with Curie temperature Tc of above 600 C. In this talk, different cations of La3+, Ga3+, Mn2+ and Gd have been introduced into the perovskite A- and/or B- site of BF-PT. The relaxor Pb(Mn,Nb)O (PMN) ferrroelectrics was also introduced into the BF-PT system to form BF-PT-PMN ternary piezoelectric ceramics. It has been found that the A-site La and Gd modification would increase the piezoelectric and insulating properties of BF-PT, however, causing Tc to decrease significantly. B- site Mn modification could reduce the dielectric loss to 0.004 and increase electromechanical quality factor Qm of above 560. Addition of PMN improves the sintering capability of BF-PT. The piezoelectric constant of about 72 pC/N could be achieved for BF-PT-PMN with Tc as high as 635 C. Moreover, the dielectric and piezoelectric properties of modified BF-PT ceramics were investigated as a function of temperature and electrical field. Our results indicate that modified BF-PT solid solutions could satisfy with high temperature and high power transducer applications in harsh environment.

Mon 17:00 Orangerie Device technology: transducers

Laser experimental study of the surface vibrations of EMUS sensor – (Contributed, 000397)

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In order to ensure a comprehensive monitoring of the material structuration in liquid phase, the traditional ultrasonic techniques require excitation in contact which is often inadequate for online tracking. To monitor the material evolution remotely, a new electromagnetic ultrasonic sensor (EMUS) was successfully developed in our laboratory (Acoustics'12 Nantes pp.659- 663, 2012 - IEEE Transactions on Magnetics, 49, pp.132-135, 2013 - CFA Poitiers, pp. 723-729, 2014). The EMUS transducer is based on a resonant thickness shear mode sensor (TSM) magnetically coupled to a high frequency antenna. The TSM resonator consists in a piezoelectric AT-cut quartz plate with metal electrodes on opposite sides. The application of a radio frequency electrical signal gives rise to the excitation of a shear mechanical resonance. The work presented here allows characterizing the acoustic behavior of the EMUS sensor via a time-frequency signal analysis. A laser vibrometer is first used to scan the surface of the TSM resonator and visualize the propagation of the generated surface waves. A multi-dimensional time- frequency analysis is then carried out by 3D Gabor transform to quantify the transient aspects, understand the mode conversion sequence and obtain the dispersion curves. Similarly, the eigen modes of vibration are determined and compared with the theoretically obtained by the application of the classical equation of the plate using the corresponding boundary conditions. This study shows a good agreement between experimental and theoretical results which encourages the study of acoustic interaction between the TSM resonator and a material in contact with the quartz surface. They therefore suggest that this non-destructive technique can be used to extract the viscoelastic properties of materials.

Mon 16:15 ESAL 2 Physical acoustics: Piezoelectrics and transducers

Efficient Algorithm Using a Broadband Approach to Determine the Complex Constants of Piezoelectric Ceramics – (Contributed, 000195)

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Piezoceramic property values are required for modeling piezoelectric transducers. Most datasheets present large variations in such values. For precise simulations, adjustments are necessary. A new systematic and efficient algorithm to obtain the ten complex constants of piezoelectric materials was developed. Given the electrical conductance and resistance of a piezoceramic, the objective is to find the constants that minimize the difference between the experimental and numerical curves. A finite element method routine was implemented in Matlab using 8-node axisymmetric elements. The algorithm raises the electrical conductance and resistance curves and calculates the quadratic difference between the experimental and numerical curves. Finally, to minimize the difference, an optimization algorithm based on the "Method of Moving Asymptotes" (MMA) is used. To assure the convergence of the curves, the following conditions were proposed: determining the initial values of the constants (considering the real values indicated by the manufacturer and the imaginary values to be 1% of the real values); setting the lower and upper limits of the MMA moving asymptotes; dividing the optimization process into a preliminary (2x20 elements) and a refinement (5x50 elements) mesh. In this paper, the method was applied to two 1-MHz piezoceramic discs (APC855 and Pz27). This algorithm is able to find the 20 parameters (10 real and 10 imaginary) regardless of the user intervention, allowing efficient adjustment (500 iterations) of all experimental and numerical curves over a wide frequency range (3kHz-1.3MHz). Comparing to a 4-node-element algorithm, previously implemented by the authors, this algorithm allows the convergence with fewer elements.

Mon 16:30 ESAL 2 Physical acoustics: Piezoelectrics and transducers

Carrier dynamics and piezoelectricity in GaN studied by non-contacting resonant ultrasound spectroscopy – (Contributed, 000196)

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Temperature dependencies of mechanical resonance frequencies and internal friction of a semi- insulated GaN were studied with the antenna-trasmission acoustic-resonance technique,which we originally developed as a non-contacting resonant ultrasound spectroscopy. An internal-friction peak appears during temperature change, at which the frequency gap appears. The internal-friction-peak temperature rises as frequency increases, indicating the phonon-assisted hopping conduction of carriers between the deep centers. The Arrhenius plot yields the activation energy of the hopping conduction. The frequency reduction of a quasi-plane-shear resonance mode yields the piezoelectric coefficient e_{15}.

Mon 16:45 ESAL 2 Physical acoustics: Piezoelectrics and transducers

Radiation Properties of Truncated Cones to Enhance the Beam Pattern of Air-Coupled Transducers – (Contributed, 000217)

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MOTIVATION
Ultrasonic range estimation can be performed with broadband electrostatic transducers. Their beam pattern is highly directional and presents strong attenuation a few degrees off the main axis. To access a larger area the transducer's main lobe must then be scanned by tilting and panning while emission of a chirp and reception of echoes is performed. In this new work, a structure of superposed truncated cones directs the acoustic energy from the side lobes toward the main axis to enlarge the main lobe so that a wider area is inspected in one measure with no scanning.
METHODS
To strengthen and enlarge the beam pattern's main lobe, a structure made of superposed truncated cones is mounted on the edge of the transducer. Each cone is aligned to the orientation of a side lobe from the beam pattern and has a flare rate that reflects the sound towards the angular extension of the main lobe or its proximity. The geometry of this structure is described as well as the relationship between each cone's flare angle and the desired lobe steering.
RESULTS
Acoustic simulations with different flares of truncated cones are performed in order to direct energy from the sides (50° to 90° off beam pattern's main axis) to the front (0° to 40° off main axis). Results show that the acoustic energy removed from the side lobes contributes to the main lobe (or nearby to it) depending on the desired steering in the design.

Mon 17:00 ESAL 2 Physical acoustics: Piezoelectrics and transducers

High frequency transducer dedicated to the high-resolution in situ measurement of the distance between two nuclear fuel plates – (Contributed, 000293)

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Most high flux reactors for research purposes have fuel elements composed of plates. The distance between two plates is a parameter of crucial importance, particularly concerning the irradiation history. For the High Flux Reactor of the Institut Laue-Langevin, the measurement of this distance with a microscopic resolution becomes extremely challenging for spent elements. That is the reason why a cheap and flexible solution has been considered: a robust device (transducer) based upon high frequency ultrasonic probes, adapted to the high radiation environment and thinned to 1 mm to be inserted into a 1.8 mm width water channel between two fuel plates.
To achieve the expected resolution, the system is excited with frequencies up to 150 MHz and integrated into a set of high frequency acquisition instruments. Thanks to a specific signal processing, this device allows the distance measurement through the evaluation of the ultrasonic wave time of flight.

The transmission and reflection of ultrasonic signals at normal incidence through the multilayer system of parallel layers of the transducer was modeled. The encouraging results of this model allow enhancements of the characteristics and the properties of the transducer and of the plates. The device was tested with success on a full size irradiated fuel element of the RHF on the 20th of December 2013. It was proved that the different components of the ultrasonic sensor showed good resistance to radiations. Moreover, the quality of the signal to noise ratio was clearly sufficient to obtain a very stable estimation of the inter-plate distance while some flaws may still have to be corrected to perform an absolute identification.

Mon 17:15 ESAL 2 Physical acoustics: Piezoelectrics and transducers

A Study in Wedge Waves with Applications in Acoustic Delay- line – (Contributed, 000303)

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Traditional ultrasound transducer suffers the drawbacks of noise from coupling agent and limited spatial resolution. This study takes the advantage wedge waves and develops a new acoustic delay-line. Wedge waves (WW) are guided acoustic waves propagating along the tip of wedge-shaped waveguides with their motion tightly confined near the wedge tip. Without apex truncation, WW's are free of dispersion. While a wedge corner is used for contact area, the wedge apex is used for delay-line carrying WW's. In this way, polarization of the acoustic signal can be controlled by selecting the tilting angle of the WW delay-line. The WW delay-line for detecting ultrasonic signals are characterized experimentally. The experiment configuration consists of a 5MHz shear wave transducer and a wedge acoustic delay-line for signal excitation and detection. In this research, the wedge delay-line is composed of a 2.25MHz shear piezoelectric transducer and an aluminum wedge with apex angle 60°. The signal is measured with various contact angles between wedge delay-line transducer and specimen. The waveforms detected under different contact angle starting from 35° to 90° with an interval angle is 5°. The detected signal is found to increase as the contact angle increases. The result shows when contact angle is approaching to 90°, the WW transducer receives more contributions from the in-plane shear wave. The wedge delay-line transducer are characterized experimentally. Advantages of wedge delay-line transducer include point-wise contact area, no coupling agent needed and polarization selection by managing the tilting angle.

Mon 17:30 ESAL 2 Physical acoustics: Piezoelectrics and transducers

Estimation of acoustic radiation force and its effectiveness by visual observation of liquid crystal shape change – (Contributed, 000412)

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Acoustic radiation force is a non-contact force for handing microparticles from DNA molecules to cells within a microfluidic pathway. One of the advantages of acoustic radiation force is that the flexible control of wider acoustical force field, which enables us to handle samples for concentration, line-up, mixing, and separation. Moreover, simple superposition of higher harmonics of fundamental acoustic ultrasounds enables us to modify the gradient of force field. In this presentation, a variety of fundamental usage of acoustic radiation force in microfluidic region for handling DNAs to cells and also introduced the potential damage on DNAs to cells caused by acoustic radiation fore. And we also evaluate the origin of acoustic radiation force for molecule level handling exploiting the liquid crystal lattice shape change itself without any of microbeads movement measurements. The results introduce the potential of acoustic radiation force for practical application in microfluidics not only cells but also molecules.

Mon 17:45 ESAL 2 Physical acoustics: Piezoelectrics and transducers

Analytical sensor response function of viscosity sensors based on layered piezoelectric thickness shear resonators – (Contributed, 000443)

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Resonant piezoelectric sensors based on bulk acoustic wave (BAW) thickness shear resonators are promising for the inline measurement of fluid viscosity, e.g., in industrial processes. The sensor response function can be derived from the general rigorous transfer matrix description of one-dimensional layered structures consisting of piezoelectric and non-piezoelectric layers of arbitrary number. The recently published model according to Nowotny et al. provides a complete analytical description of the electrical and mechanical behaviour of such structures with two electrodes and arbitrary acoustic termination impedances (Rig-1d-Model). We apply this model to derive the sensor response functions and the mechanical displacement curves of the following configurations used for viscosity sensors in practice: 1) An AT cut quartz crystal plate in contact with atmospheric air at the backside plane and with the liquid under investigation at the front side plane (aQL). 2) An AT cut quartz crystal in contact with the liquid under investigation at both sides (LQL). It is shown that in the aQL case the originally only heuristically introduced and well established sensor response function according to Kanasawa can be derived from the Rig-1d-Model by introducing the minor approximation of assuming vacuum termination instead of atmospheric air termination at the backside plane. Furthermore and of more fundamental importance, it is shown that a significant outcome from the Rig-1d-Model sensor response function derivation can be advantageously used: The resonance frequency shift is solely connected to the imaginary part of the acoustic impedance, whereas the increase of the resonance half width is solely connected to the real part of the acoustic impedance of the termination medium. Experimental results are presented for the LQL configuration using a viscosity reference oil as test fluid.

Mon 15:00 Main Hall Acoustic waveguide applications (poster)

Packageless and CMOS Compatibility of SAW Devices: Theoretical and Experimental Investigations – (Contributed, 000510)

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Surface acoustic wave (SAW) devices are the key elements in communication systems and are employed as resonators, filters or delay lines. They are more and more used as sensors due to several advantages like small size, high sensitivity to various physical and chemical parameters, low price and the possibility to be wireless and passive. However, SAW devices must be protected from environment contaminations which can affect the acoustic wave propagation conditions. Currently, SAW devices are typically packaged in hermetic enclosures because of this surface sensitivity. However, the packages represente 50% of the final device. The search of a new or improved processes and technologies is an expanding field, mainly in order to minimize the device dimensions with CMOS compatibility. The flexibility of SAW devices permits to improve or to find new processes and technologies of packaging. Packageless structures are becoming more attractive in order to reduce dimensions and device complexity in production. To create the packageless structure, two concepts may be considered: isolated layer acoustic wave (ILAW) and waveguiding layer acoustic wave (WLAW). The principle of the first one is based on a combination of the high and low acoustic impedance layer forming a Bragg like mirror thus confining the acoustic wave. The second concept is the confinement of the wave in a low acoustic velocity layer enclosed between two high acoustic velocity materials. The possibility to perform a packageless structure with CMOS compatibility for acoustic wave sensors applications based on AlN/IDT/ZnO/Si structure was investigated theoretically by two dimensional finite element methods. The effect of thicknesses of AlN and ZnO thin films on structure performance and wave confinement was simulated. Theoretical predictions were confirmed by in-situ measurements of frequency, insertion loss and thickness during magnetron sputtering deposition of AlN layer on ZnO/Si.

Mon 15:00 Main Hall Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics (Special Session in Honour of Professor Emeritus Oswald Leroy) (poster)

Acousto-optic filtration of interfering light beams for 3D visualization of amplitude and phase structure of micron-size specimens – (Contributed, 000137)

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The problem of 3D visualization of amplitude and phase structure of micron- size specimens is discussed. A technique for acousto-optic image filtration in full-field interferometry is proposed. It is based on the spectral selection of light in the registration channel of the Michelson (reflectance scheme) or Mach-Zehnder (transmittance scheme) interferometer by imaging acousto-optical tunable filter. The scheme does not contain any moving components. The technique is applicable for various full-field spectral-domain systems in profilometry, optical coherence tomography and digital holography. It is experimentally shown that obtained spectral signals be may be effectively used for 3D structure visualization of optically inhomogeneous objects.

Mon 15:00 Main Hall Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics (Special Session in Honour of Professor Emeritus Oswald Leroy) (poster)

Photoelastic and Acousto-Optic Properties of KDP Crystal Applied in Wide Angle Tunable Filters – (Contributed, 000241)

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At present, scientific literature describes a considerable number of acousto-optic devises differing in design, function and purpose. However, scientists and engineers meet difficulties each time they intend to select spectral lines and process images in the ultraviolet region of spectrum. For example, problems arise when one carries out acousto-optic spectral analysis of atmosphere of the Earth or monitors concentration of ozone in it. The report presents results on calculation and measurement of acousto- optic properties of KDP crystals applied in imaging tunable acousto-optic filters operating in the ultraviolet and visible domains of electromagnetic radiation. Effective photoelastic coefficients and figure of merit values were evaluated in the regime of wide angle diffraction. The carried out analysis was based on results of measurements of the diffraction efficiency at a single frequency of ultrasound and simultaneously at two different angles of light incidence. The measurements were carried using laser sources of light at the wavelengths λ=405 nm and λ=532 nm. Two imaging filters were applied in the experiments in which slow shear acoustic waves propagated at the angles α=9^0 and α=12^0 relatively to the [100] axis in the (010) plane. Differences between measured data on the photoelastic coefficients and those found in literature are discussed in the presentation. This reseachs were supported by the grant from Russia Science foundation (Project N°14- 12-00380)

Mon 15:00 Main Hall Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics (Special Session in Honour of Professor Emeritus Oswald Leroy) (poster)

Use of Linear Frequency-modulated Acoustic Pulses for Synthesizing Instrument Functions of AOTF Spectrometer – (Contributed, 000298)

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The synthesis of acousto-optical spectrometer instrument function is an attractive promising problem. Till now, there were some successful attempts to change specifically the form of acousto-optical tunable filter (AOTF) instrument function both momentary and averaged one. However, there is still no any universal global approach for solving the problem. In particular, the idea of the instrument function digital synthesis with use of a set of discrete frequency components meets with the negative effect of near frequencies beating that compromises this approach. We discuss another idea based on use of linear frequency-modulated (LFM) pulses as elements for the digital synthesis of the instrument function. As an example, the light collinear diffraction on the train of the pair of LFM acoustic pulses is considered. The effects of bandwidth broadening, oscillations of transmission function and the interference of two passbands are described. The study of the approach demonstrates the capability of tailoring broadband transmission windows with rather narrow bandgaps.

Mon 15:00 Main Hall Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics (Special Session in Honour of Professor Emeritus Oswald Leroy) (poster)

Dynamic behavior of a multiwavelength acousto-optic filter – (Contributed, 000350)

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Wavelength filtering in optical telecommunications can be done by taking advantages of the acousto-optic interaction in anisotropic medium and especially with a quasi-collinear interaction in paratellurite crystal. Simultaneous selection of multiple wavelengths can be performed by applying multiple RF signal with different frequencies to the transducer. The objective of the paper is to analyse, in the case of a multi-wavelength filter application, the evolution of the optical diffraction efficiency for dynamic regime according to the operating conditions. Experimental and simulated results obtained upon the 1500-1600nm wavelength range are presented. The multi-wavelength filter operation requires the superimposition in the crystal of several acoustic waves. In those case, beat frequencies appears when the acoustic wave frequencies are closed. We show experimentally, that when two closed wavelengths are selected, which correspond to a beat period T near or less than the interaction time TL (interaction length divided by the acoustic velocity) the diffracted optical beam is disturbed: temporal fluctuations of the intensity appear. Those intensity fluctuations may be critical for the development of telecommunication systems, so they must be controlled and analysed. We propose a model based on the fact that the optical diffracted intensity depends on both amplitude and frequency distribution of the acoustic field in the interaction area. So, we consider that the diffracted intensity for a selected wavelength is proportional to the acoustic power spectral density calculated for the corresponding frequency. Therefore, we propose a time-frequency analyse of the acoustic signal to get information upon the diffracted optical intensity evolution.

Mon 15:00 Main Hall Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics (Special Session in Honour of Professor Emeritus Oswald Leroy) (poster)

Application of Optical Freedom Degrees Principle to Acousto- Optic Devices – (Contributed, 000353)

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Concept of optical freedom degrees is fruitfully applied to information description of many optical and optoelectronic systems. This concept application allows to form a new view to acousto-optic devices and systems. Different acousto- optic devices have been considered from the point of view of numerous kinds of optical freedom degrees combinations contained in these devices. It has been shown that acousto-optic tunable filters (AOTF), especially with large angular aperture, demonstrate the widest possibilities in exchange different kinds of optical freedom degrees. It brings the new possibilities in information flows optimization in AOTFs. One of the most important operations which has to be performed in acousto- optic devices in order to find the possible amount of optical freedom degrees as well as the information capacity and productivity of these devices, is digitization of the processed sig-

nals in all its physical carriers, including acoustic wave propagating through the crystal in Bragg cell. The principles of this digitization have been analyzed. It has been found that the digitization principle based on calculable physical phenomena (such as, for example, light and ultrasound diffraction) has limited application whereas principles based on statistical phenomena and technical limitation produce the suitable situation for the amount of optical freedom degrees estimation. Hence, it has been found that the application of optical freedom degrees principle proposed by M.Laue and developed by D.Gabor and G.Toraldo di Francia, to acousto-optic devices, produces the fruitful way for information optimization of these devices.

Mon 15:00 Main Hall Bio-medical ultrasound for therapy (poster)

Possibilities of high intensity focused ultrasound in the treatment of hydatid cysts of the liver – (Contributed, 000014)

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Objective: The objective of this paper is to introduce the possibility of using high intensity focused ultrasound (HIFU) in the treatment of hydatid cysts of the liver.
Materials and methods: HIFU ablation was carried out in 62 patients with echinococcus of the liver. Participants ranged in age from 17 to 72 years; mean age was 40.8 (SD=14.8). Preoperative examination of all patients included ultrasound (US), computed tomography (CT) and magnetic resonance tomography (MRT). HIFU ablation of was performed using HIFU therapy system (Model JC type, Chongqing Haifu Tech Co., Ltd, Chongqing City, China) with therapeutic lens 12 cm in diameter, frequency 0,9 MHz and focal distance ranging from 10 to 16 cm. HIFU therapy was performed under general anesthesia with endotracheal intubation in this study. Effectiveness of ongoing treatment was controlled by using US, CT and MRI. Cytomorphological evidences of destructive changes of the parasites, including loss of embryonic elements, were obtained for 3-4 day after HIFU ablation.

Results: Small sizes of identified structures (about 200-800 nm) were considered as evidence of destruction of invasive microscopic acephalocysts (100-200 μm in diameter), that is crucially important in view of effective treatment of hydatid disease. Retrospective study of the treated patients was performed. Positive clinical presentation has been identified in 42 (68%) participants including: cyst disappearance - 9 cases, calcinosis - 14 cases, reducing of cyst sizes more than 1/2 - 19 cases. Traditional surgical treatment was carried out in 7 patients after HIFU treatment. For 3 years no cases of relapses was found.

Conclusion: Minimally invasive and minimal risk of HIFU ablation a significant reduction in terms of postoperative rehabilitation of patients.

Mon 15:00 Main Hall Bio-medical ultrasound for therapy (poster)

The measurement of temperature gradients in a soft tissue phantom using PVDF arrays: A simulation case using the Finite Element Method (FEM) – (Contributed, 000114)

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A simulation case is presented using the Finite Element Method (FEM) to simulate the performance of PVDF arrays to measure temperature gradients through the determination of phase shifts, i.e. time shifts of the waveform of the echo due to a change in the speed of propagation of ultrasound as a result of a change in temperature, they can be interpreted as phase shifts in the frequency domain. Making it possible to determine the change in temperature from the phase shifts; in a medium of propagation previously characterized. After simulation, the construction of the array was made using a thin PVDF film (9 thickness), uniformly polarized (Piezo Film sheet), it was cover using a conductive layer of epoxy (Conductive Epoxy CW2400J) on each of the faces. To carry out tests inside a water tank, a layer of electrical insulation was bonded to the contacts and the faces of the transducer. Linear arrays of 4 elements were simulated and then constructed; with two variants in the backing; one using acrylic and another using only air. The evaluation of the response of the arrays was first conducted in water and later on a soft tissue phantom. In both cases the Hydrogel sphere contains the volume of water at a higher temperature than the rest of the water and/or soft tissue phantom. Experimental results show a linear relationship between temperature and phase changes, which is equivalent to that reported by other authors whom had used other methods or techniques such as time delays or the spectral power density to measure temperature changes. The disadvantage of the signal processing technique used is that it is not robust against noise, since it has a high sensitivity to phase transitions. The results are very promising on noninvasive measurement of temperatures using spatial-temporal resolution,

our method relates phase shift to temperature variation. The variation of temperature with respect to time is an area of interest to explore.

Mon 15:00 Main Hall Bio-medical ultrasound for therapy (poster)

New Combinational Method for Noninvasive Treatments of Superficial Tissues for Body Aesthetics Applications – (Contributed, 000232)

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The paper introduces an innovative combinational treatment method based on ultrasonic standing waves (USW) technology for noninvasive surgical, therapeutic, lypolitic or cosmetic treatment of tissues including subcutaneous adipose tissue, cellulite or skin on arbitrary body part of patient. The method is based on simultaneous or successive applying of constructively interfering physically and biologically sensed influences: USW, ultrasonic shear waves, radio-frequency (RF) heating, and vacuum massage. Unlike all existing HIFU and non-focused systems, ultrasound energy in USW directed parallel to the body surface and fully localized in treated body region. Resulting USW efficiency is comparable with HIFU at huge increase of treated tissue volume. Continuous cyclic changes of the nodal pattern of USW with proper repetition rates corresponding to a specific resonant or relaxation times of living cells or tissue components provide effective dynamical influence of USW on tissues. Synergetic combination of USW with RF therapeutic heating and vacuum massage lowering cavitation threshold and intensifying a blood flow and clearance of disrupted cell debris along with inherent treatment process control and diagnostic possibilities offers a great future for the technology. The paper provides basic physical principles of USW as well as critical comparison of USW and HIFU methods. The results of finite-elements and finite- difference modeling of USW transducer design and nodal pattern structure in tissue are presented. Biological effects of USW-tissue interaction and synergetic aspects of USW and RF combination are explored. Combinational treatment transducer designs and original in-vitro experiments on tissues are described.

Mon 15:00 Main Hall Bio-medical ultrasound for therapy (poster)

Structure-based Ultrasound Image Similarity Measurement – (Contributed, 000251)

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I - INTRODUCTION

Being a crucial part of ultrasound image interpretation, the ultrasound local pattern similarity measurements is of high interest in medical imaging, and its applications seems evident in several fields. To just name a few, noise filtering, motion tracking and registration. However, to date, not much attention has been paid to the global ultrasound image similarity measurements, whose potential applications include speckle tracking refinement, image quality assessment. In this paper, we present a novel method for the measure of the similarity between ultrasound images, which incorporates the structural similarity measurements with the maximum likelihood estimation (MLE) framework.

II - METHODS

Mean Squared Error (MSE) was first used to estimate the similarity, which is not suitable for the ultrasound image as the ultrasound image is contaminated by the speckle noise. Structural similarity is another method to measure the similarity. The classical structural similarity assesses the visual impact of three characteristics of an image from three aspects: luminance, contrast and structure. Unlike the approach to calculate the local means, standard deviations and cross-covariance for adjacent two images directly, we propose to compute the three aspects based on the local speckle statistics, in which locally adaptive Nakagami distribution-based similarity measurements are used.

III- RESULTS

The proposed method has been tested on the synthetic images dataset and the ultrasound tongue images dataset, the results are given in the paper. The experiments demonstrate the proposed method can consistently improve the performance in the paper and this technique has been integrated into the ultrasound tongue's contour tracking system to refine the contour tracking. Although our original target is for the ultrasound tongue images, it can be extended to other kind of images which are contaminated by the speckle noise.

Mon 15:00 Main Hall Bio-medical ultrasound for therapy (poster)

Experience of using high-intensity focused ultrasound ablation (HIFU) in the treatment of benign tumors of the mammary glands – (Contributed, 000539)

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Objective: Development and implementation of alternative method treatment of benign tumors of the mammary glands. Actuality:Fibroadenoma-one of the most common diseases of the mammary glands and the major part of all benign tumors. One way to reduce morbidity and mortality from breast cancer is early detection and treatment of benign breast diseases . Methods and materials research: examined 39 patients with a diagnosis of localized fibroadenomatosis breast. At the age of 16 to 62 years. The diagnosis is based on clinical data , ultrasound , mammography , results of a core biopsy. HIFU-therapy performed using ultrasound system "JC- uses high-intensity focused ultrasound. Results: All patients were subdivided into 3 groups according to tumor size . Of the 30 patients treated fibroadenomas I group after 6 months after the HIFU -ablyatsii examined 19 patients. In 6 cases, ultrasound scanning the tumor was not visualized in 8 cases, there hyperechogenicity , reducing the diameter of Education 2 times. In 5 cases the size of fibroadenoma is not changed, but changed ehostruktura , she became hyperechoic . In group II fibroadenomas treated at 6 months were examined 8 patients , of whom 5 at ultrasonography noted hyperechogenicity , reducing the size of education in 2 times. In 3 cases, there hyperechogenicity tumor without resizing . In group III, tumor size did not change throughout the ultrasonographic tumor hyperechoic areas (areas of fibrosis) . Conclusions : 1) HIFU - therapy effective treatment for breast fibroadenoma . 2) HIFU - therapy can be used as a separate type of treatment breast fibroadenoma.

Mon 15:00 Main Hall Device technology (poster)

Design of a High-output Airborne Ultrasonic Transducer using Polymer-based Elastomer – (Contributed, 000074)

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Motivation: Nowadays, airborne ultrasonic transducer is applied in industry and daily life, whose performance needs to be improved for wider application. With the low density, low elastic modulus, and high quality factor, polyphenylenesulfide (PPS) is prospective to be applied to more powerful airborne ultrasonic transducer, because high vibration velocity can be generated easily on the PPS-based elastomer. In this paper, using the finite element method, we design and optimize the structure of transducer to obtain high sound pressure. Methods: The proposed transducer consists of a Langevin vibrator and a piece of PPS film. A PPS bar is used as elastomer, and 5 pieces of piezoelectric ceramics are clamped in the middle of the PPS blocks. The PPS film is clamped on the top of the Langevin vibrator using a rod and a bolt. Vibration generated in the Langevin vibrator is transferred to the PPS films. In structure design, first, we adjust the dimensions of these two parts to make their resonance frequencies identical, and second, we simulate and compare the sound pressure distributions generated by different vibration modes. Results: The simulation results indicate that, the L2 and B10 vibration modes are generated on the Langevin vibrator and the film under the driving frequency of 56 kHz, respectively, when the length of the Langevin vibrator is 24 mm, and the diameter of the film is 11.6 mm. The sound pressure at the distance of 300 mm reaches approximately 30 Pa under the zero-to-peak voltage of 20 V.

Mon 15:00 Main Hall Device technology (poster)

Dynamic frequencies correction in piezoelectric transducers using Artificial Intelligence techniques – (Contributed, 000110)

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In many applications, piezoelectric transducers are excited by electrical signals at frequencies near the resonance. The presence of acoustic loads alters the characteristic electrical impedance of these transducers and therefore their performance. The excitation frequency should be adjusted so that performance be maintained. This paper presents an algorithm for dynamic correction of the operating frequency based on prior knowledge of the behaviour of the transducer impedance in the presence acoustic loads. The algorithm is based on the analysis and design of adaptive systems able to correct the frequency using artificial intelligence techniques, from a survey of impedance profiles. An electronic circuit senses the electric current and determines the impedance of the transducer. When the impedance is changed by variation of the acoustic load, a searching of similar impedance values is run in the files previously stored. After that, from these selected values, an iterative process finds the final frequency that is closer than the original impedance for the required performance. The result of the searching operation is sent to a digital potentiometer that controls the frequency generated by the electronic oscillator of the system. The algorithm has been tested on power transducers used in ultrasonic applications. The results show the system is robust and the response times are around hundreds of milliseconds. In addition, preliminary results show that the technique presented can be satisfactorily used in systems for dynamic correction of frequency of piezoelectric transducers.

Mon 15:00 Main Hall Device technology (poster)

A Novel Approach for Optimization of Finite Element Models of Lossy Piezoelectric Elements – (Contributed, 000235)

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The modeling and design of piezoelectric devices by finite element methods (FEM), among others, relies on the accuracy of the dielectric, piezoelectric and elastic coefficients of the active material used, commonly an anisotropic ferroelectric polycrystals. The accurate description of piezoceramics must include the evaluation of the dielectric, piezoelectric and mechanical losses, accounting for the out-of-phase material response to the input signal. Standard FEM packages that are widely used for modeling of piezoelements and devices do not take into account losses. Sets of material constants used for FEM calculations also do not contain losses data, except for QM for radial mode of vibrations. As a result, FEM calculations of real piezoelements and devices can give inadequate results for lossy materials (composites, porous ceramics etc.). In this paper, theoretical aspects of the effective moduli method for an inhomogeneous piezoelectric media are examined. Different models of representative volume are explored. Respective equations for calculation of effective moduli of piezoelectric media with arbitrary anisotropy are derived. Based on these equations and using FEM the full set of effective moduli for PZT porous ceramics having wide porosity range was calculated. A novel approach for optimization of FEM models of lossy piezoceramic elements is proposed. The procedure of optimization has consisted in sequential and iterative application of FEM and piezoelectric resonance analysis (PRAP) to complex electric impedance spectra of piezoceramic elements. For validation of proposed optimization procedure, FEM calculations of standard shape piezoelements (disks, bars and rods) made from dense and porous PZT-type piezoceramics are fulfilled using FEM ANSYS package. Comparison shows a good agreement between initial and calculated complex sets of material constants including losses. In the case of very low-Q materials, additional corrections of material constants (effective Q for ANSYS) with recurring of optimization procedure can be fulfilled.

Mon 15:00 Main Hall Device technology (poster)

Modeling based on Spatial Impulse Response model for optimization of InterDigital Transducers (SAW-IDT) for Non Destructive Testing – (Contributed, 000249)

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This study deals with modelling SAW-IDT transducers for their optimization. These sensors are specifically developed to characterize properties of thin layers, coatings and functional surfaces. Among the methods of characterization, the ultrasonic methods using Rayleigh surface waves are particularly interesting because the propagation of these waves is close to the surface of material and the energy is concentrated within a layer under the surface of about one wavelength thick. In order to characterize these coatings and structures, it is necessary to work in high frequencies, this is why in this study, SAW-IDT sensors are realized for surface acoustic wave generation. For

optimization of these SAW-IDT sensors, particularly their band-width, it is necessary to study various IDT configurations by varying the number of electrodes, dimensions of the electrodes, their shapes and spacings. Thus it is necessary to implement effective and rapid technique for modelling. The originality of this study is to develop simulation tools based on Spatial Impulse Response model. Therefore it will be possible to reduce considerably computing time and results are obtained in a few seconds, instead of several hours (or days) by using finite element method. In order to validate this method, theoretical and experimental results are compared with finite element method and Interferometric measurements. The results obtained show a good overall concordance and confirm effectiveness of suggested method.

Mon 15:00 Main Hall Device technology (poster)

Tonpilz Underwater Acoustic Transducer Integrating Lead-free Piezoelectric Material – (Contributed, 000570)

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The tonpilz transducer is one of the most popular type of SONAR transducer. Its low cost, simplicity and good performances are well known. This considered longitudinal vibrator is typically composed of piezoelectric rings stack surrounded by a head and a tail. For decades, piezoelectric PZT ceramics, and its derived compositions have dominated the market due to their high piezoelectric properties and efficient production processes. Currently, these materials are integrated in a wide range of devices and in particular in underwater SONAR systems. This increasing success of these materials is associated with health and environmental problems due to presence of lead. Nowadays, many countries and organizations in the world are restricting or including hazardous substances in their legislation to be substituted by safer alternatives. Among the most promising lead-free compositions, there is the perovskite barium titanate. In the present work, a lead-free tonpilz transducer was fabricated integrating two rings of BaTiO3:Co. This composition was originally chosen due to their good electromechanical performances with a thickness coupling factor kt around 40% and high Q factor over 500. To measure these parameters, a specific characterization method was used and directly applied to the ring. This method involves a genetic algorithm (for optimization process) and finite element method (FEM, ATILA) to calculate the electrical impedance. It allows to characterize piezoelectric element with complex shape and multimodal behavior. This tonpilz was modelled using FEM in order to deduce several properties and, in particular, the displacement at the center on the head in air. The center frequency of the transducer is at 22 kHz. Comparisons between measured and simulated displacements are shown. Moreover, identical structure with two PZT rings (Ferroperm Pz26) was fabricated with exactly the same dimensions. Finally, a quantification of the relative measured performance of tonpilz integrating lead-based and lead-free compositions was performed.

Mon 15:00 Main Hall Device technology (poster)

A Resonance Tracking Method Using Current Sensor for High Power Ultrasonic Transducer – (Contributed, 000301)

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High power ultrasonic transducers are used in a wide range of industries. The resonance frequency shift and electrical impedance change is a key features in the application of high power ultrasonic transducer due to its high temperature. In order to achieve a stable operation, it is important to find the resonance frequency in a short time and track the resonance frequency during the operation. To solve these problems, various electrical methods have been described to track the operating frequency. This paper proposes a resonance tracking method using only current sensor and digital control algorithm. The proposed ultrasonic transducer drive system consists of AC/DC rectifier, DC/DC converter, square waveform generator, and RLC matching circuit. Various experiments are conducted to verify the performance of the proposed system and detail analysis is presented. The proposed system shows that it can find the resonance frequency within 100msec and track the resonance frequency for 10 minutes.

Mon 15:00 Main Hall Device technology (poster)

Surface acoustic wave scattering from an array of irregularities comparable with a wavelength – (Contributed, 000634)

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The design of surface acoustic wave (SAW) devices needs the accurate study of the scattering fields, arising from the interaction of SAW with periodic irregularities placed on a surface of crystal to form interdigital transducers or reflective structures (RS). To solve this problem the finite element methods are very perspective, because they allow to take into account the actual geometry of the electrodes and bulk scattering, in contrast to analytical methods.

This work describes results of finite element calculation of 2D SAW scattering fields in reflective delay line made on a $LiNbO_3$ substrate with RS formed by projections or grooves. The properly defined reflection, transmission and scattering coefficients were numerically evaluated as functions of the reflector's thickness, from infinitively small to comparable with wavelength. It was shown that these dependencies for projections are quasi-periodic and related to excitation of Eigen resonance modes in array of reflectors. In contrast to projections scattering from deep grooves does not have periodic behavior and with the depth's growth SAW scattering into volume increases while reflection coefficient doesn't reach more than 40%. The calculation of the 2D pattern of the scattered fields makes it possible to estimate the RS efficiency and clearly shows the range of the parameters for which an intensive SAW-energy radiation into the bulk occurs.
The obtained data was applied to developing RSs of various configurations, e.g., in designing SAW-based RFID tags for the 2.44 and 6 GHz frequency bands, where SAW wavelength becomes comparable to the height of electrode's structures.

Mon 15:00 Main Hall Nonlinear Ultrasonic NDE/NDT (poster)

Propagation Characteristics in the Fundamental and Second-order Harmonic Frequency Components of Surface Acoustic Waves – (Contributed, 000317)

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A surface acoustic wave (SAW) is a wave which propagates on the solid material exhibiting elastic behavior. The SAW can be produced by many ways such as a localized impact, piezoelectric transduction, or laser. In the nondestructive evaluation (NDE) field, acoustic nonlinearity measurement of SAWs has been conducted to assess material degradation such as fatigue, thermal aging, and plastic deformation.

In acoustic nonlinearity evaluation, only the magnitudes of frequency components have been considered so far. Acoustic nonlinearity can be obtained by measuring the fundamental frequency component and the second-order harmonic frequency component composed of the initial and material second-order harmonic frequency components. Theoretically, the initial second-order harmonic component is independent of the fundamental frequency component. On the other hand, the material second-order harmonic component depends on it. This implies that the tendency of the acoustic nonlinearity can be affected by the initial second-order harmonic frequency component when the phases of the initial and material second-order harmonic frequency components are not matched.
Through observing the variation in the magnitude of frequency components of a SAW according to propagation, their propagation characteristics such as phase matching and attenuation can be figured out. For that, in this study, the acoustic nonlinearity was simulated considering the initial second-order harmonic component. Experimentally, line-arrayed pulsed laser beam was employed to generate the narrow- band SAW, which were observed by two-wave mixing photorefractive interferometer along the propagation direction.
The result insists that the phase mismatch is necessary to be considered for more reasonable acoustic nonlinearity measurement by using SAWs. In both the simulation and experiment, the magnitude of the second-order harmonic frequency component was oscillated while propagating. This indicated that the phase mismatch existed and had influence on the magnitude of the second-order harmonic frequency component, which can cause the measurement error of the acoustic nonlinearity.

Mon 15:00 Main Hall Nonlinear Ultrasonic NDE/NDT (poster)

Transmission of larger amplitude ultrasound with SiC transistor pulser for subharmonic signal measurement at closed cracks – (Contributed, 000385)

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Measurement using the Subharmonic Phased Array for Crack Evaluation system requires larger amplitude ultrasound signals to generate subharmonics near closed cracks. In this study, we designed a new pulser using a SiC transistor making larger currents available with low output impedance to generate larger signal amplitudes. We report on the efficacies of the pulser in comparison with a conventional pulser. We prepared several transducers having different impedances depending on the size (20×5, 10, 15, and 20 mm^2), and materials (three commercially available PZT piezoceramics, M6, C6, and C9) of the elements. Then, we investigated combinations of excitations from the transducers and the two pulsers by measuring signal amplitude, effective voltage, and electric current for each transducer. When the C9 (20×20) transducer, which has the largest capacitance of 35 nF, was driven with a 5-cycle tone burst of 4-MHz longitudinal waves by the SiC transistor pulser, about two times larger electric current was measured compared with the conventional pulser. Among the C6 transducers, a large difference of voltage drop was observed under the conventional pulser excitation, whereas the difference decreased to one-third when driven with the SiC transistor pulser because of match in impedance. In particular, when C6 (20×5) is excited with the highest voltage setting of the SiC transistor pulser, the displacement is about 300 nm, which is about two times larger than that of M6 (20×20). In the future, we will improve our pulser using a new SiC transistor that responds to higher frequencies and consider noise reductions of excitation waveforms.

Mon 15:00 Main Hall Nonlinear Ultrasonic NDE/NDT (poster)

Evaluation of Material Nonlinearities Using Rectangular Pulse Trains for Excitation – (Contributed, 000465)

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Extraction of the nonlinear acoustic parameters of the material offer additional benefits in material properties evaluation. High power high linearity power amplifiers are required which are bulky and expensive. Conventional inspection equipment is using the rectangular pulses for excitation. Such excitation equipment is relatively simple, small size and offers significant reduction of the equipment. Aim of the presented investigation was to evaluate the suitability of the rectangular pulse trains for nonlinear material parameters study. Three assumptions were used: i) if duty cycle of the excitation is 50% then second harmonic is significantly reduced; ii) if excitation signal frequency is tightly fixed to the A/D converter sampling frequency, then there is no signal leak into neighboring Fourier bins; iii) if electrical excitation signal is registered then harmonics content at the system input can be established. Then additional harmonics appearing at the output should carry the information about the nonlinearities in the travel path. Excitation and sampling frequencies were linked using same signal for binary pulse train generation. Received signals were carefully gated to produce perfect cyclic signal. Sine wave correlation then was used to extract the harmonics content. Results of nonlinear parameters measurement for several materials are given.

Mon 15:00 Main Hall Nonlinear Ultrasonic NDE/NDT (poster)

Diagnosis of Metal Plates with Defects Using Laser Vibrometer – (Contributed, 000177)

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In this paper the method of nonlinear laser scanning vibrometry is used for diagnostics of thin cylindrical resonators with flexural Lamb waves. Resonators are made of the plate 1.2 mm thick of polycrystalline aluminium alloy D16. Latent defects and residual stresses in the plate as well as in the manufactures resonators causes nonclassical elastic nonlinearity. Structural nonlinearity was found during a study of frequency dependence of one of the resonator's natural modes on the amplitude of the flexural Lamb waves in it (the fast dynamics effect). The resonant

frequency, and hence the flexural Lamb waves velocity decreases linearly with Lamb waves amplitude increasing. Furthermore, the threshold frequency dependence on the oscillation amplitude was found. This behaviour of the resonant frequency is typical for media with nonclassical nonlinearity. Due to the strong dispersion of flexural Lamb waves velocity, the spectrum of the natural oscillations of the resonator is not equidistant and as a result, the harmonics of the fundamental Lamb mode are not the same as the natural frequencies of its higher modes. Therefore, due to break of energy and momentum conservation law, it is hard to observe generation of such harmonics. To investigate the resonant nonlinear phenomena in resonators with residual stresses and artificially created defect (crack), we used a vibromodulation technique. The low-frequency (Ω = 344 Hz) and high-frequency (ω = 75,39 kHz) flexural Lamb waves were excited simultaneously; these frequencies coincide with normal modes of the resonator. Due to the nonlinear interaction between these oscillations, it became possible to observe also oscillations on the combination frequencies ($\omega \pm n\Omega$, n = 1,2,3) which were visualized by a laser vibrometer. The local increase in their amplitude was recorded in areas with residual deformations and in the crack mouth. The studies were supported by the Russian Science Foundation (project N°14-22-00042).

Mon 15:00 Main Hall Nonlinear Ultrasonic NDE/NDT (poster)

Experimental verification of Relationship between Absolute Ultrasonic Nonlinear Parameter and Relative Ultrasonic Nonlinear Parameter – (Contributed, 000340)

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The ultrasonic nonlinear characteristic can be evaluated by the ultrasonic nonlinear parameter β obtained from the displacement of fundamental (A_1) and second-harmonic frequency components (A_2). In other words, it is necessary to measure the absolute displacement of fundamental (A_1) and second-harmonic frequency components (A_2); however, it is not easy to measure displacement of high-frequency harmonic component because the displacement of high-frequency harmonic component is very weak. Generally, relative ultrasonic nonlinear parameter β‘ using the detected wave signal amplitudes has been measured instead of measuring absolute displacement, which focus on monitoring before and after damage of a single material; however, the relative ultrasonic nonlinear parameter has never been verified in comparison with absolute ultrasonic nonlinear parameter. Therefore, this study compares the variation of relative ultrasonic nonlinear parameter with a variation of absolute ultrasonic nonlinear parameter to verify relative ultrasonic nonlinear parameter and substitute absolute ultrasonic nonlinear parameter for relative ultrasonic nonlinear parameter In this study, absolute ultrasonic nonlinear parameter is obtained by using the piezoelectric detection method, and relative ultrasonic nonlinear parameter is obtained by using the transmission method. After the experiment was conducted, the ratio of absolute ultrasonic nonlinear parameters in fused silica to Al6061- T6 and a ratio of relative ultrasonic nonlinear parameters in fused silica to Al6061-T6 is compared. The results show the ratio of absolute ultrasonic nonlinear parameters and ratio of the relative ultrasonic nonlinear parameter is almost same in fused silica to Al6061-T6. Consequently, we can verify relative ultrasonic nonlinear parameter from the absolute ultrasonic nonlinear parameter

Mon 15:00 Main Hall Physical acoustics (poster)

Experimental Study of Relationships between Ultrasonic Attenuation and Dispersion for Ceramic Matrix Composites – (Contributed, 000231)

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In this paper an experimental study of different ceramic matrix composites with high elastic losses and dispersion (porous piezoceramics, composites ceramics/crystals) were carried out. Complex sets of elastic, dielectric, and piezoelectric parameters of the porous piezoceramics and ceramic matrix piezocomposites were determined by the impedance spectroscopy method using Piezoelectric Resonance Analysis software. Microstructure of polished and chipped surfaces of composite samples was observed with the optical and scanning electron microcopies. Experimental frequency dependencies of attenuation coefficients and ultrasonic velocities for different ceramic matrix composites were compared with the theoretical results obtained using general Kramers-Kronig relations between the ultrasonic attenuation and dispersion.

Mon 15:00 Main Hall Physical acoustics (poster)

Numerical Model of Lateral Electric Field Excited Resonator on Piezoelectric Plate Bordered with Viscous and Conductive Liquid – (Contributed, 000414)

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At present time researchers pay particular attention to the piezoelectric lateral electric field excited resonators because of development of miscellaneous acoustoelectrical sensors of liquid properties. So, it seems necessary be able to calculate characteristics of the resonator, which allows choosing the optimal orientation of the piezoplate, the location and shape of the electrodes, and a method of suppressing parasitic acoustic oscillations. This work presents a numerical method of calculation of the characteristics of the lateral electric field excited resonator, which is in contact with a viscous conductive liquid. The resonator represented by thin rectangular plate of piezoelectric material. On the lower side of plate are placed two electrodes surrounded by a viscoelastic absorbing coating, and the upper side of plate is in contact with the layer of liquid with certain specified sound velocity, density, viscosity, conductivity and dielectric constant. The method is based on finite element analysis and allows to find the distribution of mechanical and electrical fields in the plate and liquid as well as conduction currents generated within the liquid. This allows to calculate the frequency dependence of the electrical impedance and admittance of the resonator. As a result was calculated the resonant frequencies of the device based on the 0.5 mm X-cut $LiNbO_3$ plate loaded with conducive (σ=0.001-1000 mSm/cm) and viscous (η=1-5000 mPa×s) liquid with dielectric permittivity (ε=10-80). It was shown that the maximum variation of the resonance frequency is 1.5% observed on 6.6MHz frequency (parallel resonance). Values of electrical impedance near this frequency were also found, and it is shown that the absolute value of the impedance can be changed 4 times while varying the parameters of the liquid within the specified limits. It is proposed to use the change of absolute values of impedances near a given frequency as informative parameter of liquid sensor.

Mon 15:00 Main Hall Physical acoustics (poster)

Angular Spectrum Method for the Focused Acoustic Field of a Linear Transducer – (Contributed, 000439)

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Many applications in nondestructive testing or acoustical imaging need more and more to increase their performances. In this paper, we develop a model using the angular spectrum approach to calculate the focused impulse field of a linear transducer through a plane fluid-solid interface. Electronic focusing by applying a cylindrical delay law, such that classical (lenses, curved transducer), leads to an inaccurate focus in the solid due to the errors introduced by the geometric aberrations of refraction. Generally, there is a significant difference between the acoustic focal distance and the geometrical focal fixed by the refraction. We performed an optimization of the delay law based on the Fermat's principle, particularly at an oblique incidence where the geometrical considerations, relatively simple in normal incidence, become quickly laborious for an oblique incidence. The numerical simulations of the impulse field are carried out with an optimal selection of input parameters to achieve good computation accuracy and a high performance of focusing. The evanescent waves have been neglected. The overall results for both compression and shear wave show the contribution of this technique to improve the focusing in the solid compared to the currently available approaches. Indeed the acoustic focal distance is very close to geometrical focal distance and allows better control of the refracted angular beam profile like refraction angle, focusing depth and focal size. To validate the model, simulation results are compared with those given by the ray propagation. Wave arrival times are correctly predicted and in good agreement.

Mon 15:00 Main Hall Physical acoustics (poster)

Characterization of ultrasonic transducers based on spectrum correction algorithm – (Contributed, 000612)

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Characterization of transducers is usually the first step of experiments so as to get correct parameters of transducers before putting them into real measurements. For ultrasonic transducers, the center frequencies are usually very high and the spectral accuracies are relatively low. There are lots of methods to characterize the transducers, most of them are based on digital sampling technique. It's inevitable to miss some useful information due to inappropriate sampling parameters and hence errors are introduced. In this paper we investigated the sources of errors and then introduced an efficient method to correct frequencies and amplitudes of the spectra of signals, which can greatly improve the accuracy of the spectra.

Tue 8:30 Grande Salle Plenary lecture III

Phononics and transforming heat transfer – (000545)

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Phononics is an emerging interdisciplinary field [1]. It deals with the fundamental principles and technology of manipulating and controlling phonons at microscopic scale. Since the first proposal of phonon diode one decade ago [2], a great progress has been achieved in this rapid developing field, including the concept of phonon transistor [3], logic gates [4], and memory [5], the experimental realization of solid- state phonon rectifier [6]. In the first part of my talk, I will give an overview of past decade's development in this direction. Emphasis will be given on the extension of phonon diode concept to the control of other energy forms including but not limited to, elastic energy [7], acoustic waves [8], heat carried by other particles like electrons [9], photons [10] and magnons [11] etc. In the second part, I will talk about the transforming heat transfer, based on which many interesting functions like thermal cloaking, thermal concentrating, and even thermal inverting, etc can be realized [12- 13].
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Tue 10:30 Claude Lefebvre Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics II (Special Session in Honour of Professor Emeritus Oswald Leroy)

X-ray Beam Parameters Acoustooptical Control and Tuning: State of Art and Prospects of Application – (Invited, 000120)

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Up to date during many years X-ray-acoustic interactions are very popular and useful instruments for investigation of space characteristics of ultrasonic wave propagation and scattering also for studying of resonators vibrations. But apart from visual range the tuning of X-ray wavelength, deflection of propagation direction were not realized before last times. Recently, we found that the nature of the interaction of X-ray-acoustic interaction depend on ratio between acoustic wavelength value and diffraction X-ray area length. Under that approach the long wave ultrasound range opens great possibilities for X- ray parameters control, tuning and retuning On those base instead of installations with usially used mechanical rotating mechanisms the special X-ray ultrasonic device for crystal structure characterization (rocking curve measurements) was designed and successfully implemented. Results of X-ray direction scanning help with long wave ultrasonic vibration are represented. The new method for measuring angular distribution of X-ray beam diffraction intensity (method for measuring X-ray rocking curves) is described. Using above device we investigated defects dynamics depend on amplitude of ultrasonic vibrations at crystals silicon, quartz, paratellurite, lithium fluorite. Some experimental results of ultrasonic control spectral parameters of x-ray beam are obtained. Using the gradient ultrasonic deformation the possibilities of focusing X ray beam were experimentally demonstrated. Some prospects of application x-ray parameters control and tuning will be discussed

Tue 11:00 Claude Lefebvre Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics II (Special Session in Honour of Professor Emeritus Oswald Leroy)

Acoustically-controlled spectral optical instruments – (Contributed, 000474)

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Dynamic Bragg gratings generated by acoustic waves are the key elements of acousto-optical devices, which are capable to control and transform the optical radiation: modulators, deflectors, tunable filters. Modern digital technologies for signal generation and control give potential to synthesize radiofrequency signal of almost any form, and, thus, to produce the acoustic field of rather complex form. In this way one can create a dynamic volume diffraction grating with a prescribed frequency, amplitude and phase distribution along the grating. New properties of the spectral selective optical elements based on such modulated periodical structures are analysed. These elements being the advanced version of acousto-optical tunable filters (AOTF) are capable of accomplishing much more complex operations on the light radiation than just a monochromatization. They, therefore, give birth to a whole lot of new techniques in spectral analyses. That is why, it is worth of talking about new generation of acoustically-controlled spectral optical instruments.

Tue 11:15 Claude Lefebvre Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics II (Special Session in Honour of Professor Emeritus Oswald Leroy)

Wavelength characterisation of the double interaction in tellurium dioxide – (Contributed, 000064)

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It is well known that the tunability over a large optical bandwidth is a great advantage of acousto-optic filters used in a number applications for optical spectroscopy or hyperspectral imaging. This is especially true for tellurium dioxide crystal which is commonly used in practice. Moreover, a specific configuration, called double interaction, in this anisotropic material allows the simultaneous diffraction of the two orthogonally polarised components of the incident optical beam using a single frequency ultrasonic carrier. We present the optical wavelength characterisation of the double interaction in the visible and near infrared regions: operating frequencies, optical incident angles, ultrasonic propagation angles, optical and acoustical anisotropy... Special attention is devoted to the optical incident angle which can be considered as a constant whatever the wavelength in the near infrared region and quasi constant for the visible region. Experimental data are presented for two acousto-optic cells which have been fabricated: the first device operates in the visible region and has been tested with a polychromatic light beam including the following monochromatic wavelengths: 405, 458, 476, 488, 496, 514, 532, 593, 633 and 671 nm. The second device operates in the near infra red region and has been tested using a continuous laser source starting from 1400 nm to 1600 nm. The large tunability of the double interaction is well confirmed.

Tue 11:30 Claude Lefebvre Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics II (Special Session in Honour of Professor Emeritus Oswald Leroy)

Imaging AOTFs with low RF power in deep-UV and Mid-IR – (Contributed, 000016)

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Acousto-Optic Tunable Filters (AOTFs) are commonly used for applications where high speed tuning and narrow resolution are required. The RF drive power for peak diffraction efficiency increases with λ^2 and depends on the acousto-optic figure of merit (M_2), which is material dependent. In the VIS-IR region between 450nm and 4.5μm tellurium dioxide (TeO_2) is the common material of choice due to the good optical properties and the high M_2. At longer wavelengths (up to about 12μm) the mercurous halides and single crystal tellurium show promise although to our knowledge tellurium single crystals are not yet commercially available . In both cases the λ^2 dependency dominates the RF power consumption and for wavelengths beyond 3μm the RF power consumption is high(>5W) for large aperture AOTFs. In the UV range (200nm - 450nm) the λ^2 dependency is no longer domi-

nant and the power consumption depends mainly on the M_2, however, for most materials transparent in the UV the M_2 is poor and thus the drive power will again be excessive (>5W) especially for large aperture AOTFs. In order to reduce the RF power requirement to reach peak diffraction efficiency, a resonant acoustic configuration is a promising solution, especially for crystal quartz in the UV range due to its low acoustic attenuation. We describe an AOTF operating in acoustic resonance made of Crystal Quartz, where the RF power consumption will be reduced by a factor up to 20 compared to a conventional UV-AOTF, thus reducing the power consumption to be within the reasonable levels (<5W).

Tue 11:45 Claude Lefebvre Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics II (Special Session in Honour of Professor Emeritus Oswald Leroy)

Reminiscences about 12th School on Acousto-Optics and Applications in Lithuania – (Contributed, 000101)

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In the present paper, the brief review of preparation, prosecution and outcome of the 12th School on Acousto-Optics and Applications held in Druskininkai, Lithuania, 29 June - 3 July, 2014, is given. The tradition of Schools on Acousto-Optics and Applications dates back to 1980, since when they were organised every three years by the University of Gdańsk, and held in various places in Pomeranian region of Poland. In 2014, it was the first time that the School was organized in Lithuania in partnership with Vilnius University. The topics of the School comprised: theoretical and experimental studies of light diffraction by ultrasound, acousto-optic devices for light modulation and deflection, signal processing, ultrasonic imaging and tomography; acousto-optic materials and structures; photoacoustic spectroscopy, optoacoustics and laser ultrasonics. The 2nd Workshop on Micro-Acoustics in Marine and Medical Research was held as a special session at the 12th School on Acousto-Optics and Applications. Another interesting special session was devoted to the acoustic properties of wood. During the School, in total 55 talks were given by both advanced scientists and young researchers from 15 countries. The School Proceedings are published in a special issue of Acta Physica Polonica A. It contains 37 articles corresponding to the plenary lectures and regular papers presented. The School was supported by Acoustical Society of America and International Commission for Acoustics, Research Council of Lithuania, and Strategisk program for forsknings - og undervisningssamarbeid (SPIRE), Norway.

Tue 13:30 Claude Lefebvre Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics II (Special Session in Honour of Professor Emeritus Oswald Leroy)

Acousto-optic principles of emission controlling in ultra-high intensity laser systems – (Invited, 000109)

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We present modern acousto-optic methods of controlling femtosecond laser pulses in ultra-high intensity lasers. The report is focused on the principles of operation and design of light dispersive delay lines. That type of devices performs direct time-domain shaping of ultrashort laser pulses by means of controlling spectral phase and spectral magnitude of laser emission. Methods for synthesis arbitrary complex spectral transmission functions are discussed. It is shown that spectral shaping of chirped laser pulses can be used for gigahertz-rate modulation of light. We also observe recent developments in other types of acousto-optic devices for controlling emission parameters in ultra-high intensity lasers. Those are the soft-edge diaphragms for spatial profiling of laser beams and acousto-optic pulse pickers. It is proposed to use transformation of laser beam plane wave spectrum due to angular selectivity of isotropic Bragg diffraction for the purpose of flat-top spatial shaping of laser beams. The report shows the capabilities of advanced ultrasonic techniques in the field of laser physics. Experimental results and instrumentation developments including new architecture of the regenerative optical amplifier are demonstrated as well.

Tue 14:00 Claude Lefebvre Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics II (Special Session in Honour of Professor Emeritus Oswald Leroy)

Lagrangian Formulation of Acousto-Optical Interaction in Nanoscale Cavities and Waveguides – (Contributed, 000365)

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Objectives - Interaction of light and sound in tiny optical cavities and waveguides is a vibrant topic nowadays. Indeed, both optical and elastic fields are tightly confined to a very small volume and surface effects become significant with the size reduction. Recent progress has shown that opto-acoustic interaction benefits from the combined photoelastic and moving-interface effects. While the photoelastic effect is classical in bulk acousto-optics, the moving-interface effect is specifically driven by the vibrations of surfaces. Assuming a photonic mode and a phononic mode are known beforehand, the diffraction efficiency for the creation of new photons can be estimated by overlap integrals. Reciprocally, the confined optical field also exerts mechanical forces on the material composing the cavity. The objective of this study is to obtain a variational principle describing the full acousto-optical interaction.
Methods - We construct a 3-wave Lagragian describing the interaction of the original optical wave, the Doppler-shifted optical wave, and the acoustic phonons. The three waves are further phased-matched in waveguides. The Langragian exhibits both volume and surface contributions to the interaction energy. First, electrostriction results in a volume force governed by the photoelastic tensor. Second, coupling of the electromagnetic field with the mechanical motion of the cavity further results in an effective surface force. We then solve the resulting elastodynamic equation subject to volume and surface optical forces.
Results - A finite element model is derived from the variational formulation. It is applied to acousto-optical (or optomechanical) interactions in a nanoscale photonic cavity. The simulation results show that acoustic resonances can be excited all-optically in the multi-gigahertz range for infrared light. The finite element model is also applied to tiny optical waveguides and compared to experiments performed with silica micro-fibers, revealing the generation of surface acoustic waves on the waveguide boundaries.

Tue 14:15 Claude Lefebvre Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics II (Special Session in Honour of Professor Emeritus Oswald Leroy)

Acousto-optics of Biaxial Crystals – (Contributed, 000266)

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At the present time, different glasses and uniaxial crystals are employed typically for manufacturing acousto-optic devices. However, biaxial crystals, in spite of great difficulties with their calculations, are of undoubted interest because these crystals permit realizing such geometries of acousto-optic interaction that are impossible in uniaxial crystals in principle. The given work is devoted to detailed analysis of acousto-optic effect in biaxial crystals by an example of alpha-iodic acid crystal (α-HIO_3)which belongs to the 222 symmetry class. The emphasis is on the Bragg angle frequency dependencies for different acousto-optic interaction planes, as well as on calculations of the acousto-optic figure of merit for isotropic and anisotropic diffraction and for different propagation directions of interacting optical and acoustic waves. The transfer functions of acousto-optic interaction are obtained and analyzed which describe the influence of an acousto-optic cell on optical images. It is found in particular that an alpha-iodic acid based collinear filter can exceed well-known calcium molybdate filters by 2 times in resolution and by 3.5 times in power consumption. This research is supported by the Russian Scientific Fund, project 14-12-00380.

Tue 14:30 Claude Lefebvre Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics II (Special Session in Honour of Professor Emeritus Oswald Leroy)

Optimum configuration for acousto-optical modulator made of KGW – (Contributed, 000171)

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Acousto-optic figure-of merit has been investigated for $KGd(WO_4)_2$ crystal, which is applicable to control high intensity laser radiation. Using the data on acoustic velocities obtained earlier and the experimentally determined coefficients of light diffraction on acoustic waves, we have calculated for the first time 12 elements of the upper half of the elasto-optic matrix. This new data permitted to calculate angular dependence of acousto-optical figure-of-merit with respect to the light polarization for "isotropic" diffraction and to find the optimum geometry, which ensures maximum diffraction efficiency.

Tue 14:45 Claude Lefebvre Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics II (Special Session in Honour of Professor Emeritus Oswald Leroy)

Development of an Acousto-Optic Method for Water Pollution Control – (Contributed, 000024)

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Nowadays, polluted water is becoming a major environmental and health issue. However, polluted water with miscible solvents, when it is discharged into nature from hospitals, chemical factories and laboratories of chemistry, physics and biology, increases the risk of contaminating water reserves, rivers, lakes and dams. The level of contamination can be assessed by fnding the refractive indices, densities or concentration. Considering the limitation of physical and chemical methods, some researchers have recommended the use of ultrasonic techniques to determine ultrasonic velocity, density and compressibility, in order to fnd out the percentage of adulteration. All the discussed techniques have certain limitations and restrictions. In this work, an acousto-optic (AO) method was developed to control the quality of water mixed with miscible solvents. A collimated laser beam passing through a transparent binary solution was diffracted by acoustic waves. It was proved that acoustic impedances of the different binary solutions have an impact on the diffraction efficiencies. In addition, we noticed that measured dependences of the velocities and the diffraction efficiencies on the liquid concentrations were non-linear and symmetrical with respect to each other.

Tue 16:00 Claude Lefebvre Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics II (Special Session in Honour of Professor Emeritus Oswald Leroy)

Influence of Paratellurite Anisotropy at the Characteristics of Acousto-optic Interaction – (Contributed, 000128)

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We present the results of paratellurite acoustic and acousto-optic anisotropy influence on the characteristics of acousto-optic diffraction. The examination was carried for the (1-10) crystallographic plane. The distribution of acousto-optic figure of merit was calculated. Also the structure of acoustic beams aroused by the transducers of various sizes at different frequencies was simulated. It is shown that anisotropy influences the acousto-optic device transfer functions significantly. Amplitude and phase inhomogeneity of acoustic beam acts in the different ways. Amplitude inhomogeneity doesn't change the interaction phase matching conditions. Rising the acoustic power it is still possible to achieve 100% diffraction efficiency. Phase inhomogeneity acts in the other way; it changes the diffraction parameters for separate plane wave components of the diffracting wave beams. Acousto-optic anisotropy affects the plane wave components of the optical beam and changes the diffraction efficiency.

Tue 16:15 Claude Lefebvre Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics II (Special Session in Honour of Professor Emeritus Oswald Leroy)

Anisotropic Light Diffraction by Ultrasound in Crystals with Strong Acoustic Anisotropy – (Contributed, 000140)

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In modern acousto-optics, crystalline materials are used predominantly for manufacturing acousto-optic instruments. Among these materials, such crystals as paratellurite (TeO_2), tellurium (Te), calomel (Hg_2Cl_2), mercurous bromide (Hg_2Br_2), TAS (Tl_3AsSe_3) and some others occupy a prominent place, which are distinguished by exceptionally large anisotropy of acoustic properties. The strong acoustic anisotropy gives two basic effects: first, it changes the acoustic field structure and, second, it leads to the acoustic energy walk-off.
In this work, the influence of acoustic beam energy walk-off on characteristics of Bragg diffraction of light is studied theoretically and experimentally by examples of paratellurite and tellurium single crystals. Angular and frequency characteristics of acousto-optic interaction are calculated in wide ranges of Bragg angles and ultrasound frequencies by means of modified Raman-Nath equations. It is shown that the walk- off can substantially change the width of angular and frequency ranges, resulting in their narrowing or broadening subject to position of the operating point in the Bragg angle frequency characteristic. Coefficients of broadening are introduced for characterization of this effect. Experimental verification of the calculations is carried out with a paratellurite cell of 10.5° crystal cut.
This research is supported by the Russian Scientific Fund, project 14-22-00042.

Tue 16:30 Claude Lefebvre Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics II (Special Session in Honour of Professor Emeritus Oswald Leroy)

Backward collinear acousto-optic interaction in germanium crystal in terahertz spectral range – (Contributed, 000076)

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The acousto-optic (AO) effect is widely used to control parameters of electromagnetic radiation. The devices based on the AO effect have many applications in optical engineering, laser technology, optical communications, astronomy, medicine, etc. The majority of scientific papers are devoted to development of AO devices operating in the ultraviolet, visible and infrared spectrum ranges. However, the AO interactions in the terahertz spectral range have practically not been considered by researchers. In general, a theoretical description of the AO interaction does not depend on a particular spectral range but there are two problematic items to consider if we examine the diffraction in the terahertz spectral domain. The first problem is to find a transparent material suitable for the AO applications while the second one is related to the inverse ratio between diffraction efficiency and wavelength of the radiation. However, invention of powerful sources of monochromatic coherent terahertz radiation such as free-electron lasers makes it possible to observe the effect in the terahertz spectrum range, in spite of the extremely small diffraction efficiency.
The purpose of this research was to find a way and to observe the so-called "backward" collinear AO interaction in case of bulk optic and acoustic waves. We found that so far single crystal germanium is one of the best materials to observe the backward interaction in the THz range. This type of diffraction takes place when wave vectors of electromagnetic and acoustic waves are collinear while the diffracted and incident electromagnetic waves propagate in opposite directions. A theoretical analysis of the bulk AO interaction is presented. The model takes into account attenuation of acoustic and electromagnetic waves in the medium. Results of our calculations were used to develop a prototype of a tunable collinear AO filter based on germanium. The device is described in the presentation in details.

Tue 16:45 Claude Lefebvre Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics II (Special Session in Honour of Professor Emeritus Oswald Leroy)

The Mode Method as a Framework for Theoretical Studies of Ultrasonic Waves Diffraction in Non-homogeneous Layered Structures – (Contributed, 000533)

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Ultrasonic waves propagation in non-homogeneous layered structures containing cracks, inclusions, delaminations, etc. is accompanied by diffraction phenomena that can be studied using the mode method. This method is based on the acoustic field expansion in the discrete set of eigen modes describing localized surface and waveguide waves and in the continuous set of radiation modes describing non-localized volume waves. Fundamentals of the mode method including derivations of different kinds of orthogonality conditions and derivations of coupled equations systems for unknown expansion coefficients in the case of two-dimensional isotropic structures are given in the paper. These systems of equations are generally described by infinite systems of linear algebraic equations for the case of radiation modes absence, existence of radiation modes results in the systems of coupled integral equations. Using the mode method, several concrete problems of ultrasonic waves diffraction in non-homogeneous layered structures are presented in the paper such as: Scholte-Stoneley wave excitation and conversion at the edge of a fluid loaded plate, interaction of Lamb modes with delaminations in plates coated by highly absorbing materials and nonlinear modulation of Lamb modes by clapping delamination. It is shown that both stress-free and slip delaminations can be revealed by monitoring the amplitude of an incident Lamb mode along the plate surfaces. Lamb modes modulation by clapping delamination leads to spectral enrichment due to cross-modulation spectral components between the probing and modulating waves, this can serve as a tool for nondestructive testing of bilayers.

Tue 10:30 Saint Pierre — Bio-medical ultrasound for therapy II

Modeling acoustic vaporization of encapsulated droplets – (Contributed, 000028)

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Acoustic Droplet Vaporization (ADV) refers to the phase change of liquid droplets induced by ultrasound to form vapor bubbles. This process is investigated for clinical applications : vascular imaging, targeted drug delivery, embolotherapy or thrombolysis. ADV is generally realized from perfluorocarbon (PFC) emulsions with a low boiling temperature close to body temperature. Because of their small diameter ($<$ 1000 nm) and surface tension effects, droplets do not vaporize spontaneously, remaining in a superheated liquid state even if their normal boiling point is below the physiological temperature. Experimental studies have shown the efficiency of the vaporization of encapsulated PFC droplets. However, few theoretical works have been developed for the ADV of encapsulated droplets. The present model extends previous studies, now including both the encapsulating shell and the outer liquid. The particle radial motion is governed by a generalized Rayleigh-Plesset equation accounting for the evaporation rate and surface tension at the liquid/vapor interface, and the shell viscoelasticity. It is coupled to heat equations ruling the temperature field around the bubble and the mass flux through the surface. Numerical simulations reveal behaviors of the vapor nucleus substantially different from the case of a vapor bubble in an infinite medium. Depending on the encapsulation, the evaporation process may be stopped by the shell rigidity, thus trapping the bubble around an equilibrium radius inside the droplet. Model amplitude thresholds show qualitative agreement with literature measurements, and allow to quantify the effect of the droplet encapsulation. Above ADV threshold, the growth of the vapor bubble is shown to be mainly affected by the surface tension, the density contrast between inner and outer liquids, and the rigidity of the encapsulating shell [with the financial support of ITMO Cancer AVIESAN (Alliance Nationale pour les Sciences de la Vie et de la Santé) in the frame of Plan Cancer].

Tue 10:45 Saint Pierre — Bio-medical ultrasound for therapy II

Treatment of Prostate Cancer with HIFU – (Invited, 000396)

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So far, the most extensive results from HIFU obtained in urology are transrectal prostate ablation, which appears to be an effective therapeutic alternative for patients with Prostate Cancer. HIFU treatment can be used either alone or in combination with radiotherapy (ERBT) and can be repeated multiple times. HIFU treatment is performed under real-time monitoring with ultrasound or guided by MRI. Two indications are validated today: primary care treatment and EBRT failure. HIFU is an evolving technology perfectly adapted for focal treatment. Thus, HIFU focal therapy is another pathway that must be explored when considering the accuracy and reliability for PCa mapping techniques. HIFU would be particularly suited for such a therapy since it is clear that HIFU outcomes and toxicity are relative to the volume of prostate treated.

Tue 11:15 Saint Pierre — Bio-medical ultrasound for therapy II

Radiation force of a focused ultrasound beam to reposition small solid objects in application to kidney stone disease – (Invited, 000154)

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Ultrasound in medicine is traditionally either used for low-intensity diagnostic applications to image internal structures of the body, or high-intensity therapeutic applications to thermally or mechanically affect biological tissue. Here we report on a different application of ultrasound that uses the ability of ultrasound to create a force on objects. This property of ultrasound is caused by the fact that waves carry not only energy, but also momentum. In the interaction of a wave with a scatterer, part of the wave momentum is transferred to the object and thus results in a force, which is called the radiation force. To theoretically describe the effect, an approach was developed to calculate the radiation force of an arbitrary acoustic beam on an elastic sphere in a liquid medium. In addition to radiation force, we studied the ability of vortex ultrasound beams created by a sector array to transfer angular momentum and rotate small solid objects. Our group has introduced a new clinical application of radiation force to transcutaneously reposition kidney stones with megahertz frequency focused beams radiated by single- or multi-element piezoelectric transducers. This technology can be used to facilitate the passage of small (<5mm) stones or relocate an obstructing stone. *In vivo* experiments in pigs have shown that ultrasonic propulsion is effective and safe, without evidence of injury. This work was supported by RBBR 14-02-00426, NIH DK43881 and DK092197, and NSBRI through NASA NCC 9-58.

Tue 11:45 Saint Pierre — Bio-medical ultrasound for therapy II

Preliminary Results in the Application of Ultrasound During the Injection of Drugs – (Contributed, 000435)

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During the injection of drugs into the brain a phenomenon known as back-flow is presented, whereby the injected drug flows along the needle track rather than spread inside the target tissue. This back-flow is a major problem because it produces an inadequate distribution of the drug. Previous studies have shown that backflow is dependent on some parameters such as the geometry of the needle, insertion speed and flow rate at which the infusate is injected. Also, this phenomenon is reduced when a radial compressive stress exists in the needle-tissue interface. In view of this, in this paper we propose an experimental setup to evaluate the effect of using ultrasonic wavefronts on the drug delivery distribution. A needle of 0.36 mm of diameter is coupled to a linear actuator which moves at a speed of 0.2 mm/s in a phantom tissue sample of agarose gel. A single disk-like ultrasonic transducer with a through hole at its center to allow the insertion of the needle is used to generate the acoustic field. At the same time, a pump system injects a tracer inside the sample and make visible the amount of liquid that is returned by effect of backflow. A numerical model of the acoustic field inside the sample is presented. Also, preliminary results with and without the application of ultrasound are discussed.

Tue 10:30 Gouv — Bulk wave NDT/E: modelling and simulation

Independent Dual Focusing of Ultrasonic Phased Array Transducer in Two Orthogonal Planes – (Contributed, 000214)

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Ultrasonic imaging of the internal subsurface defects of thin multi-layered samples is very actual task for quality control of metal composites. The contact type linear ultrasonic phased array transducers (ULPAT) can be used for fast detection of different types of internal defects located at different depths within the sample. However, due to a low lateral resolution in one plane application of ULPAT is limited. The objective of this work was to enhance spatial resolution by means of dual focusing technique of ULPAT in two orthogonal planes. The design of special wedge possessing a convex cylindrical lens for contact type testing was proposed. The lens enables fixed geometrical focusing of the excited beam in one plane while in another orthogonal plane the beam is electronically focused in arbitrary space by the active aperture of the ULPAT. Directivities of the excited ultrasonic beam and detection of artificial defects were investigated by ray-tracing model and CIVA package. The results demonstrate that such

technique of resolution enhancement can provide extended possibilities of quantitative ultrasonic imaging compared to the case when the ultrasonic field is focused in single plane only. The experimental verification was performed by ultrasonic examination of appropriate thin steel specimen possessing the artificial subsurface defects, such as 6 flat bottom holes (FBH) of different depths and diameters. Improvement of detection was demonstrated by essentially increased number of detected FBH, from 33 % up to 83 %. Finally, the efficiency was demonstrated on detected intermediate layer of aluminium-glue powder of multi-layered metal composite sample of the aluminium foam precursor material, investigation of which by conventional testing techniques is quite complicated due to relatively thin layers and similar acoustic properties.

Tue 10:45 Gouv Bulk wave NDT/E: modelling and simulation

Elastodynamic models for extending GTD to penumbra and finite size flaws – (Contributed, 000398)

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The scattering of elastic waves from an obstacle is of great interest in ultrasonic Non Destructive Evaluation (NDE). There exist two main scattering phenomena: specular reflection and diffraction. This communication is devoted to possible improvements of the Geometrical Theory of Diffraction (GTD), one classical method used for modelling diffraction from scatterer edges. GTD notably presents two important drawbacks: it is theoretically valid for a canonical infinite edge and not for a finite one and is not valid around the direction of specular reflection. To face the first inconvenient, two 3D incremental methods have been developed: one based on the Huygens' principle and a second called ITD (Incremental Theory of Diffraction), a method initially developed in electromagnetism. These incremental methods have been validated through experimental results. As to the second drawback, a GTD uniform correction, the Uniform Theory of Diffraction (UTD) has been developed in the view of designing a generic model able to correctly simulate both specular reflection and diffraction. A numerical comparison has been done between UTD and UAT (Uniform Asymptotic Theory of Diffraction) which is another uniform GTD correction.

Tue 11:00 Gouv Bulk wave NDT/E: modelling and simulation

Damage In cement-based Material during loading: characterization by Ultrasonic Velocity and Attenuation Tomography – (Contributed, 000449)

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Abstract:
The present work aims to characterize damage in cement-based geomaterial during loading by using the non-destructive method like ultrasound. For this purpose, a system of ultrasound which consists of 96 channels was built up and the specific sensors which allow measuring at the same time three types of waves (a bulk wave and two shear waves) were chosen. The continuous measurements enable to construct image of ultrasonic velocity as well as the attenuation of each wave during loading. The difference tomography method using the differential arrival times or relative amplitudes at each stage of loading with respect to the initial stage confirms its efficacy of this non-destructive method. The results show that all three types of wave can be used to capture the progressive damage in material.
Keywords: ultrasonic, tomography, damage, geomaterial, non-destructive method.

Tue 11:15 Gouv Bulk wave NDT/E: modelling and simulation

Ray-based simulation of defect echoes for ultrasonic Non Destructive Testing – (Contributed, 000558)

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In order to compute flaw echoes, semi-analytical models commonly use flaw scattering coefficients for incidence and observation wave directions deduced from plane-wave approximations. In practice, the plane-wave approximation of the radiated beam field can lead to significant inaccuracies in unfavorable cases, such as for wide probe apertures, outside of the focal region, or for distortions of the beam due to irregular part geometries.
The present work aims at improving the accuracy of simulation methods used in the ultrasonic NDT module of the Civa simulation software. The proposed approach relies on a representation of the ultrasonic field as a sum of rays. Plane wave approximations are applied to each ray, as opposed to the total field, allowing a more accurate field description for echo calculations. Therefore, a diffraction coefficient is attributed to each pair of incident and observed ray instead of having only one coefficient for the total field. A dedicated algorithm allows the total computation times of the two methods to remain of the same order, despite the larger number of coefficients. Additionally, the computation of incident fields is ray-based as well and readily provides the input needed for the diffraction calculation without needing an extra step of expressing the fields as sets of rays.

Several cases that illustrate the improvement brought by this new method are presented, with comparisons to results obtained by a finite element model.

Tue 11:30 Gouv Bulk wave NDT/E: modelling and simulation

Numerical Simulation of Ultrasonic Wave Propagation in a Cylindrically Shaped Dental Implant Prototype – (Contributed, 000379)

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Dental implant stability, which is an important parameter for the surgical outcome, can now be assessed using quantitative ultrasound. However, the acoustical propagation in dental implants remains poorly understood. The objective of this numerical study is to understand the propagation phenomena of ultrasonic waves in cylindrically shaped prototype dental implants and to investigate the sensitivity of the ultrasonic response to the surrounding bone quantity and quality. An axisymetric 3-D finite element model has been developed for studying the behavior of the system excited by a 10 MHz pulse ultrasonic source. The results show that the implant ultrasonic response changes significantly when a liquid layer is located at the implant interface compared to the case of an interface fully bounded with bone tissue. A dedicated model based on experimental measurements was developed in order to account for the evolution of the bone biomechanical properties at the implant interface. The effect of a gradient of material properties on the implant ultrasonic response is investigated. Based on the reproducibility of the measurement, the results indicate that the device should be sensitive to the effects of a healing duration of less than one week. In all cases, the amplitude of the implant response is shown to decrease when the dental implant primary and secondary stability increases, which is consistent with the experimental results. This study paves the way for the development of a quantitative ultrasound method to evaluate dental implant stability.

Tue 11:45 Gouv Bulk wave NDT/E: modelling and simulation

Simulation of Ultrasonic Materials Evaluation Experiments Including Scattering Phenomena due to Polycrystalline Microstructure – (Contributed, 000562)

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Simulation methods are increasingly important in the area of nondestructive testing of operational components. To evaluate and optimize the performance of ultrasonic inspection and evaluation procedures, we employ a method based on Huygens' principle, the Generalized Point Source Superposition technique (GPSS). This technique allows to simulate the propagation of ultrasonic waves and their interaction with defects in media with known material parameters. In this contribution we report on the combination of GPSS with the theoretical description of ultrasonic scattering phenomena previously refined by Hirsekorn [1], which is particularly interesting e.g. for coarse-grained cast materials. The scattering theory includes phenomena like directional and position-dependent scattering effects in an isotropic polycrystalline material. The consideration of scattering effects provides additional information about the energy loss during ultrasonic wave propagation. By combining GPSS and the scattering theory we obtain a better agreement of simulated and experimental results. The presented work explains the main ëingredients' of the simulation procedure and includes an investigation of the influence of the grain density on the simulation results.

[1] S. Hirsekorn, "Calculations on Ultrasonic Scattering in Polycrystalline Structures Aiming for Simulations on Nondestructive Materials Characterization and Defect Detection", 11th European Conference on Nondestructive Testing ECNDT 2014, Prague, Czech Republic, Oct 06-10, 2014; NDT.net issue Vol. 19 No. 12 (Dec 2014)

Tue 10:30 Grande Salle Nonlinear Ultrasonic NDE/NDT II

Nonlinear Guided Wave Mixing for Localized Material State Characterization – (Contributed, 000596)

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Condition-based maintenance of structural systems requires early awareness of the material state at critical locations in the structure. The nonlinear mixing of two guided waves generates combinational harmonics (e.g., waves that propagate at sum and difference frequencies). These combinational harmonics are important because they enable measurement of material nonlinearity at frequencies away from integer multiples of the excitation frequencies where instrumentation nonlinearities exist. Lamb and shear-horizontal waves in plates as well as longitudinal and torsional waves in hollow cylinders can be activated and their interaction at a point between the transducers provides a way to characterize the material state there. Localized evolution of state can be characterized in this way by applying time delays to force the waves to interact at different points. Higher harmonic generation is known to be sensitive to features of the material microstructure in polycrystals such as dislocation density and substructures, precipitates, second phase particles, and voids. Modeling to correlate nonlinear ultrasonics results with microstructural features is necessary to use the nonlinear ultrasonics results for remaining life prediction. Thus, in addition to guided wave mixing, the aspects of model development will be presented.

Tue 10:45 Grande Salle Nonlinear Ultrasonic NDE/NDT II

Second harmonic generation of shear horizontal guided wave propagation in plate-like structures – (Contributed, 000226)

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The use of shear horizontal guided wave has been proposed as an attractive technique for surface defect characterization. Considering the second harmonics could provide sensitive information for structural health conditions, this research investigates the second harmonic generation of the shear horizontal guided wave propagation in an isotropic plate-like structure. For dispersive wave modes, it is necessary to choose the suitable wave mode at certain frequency for generating second harmonics with accumulative effect of propagation distance. In this paper, the conditions for generating cumulative second harmonics of shear horizontal guided waves are provided. The partial wave technique and normal modal analysis method are used to analyze the second harmonic field. It shows that, second harmonic field of shear horizontal guided wave is different from that of primary wave modes. Measurements of the accumulative growth of normalized second harmonic amplitudes of the shear horizontal guided modes by using wedge transducers are presented. The experimental results have a good agreement with the theoretical prediction and thus show that the use of these plate modes is favorable to detect material nonlinearity due to damage mechanism.

Tue 11:00 Grande Salle Nonlinear Ultrasonic NDE/NDT II

One-dimensional nonlinear scattering by localized hysteretic damage and its application to damage characterization – (Contributed, 000019)

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This communication concerns the development of a theoretical framework to address the problem of characterization of material damage by nonlinear ultrasound phenomena. Specifically, a one-dimensional model to predict nonlinear scattering by a confined distribution of i) dislocations interacting with point defects distributed along

their glide planes or their cores, and of ii) microcracks with or without adhesion between their faces is presented. The nonlinear properties of these forms of damage are modeled by macroscopic effective constitutive relationships, and a perturbation approach is used to solve the scattering problem. Backward and forward scattered fields are investigated and use of their main properties towards the development of selective imaging methods, which are tailored to hysteretic material damage, is briefly discussed. This model is also used to verify recent experimental results on steel samples containing small cracks or confined regions of macrograins. The mechanism associated to hysteresis of large grains is modeled by the interaction between dislocations and point defects along their glide planes. Theoretical predictions confirm that the exponent of a power law, linking the energy dissipated nonlinearly to the energy of a scaled linear field, is sensitive to the physical nature of damage. For instance, the interactions of dislocations with glide and core PDs are shown to be characterized by different values of the exponent. Finally, the agreement between experimental findings and model's predictions provide encouraging support to the use of the simple effective constitutive relationships proposed in this work.

Tue 11:15 Grande Salle Nonlinear Ultrasonic NDE/NDT II

Effect of Mixed Dislocations on Nonlinear Acoustic Responses in Plastic Deformation Materials – (Contributed, 000179)

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A new analytical model is proposed in this paper for describing the influence of mixed dislocation on the nonlinear acoustic responses in the plastic deformed material, which is derived based on the total line energy of the mixed dislocation and variable line tension. The analytical model shows a strong sensitivity to the Poisson's ratio ν and the character and fraction of dislocations. The numerical calculations reveal that the nonlinear parameter β predicted by the present model is the same as those predicted by the existing models at ν=0. However, for the edge dislocation, the prediction of β by the present model shows an obvious growth as the ν increases, which is significantly different from those of the previous models and also indicates that β should be more sensitive to the edge dislocation in materials with large Poisson's ratio. In order to testify the validation of the proposed model, for ease of comparison, an existing experimental data of 304 stainless steel both have been applied for the present model and the existing ones. A good agreement between the experimental data and the results predicted by the proposed model indicates that the new model should be more practical and general than the existing ones. The analytical model presented here can help us to well understand the interaction of the mixed dislocation and the acoustic nonlinearity regarding to the Poison's ratio, the dislocation character and fraction, and the direction of Burger vector. The results also indicate that the established model may serve as a potential tool to make a quantitative prediction of the acoustic nonlinear parameter with the influence of mixed dislocation caused by the plastic deformation in engineering metals.

Tue 11:30 Grande Salle Nonlinear Ultrasonic NDE/NDT II

Diagnosis of Nonlinear Elastic Properties of The Boundary of Two Flat Rough Solids by Surface Acoustic Waves – (Contributed, 000254)

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The paper presents the results of experimental investigations of nonlinear elastic properties of boundary between two flat rough surfaces of solids. The plates made of aluminum and steel were used as the samples. The study of the elastic properties of the boundaries was carried out using surface acoustic waves (SAW). SAW at the interface of solids were excited and taken by wedge transducers at frequencies of 1.25 MHz and 2.5 MHz. Experimental studies were performed on automated ultrasonic complex RITEC RPR-5000. We investigated the effect of the static pressure applied to the boundary of two solids and the amplitude of the probing SAW of 1.25 MHz on SAW velocity and efficiency of SAW second harmonic generation on the frequency 2.5 MHz at the border of rough surfaces. The amount of pressure applied to the border varied in the range of 0-25 MPa. It was found that increasing the amplitude of the static pressure and the amplitude of probe SAW increases the velocity of SAW. SAW velocity change depending on the amplitude and the static pressure was nonlinear. According to the results of experimental measurements of the amplitudes of first and second harmonics of the SAW on the rough edge of solids nonlinear acoustic parameter of the second order depending on the external pressure applied to the interface for fixed values of the

amplitude of the probe wave was calculated. The features of calculated nonlinear parameter are caused by changes in the contact acoustic nonlinearity with increasing external pressure applied to the border. The experimental results were analyzed on the basis of the theory of contact acoustic nonlinearity. The studies were supported by the Russian Science Foundation (project N° 14-22- 00042).

Tue 11:45 Grande Salle Nonlinear Ultrasonic NDE/NDT II

Highly-Sensitive Defect-Selective Imaging and NDT via Resonant Nonlinearity of Defects – (Contributed, 000176)

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The bottleneck problem of nonlinear NDT is a low efficiency of conversion from fundamental frequency to nonlinear frequency components. In this paper, it is proposed to use a combination of mechanical resonance and nonlinearity of defects to enhance substantially the input-output conversion. The concept of the defect as a nonlinear oscillator brings about new dynamic and frequency scenarios characteristic of parametric oscillations. The experiments confirm unconventional nonlinear dynamics of simulated and realistic defects subject to resonant nonlinearity. It features threshold transition to resonant nonlinear modes of unstable nonlinear vibrations. The modes observed include sub- and superharmonic resonances with anomalously efficient generation of the higher harmonics and subharmonics. A modified version of the superharmonic resonance (combination frequency resonance) is used to enhance the efficiency of frequency mixing mode of nonlinear NDT. All the resonant nonlinear modes are strongly localised in the defect area that provides a background for high-contrast defect- and frequency-selective imaging.

Tue 10:30 ESAL 1 Picosecond laser ultrasonics II

Nanometric ultrasonics – (Invited, 000621)

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These very last years saw the development of techniques allowing the propagation of coherent acoustic waves in a frequency domain going up to 1 terahertz [1-5]. Generation and detection of such waves is obtained combining the use of semiconducting heterostructures acting as opto-acoustic transducers and of pump-probe techniques which achieve a very high temporal resolution. The acoustic wavelengths which occur in such experiments are in the range 5 to 50 nm, which opens the way towards acoustic imaging with a nanometric resolution. To estimate the potential interest of this approach it is necessary to estimate the penetration depth of this THz acoustic radiation. To this purpose, we performed a series of experiments allowing accurate measurements of the acoustic waves absorption in Gallium Arsenide in the frequency range 0.2-1 THz and the temperature range 10-90 K. Our results reveal unexpected frequency dependence for the acoustic absorption. Nevertheless we will show that this result can be understood within the framework of classical threephonon interactions. This model allows a reliable extrapolation for subterahertz and terahertz acoustical penetration length at room temperature which is large enough to allow acoustic imaging of nanometric objects embedded in solid matrices.

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Tue 11:00 ESAL 1 Picosecond laser ultrasonics II

Precise measurement of sound velocity of amorphous silica at low temperatures by picosecond ultrasounds: correction of static heating effect – (Contributed, 000105)

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Sound velocity and its temperature coefficient are important parameters of surface acoustic wave filters and film-bulk acoustic resonators because they govern resonant frequencies and their temperature dependence. While most materials show negative temperature coefficients of sound velocity (TCV), amorphous silica exhibits positive TCV around room temperature. It is then widely used as a temperature-compensate material. Picosecond ultrasound spectroscopy makes it possible to measure the sound velocity in a wide temperature range even for thin films. However, laser absorption causes significant temperature increase at the examining region because amorphous silica shows low thermal conductivity. In this study, we measured sound velocity of amorphous silica at low temperatures, and performed numerical simulations for temperature increases by static heating from laser absorption considering temperature dependence of thermal conductivity. The temperature increase reaches ∼100 K even when the back surface temperature is less than 10 K. Thus, the temperature increases by the static heating effect cannot be neglected for amorphous silica, and we corrected it for accurate measurements of TCV.

Tue 11:15 ESAL 1 Picosecond laser ultrasonics II

Picosecond laser ultrasonics for single cell ultrasonography – (Contributed, 000384)

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Applications of the picosecond laser ultrasonic technique [1] to the remote measurements of hypersound velocity and attenuation in single cells have been developed recently [2]. Experiments in single cell organelles have shown sensitivity to the rheological properties of the organelle components [3-4].

In this presentation, we report on an alternative technique where the reflections of picosecond ultrasonic pulses from a substrate-cell interface are used to probe cell-biomaterial adhesion with a sub-cell resolution. Cells are cultured on top of a thin biocompatible Ti metal film, supported by a transparent substrate. Low-energy femtosecond pump laser pulses are focused at the bottom of the Ti film to a micron spot. The subsequent ultrafast thermal expansion launches a longitudinal acoustic pulse in Ti, with a broad spectrum extending up to 100 GHz. We measure the acoustic echoes reflected from the Ti-cell interface through the transient optical reflectance changes. Analysis of the reflected acoustic pulses gives access to quantitative maps of the cell acoustic impedance and of the film-cell interfacial stiffness, simultaneously.

This set-up is particularly well-suited to the remote study of cells adhering on a metal transducer. The diameter of the optical probe spot sets the lateral acoustic resolution, comparable to conventional diffraction-limited optical imaging techniques. We demonstrate capability of cell structure imaging with the mechanical properties as the contrast mechanism. The high resolution capabilities of the label-free technique offers a unique mean for probing the mechanics of fine structures of single cells and of cell-substrate interactions.

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Tue 11:30 ESAL 1 Picosecond laser ultrasonics II

Novel Scheme for Broadband Spectrally Resolved Picosecond Laser Ultrasonics – (Contributed, 000436)

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It is known that picosecond laser ultrasonics may benefit from spectrally resolved signal acquisition [1]. The standard scheme measures the signal $s_i(\Delta t)$ at a fixed wavelength λ_i providing an excellent sensitivity ($\Delta s/s = 10^{-7}$) with poor wavelength resolution [2]. The complementary scheme measures the signal difference $s_j(\lambda)$ with and without pump at fixed pump-probe delay Δt_j. Here wavelength resolution is good (spectrometer limited) but signal sensitivity is poor ($\Delta s/s = 10^{-3}$). Hence multi-channel fast detectors have been used to increase the spectral acquisition rate (up to 1 kHz [3]), improving Δs/s down to few 10^{-4} or even further by optimizing an in-line CMOS detectors [4]. We propose a novel scheme in order to improve the sensitivity of broadband picosecond laser ultrasonics. Like previous experiments [2,4], it is based on photonic crystal fiber for broadband probe generation but it is using a CMOS camera coupled to a spectrometer. The main feature relies on judicious synchronization between the camera acquisition rate and the pump modulation allowing to work up to 10 kHz frequency modulation to record signal over 2500 pixels in parallel. Interestingly, it should be easily reproduced by anyone since nothing is home-made. Such detection scheme is tested on two different systems. The first system is a phononic nano-cavity which displays several distinct spectral features due to different electronic transition. The broadband detection allows to follow the opto-acoustic coupling of the phonon nano-cavity dynamics with the different electronics transition. The second system is a surface acoustic wave (SAW) device. The broadband detection will be used to investigate the SAW properties optically.

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Tue 13:30 ESAL 1 Picosecond laser ultrasonics II

Imaging sub-GHz Acoustic Whispering-Gallery Modes at Arbitrary Frequencies with Ultrashort Optical Pulses – (Contributed, 000399)

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Absorption of sub-picosecond optical pulses can generate GHz acoustic waves in media. The propagation of such waves may be detected with the delayed optical probe pulses. In particular, for surface acoustic waves, time-resolved imaging in the GHz frequency region can be carried out by spatial scanning of the probe light spot position. This allows one to study the acoustic properties of complex media such as the dispersion relations of phononic crystals[1].
In such measurements, periodic laser pulses of repetition frequency f_{rep}, typically chosen to be several tens of MHz, are used. The accessible acoustic frequencies are thus limited to nf_{rep}, where n is an integer. This limitation can be circumvented using amplitude modulation of the laser pulse trains at a variable frequency f_{mod} together with an appropriate analysis of the probe reflectance changes[2]: acoustic waves at $nf_{rep} \pm f_{mod}$ can be excited and detected in this way.
We implement this method here to study acoustic whispering gallery modes (WGMs) in micron-scale copper discs[3]. By tuning the acoustic frequencies as explained above, we image WGMs of several different orders. In addition, by fine tuning of the acoustic frequency we extract the quality factor of certain WGMs. This technique should broaden the applicability of time-resolved surface acoustic wave imaging to a variety of microscale systems.

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Tue 13:45 ESAL 1 Picosecond laser ultrasonics II

Imaging of sub-μm and μm-scale textures in H_2O ice at Megabar pressures by picosecond laser ultrasonic interferometry – (Contributed, 000125)

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The evaluation of elastic properties of materials at Megabar pressures is very important for condensed matter physics, seismology and planetology. Recently picosecond laser ultrasonic technique was applied for measurements of elastic properties of materials in diamond anvil cell (DAC) [1]. Sub-nanosecond laser ultrasonic technique was also introduced for measurements in DAC [2]. In this communication, we report on an application of picosecond laser ultrasonic interferometry for the characterization of materials compressed to Megabar pressures in DAC. It was recently demonstrated that this technique provides unique opportunity for the depth-profiling of material with nanometers spatial resolution at normal ambient conditions [3]. In an inhomogeneous medium, the transient reflectivity signal obtained by this technique indeed contains, at each moment of time, the information on the local elastic properties of the medium at the position where is located the laser-generated picosecond acoustic pulse during its propagation in the depth of the sample. The present communication describes characteristic features of the micro-crystallinity of H_2O ice revealed at pressures up to 84 GPa by two-dimensional imaging achieved by this technique [4]. The imaging of ice in-depth and in one of the lateral directions indicates the feasibility of three-dimensional imaging in DAC, with tens of nanometers in-depth resolution, and lateral resolution controlled by laser focusing, thus providing the value of the elastic modulus along the sample depth for each lateral position of the laser beam. The results obtained by the picosecond laser ultrasonic technique are eventually compared with photo-acoustic measurements conducted up to 25 GPa in H_2O ice using a sub-nanosecond laser [2].

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Tue 14:00 ESAL 1 Picosecond laser ultrasonics II

Ultrafast photogeneration and photodection of coherent longitudinal and transverse acoustic phonons in ferroelectric BiFeO3 – (Contributed, 000630)

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In this communication we discuss the ultrafast photogeneration/photodetection of coherent acoustic phonons in ferroelectric BiFeO3 (BFO). The experiments have been conducted within the classical pump-probe scheme employing femtosecond lasers. The coherent acoustic phonons are probed within the time-resolved Brillouin scattering. We will show first how it is possible to obtain large transverse acoustic signal (TA mode) in such ferroelectric material as never reported up to now in any metals or semiconductors. We will discuss the possible explanation of this large TA signals and in particular the contribution of the inverse piezoelectric effect. [1,2]. In a second part, we will discuss the ultrafast optical mode-conversion that can be induced by GHz coherent acoustic phonons via the photoelastic interaction in such optically anisotropic BFO material. The ordinary to extraordinary (and vice-versa) optical mode-conversion process is analysed thanks to the monitoring of the interaction of a delayed probe light with the propagating coherent acoustic phonons. We show, with a complete theoretical support, that this mode conversion process can be very efficient in anisotropic ferroelectric material like BiFeO 3 while no measurable effect has been observed in the canonical anisotropic calcite crystal. These results pave the way to the manipulation of the photon polarization at the picosecond time scale with coherent acoustic phonons. They could be useful for emerging hybrid photonic/phononic devices.

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Tue 10:30 Esplanade Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" II

Interaction of Two-Phase Flows and Ultrasound in Hypergravity Conditions – (Contributed, 000067)

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The presence of air bubbles in certain space systems like fuel tanks, thermal control systems or life support systems can lead to undesired effects which usually lead to a reduction on the efficiency of the systems. These applications usually have to ensure the operation of the systems while undergoing different conditions, which include different gravity levels. Active manipulation of air bubbles in liquids with ultrasound has been shown to be a viable and effective method to control bubbles in the past. Therefore, it is of interest to further investigate the interplay between ultrasound and different gravity levels. A series of experiments to study the effects of ultrasound on rising air bubbles in hypergravity have been carried out. The experiments were conducted at the Large Diameter Centrifuge (ESTEC), in the frame of the ESA "Spin Your Thesis!" 2012 contest, which allowed gravity levels up to $20g_0$. Ultrasound were applied on a cubical test cell filled with water by means of two piezoelectric transducers. Air bubbles were injected inside the test cell by means of a syringe pump, while ultrasound was activated in two different directions: parallel and perpendicular to the axis of gravity, each direction using a different frequency. We have observed different effects of the ultrasound on the rising bubbles from detachment from the nozzle to reaching the free surface. The obtained data shows that ultrasounds have a strong effect on the formation of the bubbles and their rising trajectory, delaying the time to reach the free surface and even levitating bubbles.

Tue 10:45 Esplanade Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" II

Microchannel Anechoic Corner for Microparticles Manipulation via Travelling Surface Acoustic Waves – (Contributed, 000108)

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We present efficient microparticle manipulation technique based on microchannel anechoic corner induced via traveling surface acoustic waves (TSAWs). An acoustofluidic device, composed of a pair of slanted interdigitated transducers (SIDTs) and a polydimethylsiloxane (PDMS) microchannel, is used to manipulate particles of different diameters. The SIDTs disseminate tunable TSAWs normal to the microchannel at desired locations, with required frequencies (130∼200MHz) and amplitudes. The TSAWs interact with the particle carrying fluid to selectively deflect hydro- dynamically pre-focused particles (3.2, 4.2, 4.8μm) from their streamlines. A rightward propagating TSAW, with suitable frequency (135MHz), pushes only selected larger particles (4.8μm) from their streamline into a top-right corner of the microchannel while other particles (3.2 and 4.2μm) flow unaffected in the central region. Downstream, a leftward propagating TSAW (175MHz), misses the larger particles in the top-right corner of the microchannel, deflect only the middle sized particles (4.2μm) into the top-left corner while leaving behind the smaller particles (3.2μm). The separation of particles with diameter 3.2, 4.2 and 4.8μm is realized in a continuous flow. The larger particles remain unaffected by the left-propagating TSAW because of the anechoic nature of the top-right corner of the microchannel. This unique phenomenon is called here as *corner effect*. The *corner effect* is a result of TSAW coupling with the fluid at the Rayleigh angle which is approximately 22° with the channel wall such that the fluid is water and the substrate is $LiNbO_3$. The *corner effect* is utilized to separate different diameter particles and exchange medium around them.

Tue 11:00 Esplanade Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" II

Focusing microparticles inside droplets using acoustics – (Contributed, 000077)

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Motivation
Droplet-based microfluidics has emerged as an exciting tool with applications for single-cell analysis. One obstacle has been the lack of precise methods to control the position of particles or cells *inside* the droplets. The challenge is to overcome the drag force from the internal fluid streams in the droplets. Recently, acoustics have been combined with droplet microfluidics, to control the position of aqueous droplets in microfluidic channels. Here, a method is introduced that uses integrated bulk acoustic standing waves to reproducibly position microparticles inside moving droplets.
Methods
An isotropically wet-etched glass chip with a glued piezoelectric element was used to generate aqueous droplets containing polystyrene microparticles (7 μm) in an organic phase. The channel depth and top-width were 150 μm and 435 μm, respectively, corresponding to a resonance frequency of around 1.9 MHz in water. The total flow rates were set between 3-18 μl/min, and different flow rate ratios were evaluated. At resonance, the microparticles will be moved towards the centre of the microchannel, due to gradients of the acoustic pressure field.
Results
The microparticles were acoustically positioned to the centre of the nanoliter-sized droplets at the resonance frequency, at total flow rates between 3-12 μl/min (water:oil ratio 1:2). At higher flow rates reduced focusing was seen due to insufficient time for the primary acoustic radiation force to act.
This new method to control the position of microparticles inside droplets by bulk acoustophoresis opens up for a range of on-chip droplet-based assays that are not possible to perform today.

Tue 11:15 Esplanade Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" II

Acoustophoresis of Disks – (Contributed, 000090)

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Motivation
Unlike acoustophoresis of spherical particles, acoustophoresis of disk-shaped particles causes an acoustic radiation *torque* which induces disk rotations. Hence the present paper aims to study the acoustophoretic dynamics of disks which are exposed to an ultrasonic standing wave in a microfluidic environment. Application potential is expected for disk-reinforced composites and sound intensity measurements similar to the well-known "Rayleigh disk". Relevance is also given for acoustophoresis of blood samples, since red blood cells are disk-shaped, and for the orientation of non-spherical cells e.g. in flow cytometry.

Methods
With a 3D numerical simulation model for acoustic radiation forces and torques, we studied the dynamics of disks with radius$\ll$wavelength in water. The numerical approach in Comsol Multiphysics allowed to calculate forces and torques for arbitrary disk position, orientation, shape, density and stiffness. The simulations were validated with simplified special cases, where analytic solutions exist in literature (by Gor'kov, King, Rasmussen, Awatani, Wei et al.).
Experiments with alumina disks (diameter 7.5 μm), suspended in an aqueous liquid in a silicon microchannel, confirmed the numerical and theoretical results on the microscale and at ultrasonic frequencies around 2 MHz. The microfabricated devices were excited piezoelectrically with a bulk acoustic wave approach.

Results
Numerical and experimental results describe the acoustophoretic rotation of disks towards an equilibrium position, where the disk axis points in the direction of the standing wave. Numerical simulations revealed the mechanism which generates an acoustic radiation torque, and they allowed modeling beyond the scope of analytic solutions, which only exist for certain disk angles and shapes. By means of the simulations, an ellipsoid with optimized maximal torque could be identified. High-speed microscopy videos of disk acoustophoresis on microfluidic chips were characterized by motion analysis, completing the matching triad of numerical, analytic and experimental results on disk acoustophoresis.

Tue 11:30 Esplanade Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" II

Surface Acoustic Wave Deagglomeration and Alignment of Carbon Nanotubes – (Contributed, 000081)

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Carbon nanotubes agglomerate into 10-100 μm bundles that are difficult to separate, even after suspension in solution. Here a dry and rapid ($\approx$10 s) method to deagglomerate bulk, unbound multi-walled CNT bundles due to surface acoustic waves in a piezoelectric substrate is reported for the first time. The process first forms 1-μm CNT bundles from extremely large mechanical accelerations due to the surface acoustic waves; these bundles are consequently susceptible to acoustic wave-induced evanescent, quasistatic electric fields that couple into the bundles and form a mat of long (1-10 μm) individual nanotubes on the substrate surface. These may then be aligned along the direction of shear, and notably independent of the SAW propagation direction, through sliding of a cover slip in the desired alignment direction. Further, the intrinsic structure of the nanotubes is unaffected as verified using Raman spectroscopy. Uniquely simple, the approach avoids the many shortcomings of other CNT deagglomeration techniques- particularly surface modification and suspension in solution-to rapidly separate and align large numbers of CNTs, thereby overcoming a key limitation in their use for a diverse range of applications.

Tue 11:45 Esplanade Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" II

Acoustic trapping of microvesicles from small plasma volumes – (Contributed, 000314)

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Extracellular vesicles (EVs) are released from many cell types and can be found in different body fluids, e.g. blood, urine and cerebrospinal fluid. They contain proteins, mRNA/miRNA, express antigens and are involved in many cell signaling processes, including RNA transfer between cells. There is currently a focused effort to understand EVs biological function and how they can be used as diagnostic tools.

The process for isolating EVs from blood involves several centrifugation steps leading to low recovery, potential damage to the EVs and sample volumes of several hundred microliters. We present an acoustofluidic method of enriching cell-derived extracellular vesicles. Based on seed particle-enabled acoustic trapping, it enables rapid access to vesicles from small sample volumes. Fluorescent 500 nm polystyrene particles were trapped and enriched from different sample volumes as a feasibility test. Time-lapse images of fluorescent EVs during enrichment demonstrate successful enrichment of Annexin V and CD42 stained EVs. EVs were enriched from human cell-free plasma while experimental parameters (e.g. flow rate, sample volume, plasma concentration) were varied in order to test the system. For each experiment, the enriched EVs were stained and analyzed using flow cytometry. Finally, the concentration of EVs in patients with ST segment elevation myocardial infarction (STEMI) were compared to healthy controls using both the acoustic method and a standard protocol based on serial centrifugation.

The results show that the acoustic trapping system can enrich platelet-derived EVs from human plasma using samples volumes down to 10 μl with a significantly higher recovery than the centrifugation-based protocol.

Tue 10:45 Citadelle 2 High power ultrasound in materials engineering

Ultrasonic metal welding of aluminum to titanium joints for lightweight applications – (Contributed, 000151)

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Hybrid lightweight structures shape the development of future vehicles in traffic engineering and the aerospace industry. For multi-material concepts made out of aluminum and titanium alloys, the ultrasonic welding technique is an appropriate and effective joining technology. The welded structures can be realized in the solid state, even without gas shielding. In this paper the conventional ultrasonic spot welding with longitudinal oscillation mode is compared to the recent ultrasonic torsion welding with torsional waves at 20 kHz frequency. For each technique the process parameters welding force, welding energy and oscillation amplitude were optimized for the hybrid joints using design of experiments. Relationships between the process parameters, mechanical properties and related welding zone should be understood. Central aspects of the research project are microscopic studies of the joining zone in cross section and extensive fracture surface analysis. Detailed electron microscopy and spectroscopy of the hybrid interface help to understand the interfacial formation during ultrasonic welding. Furthermore kinematic and thermal characteristics are determined online with high resolution by laser vibrometry and thermometry. The research project is supported by the German Research Foundation.

Tue 11:00 Citadelle 2 High power ultrasound in materials engineering

Deformation and impact characteristics by applying ultrasonic vibrations to a carbon fiber-reinforced polymer plate – (Contributed, 000227)

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Impact-reduction structures and materials do not necessarily absorb sufficient energy from the impact. Furthermore, the impact-reduction characteristics cannot be changed instantaneously. As such, in this study, we aim to develop an impact-reduction system by applying ultrasonic vibrations, which can change the rigidity of the material instantaneously in the event of an impact. We have studied the impact-reduction characteristics of high-tensile steel and aluminum alloy plates to which ultrasonic vibrations were applied. This study was carried out to verify if the ultrasonic vibrations were applicable to a carbon fiber-reinforced polymer (CFRP) plate. We fabricated an ultrasonic bender that consists of a bolt-clamped Langevin type transducer (BLT) with a wedge horn, a slide guide, and anvils. The diameter and the resonant frequency of the BLT are 56 mm and approximately 17 kHz, respectively. The deformation characteristics were measured in both cases, i.e., in the presence and absence of ultrasonic vibrations. The ultrasonic transducer was driven at a voltage of 200 Vrms. In the absence of vibrations from the ultrasonic transducer, a CFRP plate was bent to its limit at a static load of 865 N and a deformation amount of 7.11 mm. However, in the presence of vibrations from the ultrasonic transducer, a CFRP plate was bent to its limit at a static load of 770 N and a deformation amount of 8.24 mm. Thus, it was confirmed that the stress involved in the plastic deformation decreases and the deformation amount increases by the application of ultrasonic vibrations. Furthermore, the impact-reduction characteristics were measured. The impact was applied by using a drop weight fitted on a slide guide. The impact force decreased by up to 38% upon the application of the ultrasonic vibrations.

Tue 11:15 Citadelle 2 High power ultrasound in materials engineering

High power ultrasound for the impregnation and consolidation of thermoplastic composites – (Contributed, 000319)

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The strong potential of continuous fibre-reinforced thermoplastic composites for high performance applications needs to find faster and more efficient manufacturing processes. In this work, high power ultrasound has been applied to the simultaneous deposition, impregnation and consolidation of commingled thermoplastic rovings. An experimental equipment devoted to the manufacturing of composites, using a commingled roving (i.e. made of dry reinforcement fibres and matrix fibres), has been developed. The proposed system integrates in a single process fibre impregnation and ply consolidation. The equipment consists of an ultrasonic welder, whose titanium horn can be put in contact with the commingled roving during filament winding. During winding, the horn provide energy to the commingled roving that, at the same time, is in contact with the mandrel and the horn. Different friction mechanisms generated by ultrasound are able to melt the thermoplastic matrix. At the same time, pressure is applied and the reinforcement fibres are impregnated. The technique is very fast, ease to automate and has the potential for online quality control. Thanks to this experimental set-up, several prototypes of composite cylinders have been produced starting from commingled rovings made of E-glass fibers and Polypropilene filaments. The physical, mechanical and morphological properties of consolidated specimens have been measured and related to the different processing conditions. Finally, the heat transfer phenomena occurring during the in situ consolidation have been simulated solving by finite element (FE) analysis an energy balance accounting for the heat generated by ultrasonic waves and the melting characteristics of the matrix.The FE analysis has been used to obtain the temperature distribution and the optimized the process parameters.

Tue 11:30 Citadelle 2 High power ultrasound in materials engineering

Effect of Ultrasonic irradiation on preparation and properties of ionogels – (Contributed, 000320)

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Ionic liquids (ILs) are a novel class of materials having good electrical conductivity, wide liquidus range, large electrochemical window, good thermal stability and have negligible vapor pressure. However, liquidus nature of ionic liquids hinders its applications in many electrochemical devices. Therefore, ILs need to be entrapped in porous matrices like SiO2, TiO2, CNT etc. or in dispersed in polymeric membranes. Resulting materials are called "ionogels". In ionogels, pore parameters viz. pore diameter, pore size distribution , porosity, pore volume and surface area can be modified by changing catalyst, amount of IL, gelation temperature etc. However, these methods suffer from the drawback that pore size distribution is not uniform. Recently, ultrasonic irradiation with controlled power has been found to affect the pore parameters of ionogels obtained using hydrolytic and non-hydrolytic routes. Therefore, in the present talk, role of ultrasonic irradiation on the preparation and properties of ionogels synthesized by using ionic liquids 1-ethyl-3-methylimidazolium thiocyanate ([EMIM][SCN]) and 1-butyl-3-methylimidazolium hexafluorophosphate [BMIM] [PF6] has been discussed. The properties of ionogels so prepared have been studied using N2-sorption measurement (BET characterization for the determination of pore parameters), pulse echo technique for the measurement of velocity of ultrasonic waves and hence elastic modulus of resulting ionogels, DSC, TGA, FTIR, TEM, SEM etc. techniques have also been used to characterize ionogels. BET analysis shows some change in pore parameters due to the ultrasonic irradiation. From the N2- sorption measurement, it has been found that BET surface area increased (due to creation of pits on the surface caused by ultrasonic irradiation) while pore volume, average pore size and porosity for ultrasonicated samples decreased. Elastic modulus of the samples containing IL in silica matrices has been found to change with IL content. Ultrasonic irradiation has been found to affect the gelation dynamics and kinetics and pore parameters.

Tue 13:30 Gouv Nonlinear Ultrasonic NDE/NDT III

Non-Destructive Evaluation of Kissing Bonds using Local Defect Resonance (LDR) Spectroscopy: A Simulation Study – (Contributed, 000566)

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With the growing demand from industry to optimize and further develop existing Non-Destructive Testing & Evaluation (NDT&E) techniques or new methods to detect and characterize incipient damage with high sensitivity and increased quality, a lot of research has been performed to better understand the typical behavior of kissing bonds, such as delaminations and cracks. Recently, it has been shown experimentally that the nonlinear ultrasonic response of kissing bonds could be enhanced by using Local Defect Resonance (LDR) spectroscopy. LDR spectroscopy is an efficient NDT technique that takes advantage of the characteristic frequencies of the defect (defect resonances) in order to provide maximum acoustic wave-defect interaction. In fact, for nonlinear methodologies, the ultrasonic excitation of the sample should occur at either multiples or integer ratios of the characteristic defect resonance frequencies, in order to obtain the highest signal-to-noise response in the nonlinear LDR spectroscopy.
In this study, the potential of using LDR spectroscopy for the detection, localization and characterization of kissing bonds is illustrated using a 3D simulation code for elastic wave propagation in materials containing closed but dynamically active cracks or delaminations. The model allows to reveal the presence of local defect resonances, to establish the link between several types of defects and their characteristic resonances and to assist in the further design and testing of LDR spectroscopy.
The research leading to these results has gratefully received funding from the European Union Seventh Framework Programme (FP7/2007- 2013) for research, technological development and demonstration under the Grant Agreements n° 315435 (StirScan) and n° 314768 (ALAMSA).

Tue 13:45 Gouv Nonlinear Ultrasonic NDE/NDT III

Cumulative Ultrasonic Nonlinear Parameter to Evaluate Thermal Degradation in Aluminum alloy – (Contributed, 000339)

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The second-order ultrasonic nonlinear parameter β has been studied for the evaluation of material degradation. However, there are some limits to the assessment of thermal aging of aluminum alloy due to the fluctuation in the value of nonlinear parameter β with the aging time, which is because the value of nonlinear parameter β strongly depends on the behavior of precipitate that can evolve and dissolve while exposed to high temperature. That is, the value of the nonlinear parameter does not one-sidedly increase with the thermal aging. In this case, it is difficult to evaluate the damage level from the measured value of the nonlinear parameter. In order to overcome such limitation, we propose a new parameter β_c which is defined by accumulation of the measured nonlinear parameter β over the aging time. In order to verify the usefulness of the proposed parameter, the relative nonlinear parameters were measured in aluminum alloy specimens heat-treated with different aging temperature and aging time, and their accumulated values were obtained in accordance with the aging time. Thereafter, the tensile tests were conducted to obtain the stress-strain curves of all specimens, which provided information on the strength variation induced by thermal aging. Results showed that the cumulative nonlinear parameter one-sidedly increased in accordance with the aging time, which was agreed well with the reduction in the strength.

Tue 14:00 Gouv Nonlinear Ultrasonic NDE/NDT III

Measurement of the Absolute Value of Ultrasonic Nonlinear Parameter with a Laser Doppler Vibrometry – (Contributed, 000559)

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In field of a classical nonlinear ultrasonic NDT/NDE, a nonlinear parameter can be measured from the second harmonic frequency component of the ultrasonic waves. In actual experiments on metal specimens, however, absolute nonlinear parameter is very difficult to measure since their nonlinear parameter is not so large. There are various reasons of these difficulties; first, the calibratable measurement system of ultrasonic waves to obtain absolute value is

not easy to setup. Second, the pure single frequency component input ultrasonic waves is required but input ultrasonic wave has already higher harmonic component which cannot be ignored. Third, the transducer contact leads to bad test repeatability. This work proposed a method to measure the absolute value of the ultrasonic nonlinear parameter with a laser Doppler vibrometer and an acoustic buffer. A laser Doppler vibrometer was employed for absolute displacement of the ultrasonic waves. An acoustic buffer is to realize far field plane wave condition and to improve the repeatability of the transducer installation. Second harmonic component of the input ultrasound was also considered to calculate nonlinear parameter. To verify the feasibility of the present method , experiments on aluminum and borosilicate glass samples were conducted and the results showed quite similar values with references.

Tue 13:30 Esplanade Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" III

Dynamics of Polymer-coated and Lipid-coated Microbubbles in an Acoustofluidic Device – (Contributed, 000499)

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In this paper, we investigate the ultrasonic-driven dynamics of lipid-coated microbubbles in a custom microfluidic device, designed to host simultaneously optical and acoustic manipulation of microbubbles (6-10 μm diameter). In particular, we describe three experiments: 1) Acoustical manipulation of commercially available, polymer-coated microbubbles at 160-175 kHz, to provide initial benchmarking data. Here we conclude that, in the explored range of frequencies, such bubbles cease to behave like solid particles when a certain threshold pressure is exceeded. We measure secondary Bjerknes forces above the threshold.
2) Calibration of the acoustofluidic device at pressures above the threshold, conducted to have reliable pressure data when classical Gork'ov theory may not apply. We obtain a self-calibration by image processing, monitoring the Brownian motion of trapped polymer-coated microbubbles.

3) Repeat of experiments 1 and 2, but using custom-made lipid-coated microbubbles. In this part of the study, we observe differences with the previous case, attributable to the different coating, and from these infer characteristics of the coating itself. We also discuss the formation of subwavelength structures, different for the two types of bubbles, in the context of different theories for their . Finally, we use high-speed cinematography to highlight volume oscillations, when present.

Findings are interesting for the general acoustofluidic community, but in particular to those researchers already working with microbubbles or moving from solid particles to compressible ones.

Tue 13:45 Esplanade Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" III

On-Demand Production of Size Controlled Droplets Using Surface Acoustic Waves – (Contributed, 000555)

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In the field of microfluidics the ability to perform complex fluid handling relies on precise control over discrete packets of fluid. The objective of this work is to realise this through the production of size controlled droplets within a microfluidic device utilising a single nozzle. Our group has previously demonstrated that a pressure source generated by high frequency Surface Acoustic Waves (SAW) can be used as the driving mechanism behind microfluidic droplet production in a water/oil device. By designing a microfluidic device containing a nozzle smaller than the channel height, a stabilised oil-water interface was produced. Through precise control of the power levels and pulse lengths applied using SAW, we are able to precisely manipulate the pressure field applied to the oil-water interface. Thus the velocity and displacement of the interface can be modulated to produce a range of droplet sizes down to 12μm in the devices presented in this paper. Depending on the flow rates induced within the device, droplets can be produced in squeezing, dripping and jetting regimes. Critically, the size and number of droplets can be modified on demand simply through tuning of the SAW parameters, giving this device a high degree of flexibility.

Tue 14:00 Esplanade Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" III

Characterization of Adhesive Properties of Red Blood Cells Using Surface Acoustic Wave Induced Flows for Rapid Diagnostics – (Contributed, 000053)

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Current conventional methods used to research potential disease diagnostics focuses heavily on the biological and immunological aspects. However, the study of biomechanics of pathogenic diseases allows for both intrinsic and extrinsic study at a cellular level to be carried out. For instance, malaria infection is confronted with several limitations with its diagnostic approaches which include a lack of reproducibility, limited throughput and reduced sensitivity when examining mixed infections or early stages of invasion. Furthermore, logistic issues such as adequate staff training and the ability to maintain good quality visualization apparatus and techniques in remote areas, where the disease is most prominent is an added challenge. The ability to exploit acoustic properties within microfluidic systems allow for a new simple approach that has the potential to increase the efficiency of diagnostic methods. Here, we examine the biomechanics of cell de-adhesion in both healthy and malaria-infected red blood cells using surface acoustic waves (SAW). Unlike techniques which have focused on blood flow forces and detachment rates in microchannels and chambers, a method which requires small fluid samples and low power, thus highlighting potential capacity for rapid diagnosis is presented. Specific analysis was conducted on the shear stresses required to selectively peel healthy cells from diseased cells for varying power inputs. Experimental results demonstrated a strong relationship between cell type and adhesive strength. Moreover, various cell populations contained in a 9 μl droplet were differentiated utilizing acoustic streaming within a short time period (i.e. 30 seconds). More specifically, the percentage of red blood cells (healthy, treated, Malaria infected) remaining on the substrate after excitation were 85%, 60%, 9% respectively, hence, giving rise to a proficient, yet simple technique that can be used as a surveillance tool for effective diagnosis.

Tue 14:15 Esplanade Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" III

An integrated acoustic sample preparation system for rapid sepsis diagnosis from blood – (Contributed, 000318)

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Sepsis is an acute inflammatory response to an infection, usually caused by bacteria. It is one of the most common reasons for admission to intensive care units in Europe and the United states and has a mortality rate of around 30%. To survive, it is important to be administered an effective antibiotic treatment as fast as possible. The current gold standard for detection of sepsis-causing bacteria is blood culture - a method that takes on average 15h and requires several subsequent steps resulting in a total identification time that may go well over 24 hours. Clearly, there is a need for a faster method of identifying sepsis-causing bacteria in blood.
We now present the ACUSEP-system that based on acoustic forces separates bacteria from blood, enriches the bacteria and finally releases the bacteria to a dry-reagent PCR-chip for detection. The process from blood sample to bacteria identification takes less than 2 hours per PCR-chip and the system is mostly automated to reduce contamination risks through manual sample handling. The system was tested both using Pseudomonas putida spiked into whole blood and in an 11 week long clinical study on patients with suspected sepsis. A detection limit of 1000 bacterial/ml was determined for the P. putida tests and the system was capable of detecting Escherichia coli in half of the confirmed cases in patients. This indicates that the ACUSEP-system is capable of detecting bacteria in clinical blood samples in the upper range of clinically relevant bacteria concentrations.

Tue 14:30 Esplanade Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" III

Acoustic Impedance Matching Enables Separation of Bacteria from Blood Cells at High Cell Concentrations – (Contributed, 000470)

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Time is critical when diagnosing sepsis, since mortality increases with every hour of delay of appropriate treatment. Still, the gold standard to identify sepsis-causing bacteria is blood culture, which usually takes 6-130h. To reduce time to diagnosis, we have developed an acoustophoresis-based method to directly sort out bacteria from blood samples. We here demonstrate a 40x increase in throughput by acoustic impedance matching and flow rate increase.
Blood is hydrodynamically laminated along the sidewalls of a separation channel by a central buffer inlet. The red blood cells (RBCs) are acoustically focused to the central buffer, whereas smaller bacteria remain along the sidewalls due to the size dependence of the acoustic force.
At 1% blood concentration the bacteria recovery was 99.7%. Increasing the blood concentration to 20% increased the acoustic impedance (density times speed of sound) of the sample, causing the entire sample fluid to be acoustically focused. This was successfully prevented by increasing the acoustic impedance of the center buffer. With impedance matched buffers bacteria recovery was found to be 89.8% at 20% blood, showing a small decrease in recovery since red blood cells hydrodynamically pulled neighboring bacteria with them at the higher cell concentration.
By using acoustically matched fluids we were able to reduce the time to process 1ml whole blood from over 8h to 12.5min using acoustophoresis. The throughput for a single channel was found to be higher than any comparable microfluidic method, providing a possible sample preparation method for the development of a new sepsis diagnosis system.

Tue 14:45 Esplanade Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" III

Dynamic Acoustic Field Activated Cell Separation (DAFACS) for Regenerative Medicine – (Contributed, 000155)

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We demonstrate a novel approach utilizing on dynamic acoustic field that is capable of separating an arbitrary size range of cells. Advances in diagnostics, cell and stem cell technologies drive the development of application specific tools for cell and particle separation. In this presentation, we demonstrate the Dynamic Acoustic Field (DAF) method with separation of different diameter and different density of particles/cells in a heterogeneous medium. In a flow-less cavity two opposing transducers were excited, consequently a linear interference pattern of nodes and antinodes was formed in the interstitial media. As a result the micro-particles were trapped at the minima of the potential acoustic energy density. Electronically shifting the excitation phase of one of the transducers from 0° to 360°, proportionally translates that pattern in the direction of the added phase delay. Within each cycle the phase is swept completely through 360° over a time tramp and then allowed to rest for a period trest before commencing the next cycle. Sets of polystyrene particles were subjected to dynamic acoustic field. The measured performance showed high purity (up to 100 %), and high efficiency (up to 100 %). We also tested the separation performance against particle density. Then we applied the dynamic acoustic field to separate porcine dorsal root ganglion (DRG) neurons from a freshly isolated mixture containing myelin debris and other non-neuronal cells. By experimental result it is demonstrated that the DRG cells follow the shifted acoustic field while the debris exhibits minimal displacement of the original node.

Tue 13:45 Saint Pierre Bio-medical ultrasound for therapy III

First clinical experience of intra-operative high intensity focused ultrasound in patients with colorectal liver metastases: a phase I-IIa study – (Contributed, 000467)

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Background: Surgery is the only curative treatment in patients with colorectal liver metastases (CLM), but only 10-20% of patients are eligible. High Intensity Focused Ultrasound (HIFU) technology is of proven value in several indications, notably prostate cancer. Its intra-operative use in patients with CLM has not previously been studied. Preclinical work suggested the safety and feasibility of a new HIFU device capable of ablating volumes of up to 2cm x 2cm in a few seconds. Methods: We conducted a prospective, single-centre phase I-IIa trial. HIFU was delivered immediately before scheduled hepatectomy. To demonstrate the safety and efficacy of rapidly ablating liver parenchyma, ablations were performed on healthy tissue within the areas scheduled for resection. Results: In total, 30 ablations were carried out in 15 patients. These ablations were all generated within 40 seconds and on average measured 27.5mm x 21.0mm. The phase I study (n=6) showed that use of the HIFU device was feasible and safe and did not damage neighbouring tissue. The phase IIa study (n=9) showed both that the area of ablation could be precisely targeted on a previously implanted metallic mark (used to represent a major anatomical structure) and that ablations could be undertaken deliberately to avoid such a mark. Ablations were achieved with a precision of 1-2 mm. Conclusion: HIFU was feasible, safe and effective in ablating areas of liver scheduled for resection. The next stage is a phase IIb study which will attempt ablation of small metastases with a 5 mm margin, again prior to planned resection.

Tue 14:00 Saint Pierre Bio-medical ultrasound for therapy III

Enhanced Wound Healing Through Low Frequency (20 kHz), Low Intensity (100mW/cmˆ 2) Ultrasound – (Contributed, 000003)

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The objective of this work was to verify that ultrasound delivered at level of 55 kPa (about 100 mW/cm2, ISPTP) was clinically viable in promoting chronic venous ulcer (VU) wounds healing. Over 500,000 patients are treated for VU annually at the direct expense $2,400 per month, before factoring in indirect costs due to pain and limited productivity. Hence, even modest (25%) shortening of the time needed for healing would allow substantial cost savings. Patients (n=16) were enrolled according to the IRB protocol, and randomly assigned into treatment or control groups. They were treated weekly (15 minutes) for a maximum of 12 visits or until wound closure using a novel, fully wearable, tether-free, ultrasound applicator. The treatments were given in addition to standard of care compression therapy as ordered by the physician. The ultrasound treated group had statistically improved ($p<0.04$) rate of wound size change (reduction of 8.2%/wk) compared to the rate of wound size change for the control group (increase of 7.5%/wk on average). This study indicates that 20 kHz ultrasound treatment of chronic venous ulcers combined with the current standard of care promotes the healing process and can potentially be performed at the patient's home. Acknowledgement: NIH 5R01EB009670.

Tue 14:15 Saint Pierre Bio-medical ultrasound for therapy III

Characterization of temperature effect induced by a HIFU transducer in TMM and in sheep and calf liver – (Contributed, 000535)

B. Karaboce

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The temperature effect produced by a focused ultrasound transducer has been investigated by using T type thermocouple temperature sensors embedded in TMM (tissue mimicking material) in an automated positioning system. The temperature change and the temperature distribution due to applied ultrasound power have been characterized in TMM. Pennes' bioheat transfer equation for the temperature rise caused by absorption of HIFU energy was investigated. HIFU (high intensity focused ultrasound) transducer with a resonance frequency of 1.1 MHz and 3.3 MHz was used as source. Same measurements were realized for sheep and calf liver in order to observe cauterization. Effect of ultrasound in liver pieces was displayed and dimension of cauterization has been measured. Measurement results for TMM and liver were compared so that it is possible to transfer the laboratory measurements to clinical studies. All measurements were carried out in the system at TÜBITAK UME (The Scientific and Technological Research Council of Turkey, the National Metrology Institute) Ultrasound laboratory.

Tue 14:30 Saint Pierre Bio-medical ultrasound for therapy III

Heating by Therapeutic Ultrasound Measured with a 2D Thermotropic Liquid Crystal Sensor in a Prototype Phantom – (Contributed, 000409)

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Thermotropic liquid crystals (TLC) have already been used for qualitative 2D imaging of ultrasound beam profiles previously. Here, a new quantitative approach is presented, based on custom-made TLC sensor foils showing colour changes from 42 °C to 61°C (i. e. adapted to the temperature range of important thermal bioeffects like protein denaturation) placed between novel types of optically transparent ultrasound absorbers based on chemical relaxations. The design of the compact phantom also allows the use inside MRI/HIFU scanners (tested up to 3T), with a digital camera at some distance. Important details of the phantom setup are given and all parts and procedures critical for quantitative evaluation are discussed.

Tue 14:45 Saint Pierre Bio-medical ultrasound for therapy III

Suitability of a Statistical Backscatter Technique using a HIFU Transducer as Pulser/Receiver to serve as a Universal Method for in situ Cavitation Metrology – (Contributed, 000395)

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There exist numerous cavitation detection methods like optical methods, active and passive acoustic methods and sonochemical methods. However, the results obtained from the different methods often show a poor agreement. In this work a simple method based on backscattered signals is presented which uses a high-intensity focused ultrasound (HIFU) transducer as a pulser/receiver. A practical advantage of this method is that almost no additional devices are required additional to the ones used anyway for HIFU sonications. A second advantage of this method is its inherent geometrical alignment. The method has been applied to measure the cavitation onset and the cavitation probability in different Agar-based tissue-mimicking materials and the results will be reported in this talk. Special attention is paid to the dependence of the cavitational response on the gas content in the respective medium and on different sonication settings like burst length and pulse repetition rate. Additionally, an assessment will be given about the suitability of this method to serve as a universal standard method for in situ cavitation metrology.

Tue 13:45 Citadelle 2 Ultrasound in Food science, Pharmaceutical and Cosmetics

Microbial inactivation by ultrasound assisted supercritical fluids – (Contributed, 000030)

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A combination of supercritical carbon dioxide (SC-CO2) and high power ultrasound (HPU) has been developed and tested for microbial/enzyme inactivation purposes, at different process conditions for both liquid and solid matrices. In culture media, using only SC-CO2, the inactivation rate of E. coli and S. cerevisiae increased with pressure and temperature; and the total inactivation (7-8 log-cycles) was attained after 25 and 140 min of SC-CO2 (350 bar, 36 °C) treatment, respectively. Using SC-CO2+HPU, the time for the total inactivation of both microorganisms was reduced to only 1-2 min, at any condition selected. The SC-CO2+HPU inactivation of both microorganisms was slower in juices (avg. 4.9 min) than in culture media (avg. 1.5 min). In solid samples (chicken, turkey ham and dry-cured pork cured ham) treated with SC-CO2 and SC-CO2+HPU, the inactivation rate of E. coli increased with temperature. The application of HPU to the SC-CO2 treatments accelerated the inactivation rate of E. coli and that effect was more pronounced in treatments with isotonic solution surrounding the solid food samples. The application of HPU enhanced the SC-CO2 inactivation mechanisms of microorganisms, generating a vigorous agitation that facilitated the CO2 solubilization and the mass transfer process. The cavitation generated by HPU could damage the cell walls accelerating the extraction of vital constituents and the microbial death. Thus, using the combined technique, reasonable industrial processing times and mild process conditions could be used which could result into a cost reduction and lead to the minimization in the food nutritional and organoleptic changes.

Tue 14:00 Citadelle 2 Ultrasound in Food science, Pharmaceutical and Cosmetics

New Ultrasonic Controller and Characterization System for Low Temperature Drying Process Intensification – (Contributed, 000088)

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Process intensification constitutes a high interesting and promising industrial area. It aims to modify conventional processes or develop new technologies in order to reduce energy needs, increase yields and improve product quality. When drying at low temperature, heat degradation is diminish, although long drying times may induce quality losses and involve high operating costs. It has been demonstrated by this research group (CSIC) that power ultrasound have a great potential in food drying processes. The effects associated with the application of power ultrasound (turbulence, structure diffusion, acoustic streaming, etc.) can enhance heat and mass transfer and may constitute a way for process intensification. The aim of this work has been the design and development of a new ultrasonic system for the power characterization of piezoelectric plate-transducers, as excitation, monitoring, analysis, control and characterization of their nonlinear response. For this purpose, the system proposes a new, efficient and economic approach that separates the effect of different parameters of the process like excitation, medium and transducer parameters (voltage, current, frequency, impedance, vibration velocity and temperature) by observing the electrical, mechanical and thermal behavior, and controlling the vibrational state. In order to determine the suitability of this new system, two different transducers have been experimentally characterized. Results clearly show the benefits of the ultrasonic system in the re-design and optimization of power ultrasonic transducers for food processing.

Tue 14:15 Citadelle 2 Ultrasound in Food science, Pharmaceutical and Cosmetics

Influence of the ultrasonic power applied on freeze drying kinetics – (Invited, 000160)

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Air drying is one of the oldest methods applied for preserving food. However this operation has as main drawbacks, energy consumption and the long processing time, therefore, is an operation highly prone for intensification. In this sense, the atmospheric freeze drying (AFD) technique allows obtaining high quality products, similar to those obtained by vacuum freeze drying, but at lower costs because the continuous production and no vacuum is needed. The effects caused by high intensity ultrasound (turbulence, structure diffusion, acoustic streaming, etc.) can enhance heat and mass transfer. However the magnitude of these effects is dependent on the product and process variables. Thus, in hot air drying processes, the air velocity, the internal structure of the material being dried and the ultrasonic power applied has a significant influence on the increase of drying kinetics induced by ultrasound application. With regard the ultrasound application in AFD processes, it has been observed that the internal structure of material do not influence on the magnitude of ultrasonic effects. At the temperatures used in these processes, the external resistance to mass transport is negligible compared to the internal one. As a consequence no significant influence of air velocity is found. The main goal of this work was to determine the influence of the ultrasonic power applied during AFD. To examine these effects drying kinetics of apples was addressed. Experimental results showed a significant ($p<0.05$) influence of the ultrasound application on drying kinetics. The drying time was shorter as higher the ultrasonic power applied. The effective diffusion coefficient identified was significantly higher when ultrasound was applied increasing along the ultrasonic power applied. It can be highlighted that the effective diffusion coefficient was three times higher when ultrasound was applied at the lowest power tested (10.3 kW/m3) that illustrate the high intensification potential of ultrasound application in the AFD.

Tue 14:45 Citadelle 2 Ultrasound in Food science, Pharmaceutical and Cosmetics

Ultrasonic Drying Processing Chamber – (Contributed, 000186)

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The design a high intensity ultrasonic chamber for drying process was investigated. The acoustic pressure distribution in the ultrasonic chamber drying was simulated solving linear elastic models with attenuation for the acoustic-structure interaction. Together with the government equations, the selection of appropriate boundary conditions, mesh refinement, and configuration parameters of the calculation methods, which is of great importance to simulate adequately the process, were considered. Numerical solution, applying the finite element method (FEM), of acoustic-structure interactions involves to couple structural and fluid elements (with different degrees of freedom), whose solution implies several problems of hardware requirements and software configuration, which were solved. To design the drying chamber, the influence of the directivity of the drying camera open and the staggered reflectors over the acoustic pressure distribution was analyzed. Furthermore, to optimize the influence of the acoustic energy on the drying process, the average energy acoustic distribution in the drying chamber, that would determine the adequate position of the food to drying, was studied. For this purpose, the acoustic power absorbed by the samples will be analyzed in posteriors studies.

Tue 16:15 Citadelle 2 Ultrasound in Food science, Pharmaceutical and Cosmetics

Applications of Ultrasound in Food, Pharmaceutical and Cosmetic Technology: from Innovations to Industrial Applications – (Invited, 000201)

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Ultrasound is well known to have a significant effect on the rate of various processes in the food , cosmetic and pharmaceutical industries. Using ultrasound, full reproducible processes can now be completed in seconds or minutes with high reproducibility, reducing the processing cost, simplifying manipulation and work-up, giving higher purity of the final product, eliminating post-treatment of waste water and consuming only a fraction of the time and energy normally needed for conventional processes. Several processes such as freezing, cutting, drying, tempering, bleaching, sterilization, and extraction have been applied efficiently in the food, cosmetic and pharmaceutical industries. The advantages of using ultrasound for processing, preservation or extraction, includes: more effective mixing and micro-mixing, faster energy and mass transfer, reduced thermal and concentration gradients, reduced temperature, selective extraction, reduced equipment size, faster response to process extraction control, faster start-up, increased production, and elimination of process steps. Processes performed under the action of ultrasound are believed to be affected in part by cavitation phenomena and mass transfer enhancement.

This conference presents a complete picture of current knowledge on application of ultrasound in food, pharmaceutical and cosmetic processing. It provides the necessary theoretical background and some details about ultrasound processing, the technique, and safety precautions. We will also discuss some of the factors which make the combination of conventional processing and ultrasound one of the most promising research areas in the field of modern engineering.

Tue 16:45 Citadelle 2 Ultrasound in Food science, Pharmaceutical and Cosmetics

Intensification of convective drying of apple by means of acoustically assisted pretreatments: Effects of PPO activity and drying kinetics – (Contributed, 000464)

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Recently, ultrasonic assistance during pretreatments has been found to accelerate the removal of water from foodstuffs during convective drying. The effect of power ultrasound application on polyphenoloxidase (PPO) activity and drying kinetics were evaluated by applying acoustic assistance in a soaking treatment before convective drying. Treatments were carried out using three different soaking media, distilled water, apple juice, and citric acid, at 25 °C during 5 min, without acoustic assistance (0 W/cm^2), and then with two acoustic densities: 2.1 and 12.9 W/cm^2. Treated samples exhibited a decrease in the PPO activity by 13 to 58% in comparison with that in the fresh sample. The highest inactivation was observed when treatment was carried out with 12.9 W/cm^2 using apple juice (40%) and 1% citric acid (58%), whereas samples soaked in water showed the lowest decrease (19%). Convective drying of soaked samples was carried out at 50 °C and an air velocity of 1.0 m/s. Drying curves were studied until a final moisture content of 0.20 kg water/kg dm was achieved. Compared with the fresh sample, the drying time of the treated one decreased by 13.3% when it was treated with water without acoustic assistance (treatment which promoted the smallest reduction), and by 42.4% when the sample was soaked in 1% citric acid and 12.9 W/cm^2 (treatment which promoted the highest reduction).

Tue 17:00 Citadelle 2 Ultrasound in Food science, Pharmaceutical and Cosmetics

Ultrasonic-spray drying vs high-vacuum and microwave technology in blueberries – (Invited, 000515)

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The Blueberries are a good source of health beneficial compounds such as polyphenols and anthocyanins. The anthocyanins are pigments responsible of the colors reddish and blue on vegetables. The anthocyanins have showed preventive effects against cardiovascular disease, cancer, neurodegenerative disorders such as Alzheimer and it is a powerful antioxidant natural consequently, this fruit became a much solicited food, so it is desirable that their beneficial effects will maintained when it reaches the consumer. Because its high water content (approximately 85%) the berries are a food highly perishable, limiting availability of nutrients and bioactive agents in the fruit. One solution might be to store fruit at low temperature, but because volumes required to store and energy expenditure produced by the freeze, this method is expensive. Other form to conserve the fruit is to drying it. Nowadays, these products exist, they are a good source of fiber, preserving the aroma, flavor and color, but because the polyphenols are thermolabile, they have low content of bioactive agents. We studied spray drying of blueberry juice using with ultrasonic atomizer at 150°C and microwave-vacuum drying, comparing the properties of both products. The oven density of energy was 24 [mW/cm3] and the vacuum level 10-3 [mbar], the temperature of drying did not overcome 50[°C]. Has been quantified the totals polyphenol content (TPC) in mg of Gallic acid equivalent (GAE), totals anthocyanin content (TAC) in mg of Cyanidin 3- glucosidic equivalent (CGE) and antioxidant activity (AA) in μmol of trolox equivalent (TE). Results show clear advantages of drying at high vacuum and low temperatures against the spray drying at 150 C°. However the last one present interesting characteristics that will be shown in the presentation and in the full paper.

Tue 17:30 Citadelle 2 Ultrasound in Food science, Pharmaceutical and Cosmetics

Effect of Sonocatalyst Preparation Method on Decolorization of Baker's Yeast Effluent by Ultrasound – (Contributed, 000071)

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Baker's yeast effluent contains various pollutants which give high organic load and dark colour. These pollutants called melanoidins cannot be easily degradated by biological process. So, another treatment processes can be applied. In this study, ultrasound was used to remove color from baker's yeast effluent. For this purpose ultrasonic homogenizator was used. To increase decolorization, SnO2/TiO2 composites were prepared. The effect of composite preparation method and the molar ratio of SnO2/TiO2 were investigated. The composites were prepared with two different manner. In the first way, ultrasonic bath was used. In the second way, ultrasonic homogenizator was used. According to results, the prepared composite SnO2/TiO2 with ultrasonic homogenizator and 4:1 molar ratio gave 25% decolorization from baker's yeast effluent. The effect of composite preparation method on surface morphology was also investigated.

Keywords: Baker's yeast effluent, decolorization, sonocatalyst, ultrasound

Tue 17:45 Citadelle 2 Ultrasound in Food science, Pharmaceutical and Cosmetics

Determining Coagulation Time of Milk Using an Ultrasonic Technique – (Contributed, 000026)

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The coagulation time is often used as a reference to determine the time of cutting the gel, in order to expel whey trapped in the pores of the gel. Cutting time means that the gel has reached a certain firmness allowing passage from the enzymatic phase to the physico-chemical phase of the cheese making process. Therefore, cutting the gel earlier or later will have negative effects on the quality of the final product. So, optimal evaluation of the coagulation time is necessary to maximize qualitative and quantitative cheese yields. In this work a non-destructive ultrasonic technique is developed to monitor in real time the coagulation process of renneted milk in order to determine the coagulation time. The latter is determined with high precision by exploiting changes of the ultrasonic velocity in the coagulating milk. We have developed a non-invasive technique that uses a single transducer, what is very important in the food industry.

Tue 14:15 Gouv — Structural Health Monitoring

Exploitation of the reverberant propagation of elastic waves in structures: towards a concept of low-resource SHM sensor network – (Invited, 000536)

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Actual implementation of an efficient SHM system is necessarily hampered by the constraints of power-consumption and intrusiveness (weight, size, in-service integration) of sensors. In the field of ultrasound-based SHM, conventional methods rely on relatively powerful acoustic sources synchronized with the sensors, and exploit only the first propagated (ballistic) wavepackets. The aim of this paper is to present possible techniques to exploit the whole complexity of reverberation signals, in order to extract the maximum information from limited hardware, software, or power resources. A first aspect is the extraction of statistical properties of the codas of multiply-reflected signals, which can be used to estimate structural properties from a small number of sensors. In this technique, the required signal processing is relatively light and synchronization between the acquisition channels is not necessary. A second aspect is concerned with the possibility of using ambient acoustic sources, naturally present for example in transportation applications, instead of artificial power-consuming ultrasound sources. Recent developments in both aspects will be briefly reviewed, and subsequent perspectives in terms of SHM system implementations will be discussed.

Tue 14:45 Gouv — Structural Health Monitoring

One channel defect imaging in a reverberating medium – (Contributed, 000044)

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The presentation deals with an acoustic one-channel location system that takes advantage of the multiple reflections occurring in the reverberating medium under investigation. Experimental results are obtained with guided waves propagating in a bounded aluminum plate. The plate is so designed that there is no direct propagation path between the single transducer and the region of interest in the plate. In that manner, the two-dimensional image obtained in the region of interest is only based on the reverberated acoustic field measured with the single fixed transducer. The method is based on the application of topological optimization methods to wave-based location problems and on a preliminary calibration of the whole system. This calibration mainly consists in measuring the impulse response of the transducer in the region of interest before any object or defect is present. The calibration is here performed with a Laser Doppler velocimeter. The experimental results obtained with this one-channel topological imaging method show accurate location of a single small defect and of multiple small defects, with a resolving power below the wavelength.

Tue 16:00 Gouv — Structural Health Monitoring

Experimental Study of Passive Defect Detection and Localization in Thin Plates from Noise Correlation – (Contributed, 000051)

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This paper reports experimental results on a passive imaging technique for structural health monitoring to detect the occurrence of defects in plate-like structures. This technique is based on the fact that the active transient response between two sensors can be passively retrieved by cross-correlating the ambient noise-field recorded on these two sensors. A correlation matrix is estimated from friction or acoustic noise recorded on a transducer array. It is observed that the accuracy of the estimated transient responses strongly depends on the spatial distribution of noise sources. The best convergence is obtained when the noise is uniformly distributed over the whole plate area. Defects are localized by applying a dispersive beamforming algorithm to the difference between the correlation matrices obtained with and without (w/o) defect. It is shown that the quality of the active transient response reconstruction is not a strong requirement for the defect localization. Indeed, the defect is successfully localized even if the noise source distribution is not uniform, provided that it remains spatially stationary between the states w/o defect. A simple theoretical framework is proposed to interpret these results.

Tue 16:15 Gouv Structural Health Monitoring

KNN for Detection and Classification of in Service Damages in Structures Operating at Harsh Conditions – (Contributed, 000459)

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The aim of Structural Health Monitoring (SHM) is to detect, localize and identify early stage damages in operating structures in order to increase their life service, reduce maintenance cost and avoid catastrophic failure. Ultrasonic guided waves are considered as a good candidate for such an application because they can travel over long distances with small attenuation. Hence, they can cover large areas using only small number of permanently mounted sensors. This acquisition system continuously store data from in-situ structures. Consequently, signal processing and intelligent data analysis are necessary to transform the data into information about the state of the structure. However, the collected data may contain not only information about damage but also the effect of environmental and operational conditions (EOCs). Thus, to ensure a reliable damage detection approaches, these effects must be eliminated or at least reduced. This paper proposes a novel algorithm for damage detection and identification in a SHM context inspired from machine learning and pattern recognition paradigm which is the K nearest neighbors (KNN). To deal with the effects of EOCs, singular value decomposition based on principal component analysis was utilized for dimensionality reduction. This algorithm was applied to a case of study where damage was simulated artificially by adding weights on the surface of the structure. Results have shown the KNN provides a high accuracy of classification and a minimum number of false indications of damage compared to other non-parametric methods.

Tue 16:30 Gouv Structural Health Monitoring

Novelty Detection in Tubular Structures Monitoring: A Case of Study – (Contributed, 000461)

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Tubular structures Health monitoring through ultrasonic guided waves in increasing use. This is helpful to ensure optimal working conditions and to facilitate maintenance intervention strategies. . However, it is worth noting that its success is still challenging and many substantial efforts have to be undertaken. One of the main challenges is that the identification of damage requires a classification method based on a supervised learning algorithm. Whereas, there is mostly no prior knowledge of damage cases in the structures, which makes SHM applications impractical. In this situation, where only the information about the normal operation is available, the strategy of damage diagnosis is carried out with a novelty detection algorithm, also known as outlier analysis. In this paper, we investigate the use of novelty detection to detect and characterize damage severity in tubular structures. A case of study will be presented where damage was created artificially by adding weights on the surface of the structure. Two types of novelty detection algorithm were studied: univariate and multivariate analysis. Results have shown that the multivariate analysis is much better than the univariate one in terms of sensitivity and differentiation between all types of damages.

Tue 16:45 Gouv Structural Health Monitoring

Semi-supervised Methods for Robust Damage Detection of Pipelines using Sparse Representation of Guided-waves – (Contributed, 000478)

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Variations in environmental and operational conditions (EOCs) (e.g., temperature, inner pressure), in addition to the complex nature of guided-waves, are the main challenges limiting their real-world application for pipeline monitoring. This paper is part of a study whose objective is to overcome these challenges while addressing the limitations of current approaches. Specifically, our study seeks to develop methods that simplify ultrasonic guided-wave signals while retaining damage information, have low sensitivity to EOC variations, and minimize the use of transducers. In the authors' previous work, a supervised method was developed to extract a sparse subset of the signals, in time domain, that contain optimal damage information for detection purposes. In the training stage, pitch-catch records are obtained under limited range of EOCs, from both intact pipe and the pipe with an artificial abnormality. In the monitoring stage, the trained sparse discriminant vector is used to detect, in real-time, development of damage in the pipe. The authors have validated that this supervised method remains sufficiently robust to the differences of EOCs, damage location, and damage characteristics between training and test data. However, there are benefits in eliminating as many training parameters as possible. Therefore, this paper reports semi-supervised methods in which the training dataset only includes signals from the intact pipe (i.e., EOCs are the only training parameters that can vary between trainign and test data). In this paper, the following assumption is tested: a sparse subset of the signals that reconstructs the energy of the signal with minimum residual contains sufficient damage information for damage detection under varying EOCs. This assumption is evaluated through extensive controlled laboratory experiments on (A) a schedule- 40 aluminum pipe segment with artificial abnormalities, and on (B) a steel pipe segment with an actual crack, with temperatures varying from 24°C to 34°C.

Tue 17:00 Gouv Structural Health Monitoring

Nondestructive testing residual stress using ultrasonic critical refracted longitudinal wave – (Contributed, 000507)

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Residual stress has significant impacts on the performance of the mechanical components, especially on its strength, fatigue life and corrosion resistance and dimensional stability. It has been a difficulty and hot issue that how to evaluate the residual stress status of the surface or a certain depth of mechanical components quickly, nondestructively and accurately. Based on acoustoelasticsticity theory, the relationship between velocity and direction of ultrasonic propagation and stress is researched. The sensitivity of different types of ultrasonic to stress are compared, and it is found that velocity of longitudinal wave propagation along the stress direction is mostly affected by residual stress. Residual stress ultrasonic testing system for mechanical components is built. Using one transmitting-one receiving and oblique incidence way excite critically refracted longitudinal wave (LCR wave) in a certain depth (the depth which is related to the transducer frequency) in the material tested. Acoustic wedges for testing residual stress in mechanical components are designed. Using tensile and compression testing machine calibrate the testing of residual stress. By testing residual stress nondestructively in welding pipe, bolt, glass, ceramic components, and so on, the accuracy and practicability of the ultrasonic method can be verified.

Tue 17:15 Gouv Structural Health Monitoring

Feasibility of Passive Tomography of Extended Defects Using Ambient Elastic Noise Correlation – (Contributed, 000560)

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Structural health monitoring (SHM) consists in embedding sensors in a structure like an aircraft or a naval ship in order to detect defects (for example cracks or corrosion in metallic materials or delamination in composite materials) before a serious fault occurs in the structure. Guided elastic waves emitted by a sensor and propagating to another one are often used as the physical way of detecting the defect. However, the implementation of SHM systems is restricted in many situations by the electric power necessary to emit the waves.
A promising way to tackle these constraints is to use techniques based on the cross-correlations of the ambient acoustic noise in place in the structure. It has been shown that, under certain conditions, transient response between two sensors can be passively estimated from cross-correlation of ambient noise. The idea is to take advantage of the elastic noise naturally present in the structure (due to engine vibrations or aero-acoustic turbulences on the fuselage of an aircraft for example) in order to avoid the emission of the elastic waves by the SHM system.

Studies of noise cross-correlation techniques have been conducted with the aim of doing passive tomography of extended defects (such as corrosion) using an array of piezoelectric transducers. Experimental results which come from tomographic imaging algorithms will be presented.

Tue 17:30 Gouv Structural Health Monitoring

PPM-based system for guided waves communication through corrosion resistant multi-wire cables – (Contributed, 000605)

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Novel wireless communication channels are a necessity in applications surrounded by harsh environments, for instance down-hole oil reservoirs. Traditional radio frequency (RF) communication schemes are not capable of transmitting signals through metal enclosures surrounded by corrosive gases and liquids. As an alternative to RF, a pulse position modulation (PPM) guided waves communication system has been developed and evaluated using a corrosion resistant 1k22 multi-wire cable, commonly used to descend measurement tools in down-hole oil applications, as the communication medium. The system consists of a transmitter and a receiver that utilizes a PZT crystal, for electrical/mechanical coupling, attached to each extreme of the multi-wire cable. The modulator is based on a microcontroller, which transmits 60 kHz guided wave pulses, and the demodulator is based on a commercial digital signal processor (DSP) module that performs real time DSP algorithms. Experimental results are presented, which were obtained using a 1m 1k22 multi-wire cable. Although there was significant dispersion and multiple mode excitations of the transmitted guided wave energy pulses, the results show that data rates on the order of 500 bits per second are readily available employing PPM and simple communications techniques.

Tue 15:45 Esplanade Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" IV

Improved acoustophoretic circulating tumor cell separation for low target cell numbers in clinical volumes – (Contributed, 000479)

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We have developed a pressure driven system for continuous flow acoustophoretic separation of circulation tumor cells (CTC). This system allows us to process larger volumes, such as full clinical samples of about 7 mL, with an improved flow stability which includes flow sensors and feedback loop for precise flow control. It also offers simplified liquid and sample handling by simply docking the sample tube and buffers to the inlet ports, minimizing CTC losses in the system as well as a user interface that can be handled by a non-skilled operator. All these features are improvements in contrast to our previously reported syringe pump driven microfluidic flow system.
The acoustic separation device includes a 2-dimensional pre-focusing that allowed alignment of all cells in the same flow vector as they enter the acoustophoretic separation zone, which was crucial to enable separation of tumor cells at high purities versus the white blood cells (WBC) background.
The number of CTCs in a clinical blood sample is commonly in the range of <10 cells /mL and hence a CTC separating system must be able to separate CTCs from a WBC background of $\approx 10^6$ WBC/mL at very high recoveries. To investigate the performance of the CTC-separator, sample suspensions of 1mL WBCs were spiked with 10-15 tumor cells (DU145) and processed through the acoustic

separator. In principle all tumor cells were accounted for with only 0.4% WBC contamination, concluding that our CTC-system demonstrates a performance that now meet the requirements to investigate clinical samples for CTC analyses.

Tue 16:00 Esplanade Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" IV

Label-Free Enrichment of Prostate Tumor Cells Using Acoustophoresis and Negative Selection of WBCs with Elastomeric Negative Acoustic Contrast Particles – (Contributed, 000223)

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Motivation
Acoustophoresis can be used for label-free enrichment of tumor cells in human blood samples. Tumor cells have acoustophysical properties allowing them to be separated from WBCs using acoustophoresis. However, contaminating WBCs were identified to have overlapping acoustophoretic mobilities. Elastomeric particles (EP) that 1) function as negative acoustic contrast particles, and 2) bind WBCs in blood samples, can be used to alter the acoustophysical properties of WBCs; leading to reduced amounts of WBCs in the CTC fraction in the central chip outlet. We show that acoustophoresis with negative selection of WBCs using EPs can be used for improved label-free enrichment of tumor cells.
Methods
Elastomeric particles were synthesized using an emulsion process and functionalized using a CD45 monoclonal antibody. Various amounts of EPs were added to solutions containing a 1:1 mixture of WBCs and prostate cancer cells (DU145). Incubation of EPs with cell mixtures occurred at room temp for 1 hour. Acoustophoresis (1.99 MHz at 12 Vpeak-peak) was performed to separate EP bound WBCs from cancer cells. The collected fractions were enumerated using flow cytometry (BD FACSCanto^{TM} II).
Results
Our results showed increased depletion of WBCs within the central fraction as the EP to WBC ratio was increased. A maximum of ≈50-fold WBC depletion from the center fraction was obtained with a tumor cell recovery of 94.6%.

Tue 16:15 Esplanade Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" IV

Numerically efficient damping model for acoustic resonances in microfluidic cavities – (Contributed, 000351)

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Bulk acoustic wave devices are typically operated in a resonant state to achieve enhanced acoustic amplitudes and high acoustofluidic forces for the manipulation of microparticles. Among other loss mechanisms related to the structural parts of acoustofluidic devices, damping in the fluid cavity is a crucial factor that limits the attainable acoustic amplitudes and therefore the effectiveness of the device. Acoustofluidic damping can be traced back to various loss mechanisms related to viscous and thermal attenuation in the bulk as well as viscous and thermal boundary layers at cavity walls or around suspended particles. However, numerical 3D simulations that include all relevant physics are prohibitively expensive. Therefore, researchers typically resort to simplified models with an estimated acoustic loss factor.
We present a way to calculate the individual components of the fluid loss factor based on the real physics. Specifically, we derive analytical and semi-analytical expressions for the loss factor due to viscous and thermal boundary layers at the cavity walls or around suspended particles. Our results and the validity the physical assumptions we make in the derivation are carefully verified by analytical and numerical reference solutions.
For the first time, accurate 3D device simulations become numerically feasible since the boundary layers do not have to be resolved. This is demonstrated by fitting the derived fluid loss factors into the framework of classical linear acoustics to build a numerically efficient 3D device model that allows the realistic prediction of pressure amplitudes. In this sense, our work represents the missing link that will allow to make not only qualitative but also quantitative predictions of acoustofluidic forces in realistic 3D devices.

Tue 16:30 Esplanade Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" IV

Generation of Complex, Dynamic Temperature Gradients in a Disposable Microchip – (Contributed, 000147)

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Temperature gradient (TG) has demonstrated the crucial importance in many applications. However, the TG generation systems to date are not capable of making dynamic profiles in a disposable platform. In addition, these systems fail to localize the temperature control, hampering the integration of multiple functionalities on a single chip. Here we introduce an easy-to-fabricate, transparent, and disposable system for the generation of complex, dynamic TG. The heating mechanism resorts to effective acoustic absorption of polydimethylsiloxane (PDMS) under high frequency (∼MHz) vibrations. In order to generate mechanical waves and couple them with the PDMS microchip, a conventional surface acoustic wave (SAW) system was employed. The key idea is to place a PDMS microchip right on top of a slanted interdigital transducer (s-IDT). We can localize the heating of PDMS by selectively actuating portions of IDT fingers. Alternating current electronic signals having frequencies matching with the IDT finger gaps are applied for the actuation. We created TGs throughout a thin layer of PDMS, which in turn formed TGs in the gas right above the PDMS. Linear, Gaussian, and bimodal profiles of TG with temperature ranging from 40°C to 90°C were successfully created. Dynamic transitions between different profiles were accomplished in less than 30 sec. Nonlinear temperature gradients in rhodamine B solution was also made in a similar fashion. Temperature distribution of the liquid in microchannels was measured based on the calibration curve between fluorescence intensity and temperature. For future work, we plan to perform one-shot DNA melting curve measurements.

Tue 16:45 Esplanade Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" IV

Optimal design of silicon-based chips for piezo-induced ultrasound resonances in embedded microchannels – (Contributed, 000213)

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Acoustophoretic devices represent an efficient and easy-to-set-up method for the manipulation of biological samples. Despite these advantages, the identification of optimal working conditions is yet entrusted with the presence of the operator, who has to search manually for resonance states that afterwards can be tracked by the aid of electric measurements.
In a theoretical study based on variational principles, we introduce indicators enabling efficient identification by numerical analysis of ultrasound resonances and optimal working conditions for acoustophoresis in microchannels embedded in silicon-based devices driven by piezoelectric actuators. We combine standard theory for elasticity, pressure acoustics, and piezoelectricity with the Lagrangian and Hamiltonian formalism, and implement it in weak form in subsequent finite element method simulations.
We study numerically the response of the system as a function of actuation frequency, and we investigate the dependency of the acoustic power of material parameters and geometry. The results are used to discuss the reliability and robustness of the introduced resonance indicators. Some interesting features of the numerical model in the context of breaking the symmetry for the chip/piezo structure are addressed. The present work represents a first attempt of introducing rigorous quantitative indicators to be used for quality assessments of acoustic resonances by external measurements.

Tue 17:00 Esplanade Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" IV

Surface acoustic wave controlled integrated band-pass filter – (Contributed, 000368)

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We introduce a microfluidic band-pass filter for particles, that is fully integrated in a polydimethylsiloxane (PDMS) based microchannel device. This acoustic filter allows a continuous and label-free separation of particles. To demonstrate the functionality, mixtures of particles with different sizes are exposed to propagating surface acoustic waves (PSAWs) generated by two laterally displaced interdigitated transducers (IDTs), one on each side of the microchannel. Dependent on the frequency used a specific size or even a size range of particles can be extracted. We sort particles of sizes of ∼1-10 μm and estimate the size resolution to be smaller than Δr< 0.88 μm. We examine the performance of the device and achieve a throughput of ∼ 10ˆ 5 particles/s with an efficiency as high as 99%.

Tue 17:15 Esplanade — Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" IV

Analysis of a Non-resonant Ultrasonic Levitation Device – (Contributed, 000280)

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A typical ultrasonic levitator is a resonant device and basically consists of an ultrasonic transducer and a reflector. When the separation distance between the transducer and the reflector is adjusted to a multiple of half- wavelength, a standing wave field is established, allowing the levitation of small particles at the pressure nodes of the standing wave. If this distance is adjusted outside the resonance, the pressure amplitude of the standing wave decreases considerably, and the levitating particle cannot be sustained by the acoustic radiation force. In this study, a non-resonant configuration of ultrasonic levitation device is presented, which is formed by a small diameter ultrasonic transducer and a concave reflector. The influence of each levitator parameter on the levitation performance is investigated by using a numerical model that combines the Gor'kov theory with a matrix method based on the Rayleigh integral. The matrix method is used to determine the pressure and velocity distributions in the air gap between the transducer and the reflector. Then, the pressure and velocity distributions are used in the Gor'kov equation to obtain the potential of the acoustic radiation force that acts on the levitated particle. The numerical simulations show that the standing wave is mainly formed by the superposition of two counter-propagating traveling waves: the emitted wave produced by the transducer and the reflected wave by the reflector. Due to the small transducer radius, high-order reflections are rapidly spread into the surrounding medium. This particular characteristic allows the separation distance between the transducer and the reflector to be adjusted continually, without requiring the separation distance to be set to a multiple of half-wavelength. It is also demonstrated that the levitating particle can be manipulated by maintaining the transducer in a fixed position in space and moving the reflector in respect to the transducer.

Tue 17:30 Esplanade — Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" IV

Optimisation of an acoustic resonator for particle manipulation in air – (Contributed, 000029)

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Advances in micro-electromechanical systems (MEMS) technology and biomedical research necessitate micromachined manipulators to capture, handle and position delicate micron-sized particles, including airborne particles and pathogens. To this end, a parallel plate acoustic resonator system has been investigated for the purposes of manipulation and entrapment of micron sized particles in air. Numerical and finite element modelling was performed to aid the design of the acoustic resonator system which consists of 3 layers, namely the piezoelectric substrate, a matching layer and the air gap. The matching layer is introduced into the system to enhance the acoustic energy transmission from the piezoelectric substrate into the air gap. In order to obtain an optimised resonator design, careful considerations of the effect of thickness and material properties are required. It is found that at realistic specific acoustic impedance values accommodating for individual layer material quality factors, the thickness of each layer plays a larger role as compared to the material properties which has a minimal influence on the transmission of acoustic energy. Furthermore, the effect of acoustic attenuation which is dependent on frequency is also considered within this study. For the purposes of meaningful comparison, a constant energy density input scenario is considered, leading to an optimum operational frequency range. This frequency range is dependent on the size of the system considered owing to the fact that it is an open ended system and energy losses in terms of

diffraction also plays a role. Finally, experimental results demonstrated good particle levitation and capture of various particle properties and sizes ranging to as small as 14.8 μm.

Tue 17:45 Esplanade Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" IV

Measurement of 3D-forces on a micro particle in acoustofluidic devices using an optical trap – (Contributed, 000375)

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Spatial acoustic manipulation of objects within fluids and fluid-like materials is of fundamental importance in various fields of ongoing-research and application. The expanding ability to manipulate objects, like solid particles, functionalized beads, cells, etc., has strongly contributed to advances in material science, life science and biophysical research.
The effects of ultrasonic standing waves on spherical objects have been described analytically and numerical models help to predict the acoustic pressure distribution in real acoustic devices. Barnkob *et al.* (Lab Chip,2010,**10**,563) showed that it is also possible to experimentally predict the local acoustic pressure amplitudes by particle tracking and a subsequent fitting to a theoretical model. Here we present a method to *directly* measure the total time-averaged force on a dielectric silica particle in the regime of an ultrasonic standing wave.
The particles are strongly diluted in water and a calibrated single-beam gradient laser trap holds one single particle (0.5-10μm) at a specified position within a micro channel. The piezoelectrically excited acoustic standing wave is scattered by the particle and leads to an acoustic radiation force or causes acoustic streaming. Both effects displace the optically trapped particle. We monitor the displacement of the particle from the trap center in three dimensions and subsequently calculate the forces (0.2-50pN) in dependence of the particle position and excitation frequency. From the obtained quantitative data we were e.g. able to determine the real pressure distributions within acoustofluidic devices.
The two dimensional case was investigated by Lakämper *et al.* (Lab Chip,2015,**15**,290) and the derived data correspond exquisitely well with the theory and previous modeling. The three dimensional direct measurement as presented here opens up the possibility to quantify so far inaccessible small scale phenomena such as a.) the effects of local and global acoustic streaming, b.) effects of boundaries or close by objects.

Tue 16:00 Saint Pierre Cardiovascular ultrasound image and signal analysis: a powerful tool toward valid, non-invasive and low-cost disease diagnosis

Imaging the Mechanical and Electromechanical Strain of the Myocardium In Vivo – (Invited, 000480)

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Cardiovascular diseases remain America's primary killer by a large margin, claiming the lives of more Americans than the next two main causes of death combined (cancer and pulmonary complications). In particular, coronary artery disease (CAD) is by far the most lethal, causing 17% of all (cardiac-related or not) deaths every year. The latest findings using the techniques developed by our group, Myocardial Elastography and Electromechanical Wave Imaging, will be presented. Myocardial Elastography benefits from the development of techniques that can be used for high precision 2D time-shift based strain estimation and higher frame rates to obtain a detailed map of the intrinsic transmural strain in normal and pathological cases over different cardiac phases and cycles. In animal studies, Myocardial Elastography has been shown to detect and localize myocardial strain abnormalities resulting from 40% or higher coronary flow reduction. In clinical studies, coronary territories in patients with non-severe (<50%) or severe (>50%) stenoses was localized and corroborated by CT angiography. False positives by nuclear stress testing were also detected using Myocardial Elastography (at a rate of 16%) confirmed with invasive techniques (CT angiography). Electromechanical Wave Imaging (EWI) has been shown capable of noninvasively mapping the spontaneously occurring conduction wave during propagation across all four cardiac chambers in vivo. Validation with electroanatomic mapping showed good correlation of EWI with electrophysiological recordings in canines in vivo. In patients, origins of atrial flutter and atrial fibrillation were localized using isochrones and the electromechcanical wave speeds quantified while in Cardiac Resynchronization Therapy (CRT), the responders were successfully differentiated from non-responders based on their EWI activation timings. Given that all aforementioned techniques can be easily integrated in standard ultrasound scanners, they stand to make an important impact in the diagnosis and treatment of cardiovascular disease in the clinic.

Tue 16:30 Saint Pierre Cardiovascular ultrasound image and signal analysis: a powerful tool toward valid, non-invasive and low-cost disease diagnosis

4D Ultrafast ultrasound imaging of the heart: towards non invasive quantification of myocardial stiffness – (Invited, 000565)

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Cardiac pathologies are often characterized by a significant change of myocardial stiffness, re-organization of muscle fiber structure, and the accompanying dysfunction, all of which remain challenging to be quantitatively assessed in vivo. Ultrafast imaging is a novel ultrasonic imaging approach developed at Institut Langevin that provides images of the heart at thousands of images/s. Based on ultrafast imaging, Shear Wave Imaging (SWI) was developed to provides real-time mapping of myocardial viscoelastic properties. The technique relies on two successive steps: first, a shear wave is remotely induced in the myocardium using the acoustic radiation force of a focused beam, and second, the shear wave propagation is imaged using ultrafast imaging (10,000 images per seconds). The shear modulus is derived from the shear wave speed. SWI is applied to the evaluation of myocardial stiffness on animal models of cardiomyopathy. The dynamics of change in shear modulus during the cardiac cycle is measured and the relationship between the viscoelastic properties and physiological parameters such as contractility in normal and infarcted myocardium is investigated. In addition, the myocardial fiber orientation can be mapped by exploiting the anisotropy of shear wave propagation. Finally, a novel 4D ultrafast imaging platform is developed to provide thousands of volumes per second of the heart. Ultrafast imaging as well as SWI are performed in vivo in 4D using a single acquisition performed during one cardiac cycle.

Tue 17:00 Saint Pierre Cardiovascular ultrasound image and signal analysis: a powerful tool toward valid, non-invasive and low-cost disease diagnosis

The role of multiphysics modeling in establishing a robust ultrasound-based cardiovascular risk assessment – (Invited, 000575)

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Arterial stiffness has proven to be a powerful, early marker of cardiovascular diseases, with prognostic value beyond the classical risk factors like smoking, high blood pressure, cholesterol,... However, local evaluation of arterial stiffness remains technically challenging despite a wide range of non-invasive, ultrasound-based techniques developed for this purpose. Hence, we have been investigating the performance of ultrasonic measurement strategies for arterial stiffness, both from a biomechanical and image acquisition perspective. In particular, we have been studying direct tissue characterization techniques as well as strategies to locally assess the arterial pulse wave velocity (PWV), i.e. the propagation speed of the arterial pulse created by the cardiac contraction as it travels through the cardiovascular network. The former class of techniques refers to our investigation of shear wave elastography, assessing tissue stiffness by tracking shear waves artificially evoked in the tissue via the acoustic energy of an ultrasound probe. Local PWV can be non-invasively assessed in multiple ways, e.g. as the slope of the arterial diameter (ln(D)) versus blood velocity (U) signal in early systole via ultrasonic wall tracking (D) and Doppler (U) techniques.
However, previously mentioned measurement strategies are hampered in the presence of intricate vascular anatomy or tissue mechanics, inducing complex pulse/shear wave phenomena, erroneously affecting stiffness assessment. Hence, we developed a computer modeling platform for indepth investigation and validation of these measurement strategies, allowing comparison of the simulated measurement outcome with the true tissue properties, fully defined in the simulation but typically lacking during in-vitro/invivo evaluation. Hence, this is a multi-physics model, integrating both the biomechanics and imaging, which has allowed us to analyze arterial stiffness assessment techniques in varying biomechanical conditions as well as to investigate new imaging approaches and signal processing.

Tue 17:30 Saint Pierre Cardiovascular ultrasound image and signal analysis: a powerful tool toward valid, non-invasive and low-cost disease diagnosis

Automatic emboli detection system for the artificial heart – (Contributed, 000362)

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In spite of the progress in material engineering and ventricular assist devices construction, thromboembolism remains the most crucial problem in mechanical heart supporting systems. Therefore, the ability to monitor the patient's blood for clot formation should be considered an important factor in development of heart supporting systems. The well-known methods for automatic embolus detection are based on the monitoring of the ultrasound Doppler signal. A working system utilizing ultrasound Doppler is being developed for the purpose of flow estimation and emboli detection in the clinical artificial heart ReligaHeart EXT. The system will be based on the existing dual channel multi-gate Doppler device with RF digital processing. A specially developed clamp-on cannula probe, equipped with 2-4MHz piezoceramic transducers, enables easy system setup. We present the issues related to the development of automatic emboli detection via Doppler measurements. We consider several algorithms for the flow estimation and emboli detection. We discuss their efficiency and confront them with the requirements of our experimental setup. Theoretical considerations are then met with preliminary experimental findings from a) flow studies with blood mimicking fluid and b) in-vitro flow studies with animal blood. Finally, we discuss some more methodological issues - we consider several possible approaches to the problem of verification of the accuracy of the detection system.

Tue 17:45 Saint Pierre Cardiovascular ultrasound image and signal analysis: a powerful tool toward valid, non-invasive and low-cost disease diagnosis

Ultrasound-image-based texture variability along the carotid artery wall in asymptomatic subjects with low and high stenosis degrees: unveiling morphological phenomena of the vulnerable tissue – (Contributed, 000452)

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Motivation: Valid identification of the vulnerable asymptomatic carotid atherosclerosis remains a crucial clinical issue. In this study, texture differences were estimated along the atherosclerotic arterial wall, namely at the plaque, the wall adjacent to it and the plaque shoulder, i.e. the boundary between wall and plaque, in an attempt to reveal morphological phenomena, representative of the high stenosis (considered vulnerable) cases. Methods: A total of 25 arteries were interrogated, 11 with low (50-69%) and 14 with high (70-100%) degrees of stenosis. The two groups had similar ages. Texture features were estimated from B-mode ultrasound images, and included four second-order statistical parameters (contrast, correlation, energy and homogeneity), each calculated at four different image directions (00, 450, 900, 1350), yielding a total of 16 features. Texture differences between (a) wall and plaque and (b) wall and plaque shoulder were quantified as the differences in texture feature values for each tissue area normalised by the texture feature value of the wall, which was considered as reference, as illustrated in the following equation: dTFi = (TFi,W - TFi,P/S)/TFi,W, where dTFi the estimated texture difference, TFi,W the texture of the wall, and TFi,P/S the texture of the plaque (P) or the shoulder (S). Results: Significant differences in texture variability of wall vs. shoulder were observed between high and low stenosis cases for 3 features at diastole and 7 features at systole. No differences were observed for wall vs plaque, although wall texture was significantly different than plaque texture, in absolute values. These findings suggest that texture variability along the atherosclerotic wall, which is indicative of tissue discontinuities, and proneness to rupture, can be quantitatively described with texture indices and reveal valuable morphological phenomena of the vulnerable tissue.

Tue 18:00 Saint Pierre Cardiovascular ultrasound image and signal analysis: a powerful tool toward valid, non-invasive and low-cost disease diagnosis

Simultaneous Measurement of Breathing and Heartbeat Using Airborne Ultrasound in a Standing Position – (Contributed, 000103)

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Acoustic measurement in air has great potential to obtain various types of information about objects in a wide range, such as their position, shape, and movement. Because of a growing need for non-contact medical monitoring for unobtrusively observing individuals at home, we have been studying about non-contact measurement of vital information such as respiration and heart rates. There are some techniques to measure the displacement of the target from the time of flight (TOF) of the reflected signal. The time resolution of measurement using TOF determination from the amplitude of the waveform depends on the sampling period of the system. Therefore, the accuracy is not enough to measure small body-surface displacement such as heartbeat because the displacement is extremely small. Furthermore, improvement of the signal- to-noise ratio (SNR) of the reflected signal is also required. In previous papers, we have proposed the measurement system of small displacement using phase differences of reflected signals from the target. In the proposed system, the M-sequence-modulated signal was used to improve SNRs of reflected signals. The displacement of the target was measured from phase differences between temporally adjacent reflected signals. Tracking phase difference is expected to enable measurement of the displacement much smaller than the wavelength. Furthermore, we also try to measure body surface displacement by breathing and heartbeat using the proposed system under situations that the standing volunteer is breathing and holding the breath, respectively.

In this paper, we describe simultaneous measurement of breathing volunteer in a supine position using the proposed method. We try to divide into displacements by breathing and heartbeat from the displacement of the volunteer who is breathing. To divide each displacement, window functions whose central frequencies correspond to respiration and heart rates are employed. The measurement in the standing position is also performed.

Tue 10:30 Citadelle 1 Device technology: arrays and imaging

Evaluation of the side lobe level properties of 1-3 and 2-2 piezocomposite sonar transducers with printed triangular shape electrodes in comparison to a conventional transducer comprising six PZT bars with analogue network – (Contributed, 000468)

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In a sonar line array the side lobes in the horizontal direction are controlled (reduced) using signal processing, while in the vertical direction are determined by the transducer design. Conventionally, this is done by using a transducer comprising discrete PZT bars spaced vertically and an analogue electronics network to apply different amplitudes to the bars. In this paper we present such a transducer comprising six PZT bars with its analogue network to produce a triangular shading (-26 dB main / side lobe level) and compare its performance to transducers made of 1-3 and 2-2 piezocomposite materials with printed triangular shape electrodes. All transducers were designed to resonate around 400 kHz. The measured receiving frequency response and polar directivity responses of the three transducers (including networks) will be presented and compared to the theoretical simulations. The results obtained showed significant improvement to the main lobe to side lobe ratio with both 1-3 and 2-2 piezoelectric based transducers. The transducers made with 1-3 piezocomposite material also achieved higher receiving response level. The fabrication of the 1-3 and 2-2 piezocomposite transducers with the printed electrodes also proved to be simpler and more cost effective.

Tue 10:45 Citadelle 1 Device technology: arrays and imaging

Volumetric security alarm based on a spherical ultrasonic transducer array – (Contributed, 000005)

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Most of the existent alarm systems depend on physical or visual contact. The detection area is often limited depending on the type of the transducer, creating blind spots. Our proposition is a truly volumetric alarm system that can detect any movement in the intrusion area, based on monitoring the change over time of the impulse response of the room, which acts as an acoustic footprint. The device depends on an omnidirectional ultrasonic transducer array emitting sweep signals to calculate the impulse response in short intervals. Any change in the room conditions is monitored through a correlation function. The sensitivity of the alarm to different objects and different environments depends on the sweep duration, sweep bandwidth, and sweep interval. Successful detection of intrusions also depends on the size of the monitoring area and requires an adjustment of emitted ultrasound power. Strong air flow affects the performance of the alarm. A method for separating moving objects from strong air flow is devised using an adaptive thresholding on the correlation function involving a series of impulse response measurements. The alarm system can be also used for fire detection since air flow sourced from heating objects differ from random nature of the present air flow. Several measurements are made to test the integrity of the alarm in rooms sizing from 834- 2080 m^3 with irregular geometries and various objects. The proposed system can efficiently detect intrusion whilst adequate emitting power is provided.

Tue 11:00 Citadelle 1 Device technology: arrays and imaging

A Non-Expensive Massive Ultrasonic Array to Generate Helical Wavefronts in Air – (Contributed, 000269)

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Helical wavefronts exhibit interesting properties such as: a) a self- reconstruction capability when partially occluded, b)an annular pressure distribution (doughnut-like) with zero pressure along its principal axis and c) the ability to transport angular momentum. Also, the potential of application of this type of wavefront has already been reported, i.e. particle manipulation, robust communication, alignment devices, among others. Even though several applications have been reported in optics, little research has been carried out in acoustics and much less in air at ultrasonic frequencies. In view of this, we present experimental characterization results of a non- expensive massive ultrasonic transducer array to generate helical wavefronts in air. The multitransducer is composed by 390 elements operating at a nominal frequency of 40 kHz, precisely located on a helical surface substrate. The same excitation signal is applied to all elements. Due to the "spatial" delay applied to each element, the device is able to generate a helical wavefront of topological charge m =+1. A maximum sound pressure level of 127 dB was measured, on a transverse plane located 1.8 m far from the device, when a 15 Vpp excitation voltage was applied. This work also includes a detailed description of the excitation electronics, the electroacoustic characterization of the array elements (phase, directivity and frequency response) and the inter-element cross-talk quantification. Furthermore, a discussion of the potential of use of this multitransducer device is presented.

Tue 11:15 Citadelle 1 Device technology: arrays and imaging

Ultrasound thermometry for optimizing heat supply during a hyperthermia therapy of cancer tissue – (Contributed, 000060)

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Monitoring the temperature during a hyperthermia therapy allows optimizing the heat supply to destroy the cancer whereby the damage in the surrounding tissue is minimized. This contribution presents the fundamental research and current work to realize a locally resolved, noninvasive and intra-surgically applicable temperature measurement in tissue. This is realized by measuring the sound velocity locally resolved by an annular array, which allows noninvasive measurements although the observed tissue is not accessible from all directions. The method had been already qualified for fluids [] and analyses the echoes of moving scattering particles to obtain the time of flight to the focus of the transducer. As the parameters of the transducer are known the focus position (and thus the time of flight) can be calculated as a function of the sound velocity distribution of the propagation medium. Thus the measured time of flight allows determining the focus position and mean sound velocity simultaneously by means of this function. Varying the time lags of the signals for each element allows moving the focus and so measuring locally resolved. This contribution presents first ex-vivo measurements in tissue and thus proves the adaptability of this technique for tissue.

Tue 11:30 Citadelle 1 Device technology: arrays and imaging

Mobile Ultrasound Plane Wave Beamforming on iPhone or iPad using Metal- based GPU processing – (Contributed, 000042)

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Motivation: Mobile and cost effective ultrasound devices are being used in point of care scenarios or the drama room. To reduce the costs of such devices we already presented the possibilities of consumer devices like the Apple iPad for full signal processing of raw data for ultrasound image generation. Emerging technologies like ultrafast ultrasound imaging result in new algorithms for example for shearwave elastography or vector velocity imaging but also enable the creation of a full image with only one excitation/reception event based on plane wave imaging. This way acquisition times and power consumption of ultrasound imaging can be reduced for low power mobile devices based on consumer electronics realizing the transition from FPGA or ASIC based beamforming into more flexible software beamforming.
Methods: Software based beamforming is usually performed on a GPU utilizing massive parallel processing (like CUDA or OpenCL) but with the development of modern processors (A7, A8 and A8X) for its smartphones and tablets Apple introduced parallel GPU hardware and the framework "Metal" for advanced graphics and general purpose GPU processing for the iOS platform. We use it for medical signal reconstruction in the mobile plane wave beamforming and imaging on ultrasound channel data sets measured with our research systems "DiPhAS" in ultrafast imaging mode.
Results: We were able to integrate the beamforming reconstruction into our mobile ultrasound processing application on the iOS platform. The next step into realizing a mobile, fully software based ultrasound system was made. The beamforming can be performed at 20 Hz providing real time imaging including the postprocessing of beamformed data into images (envelope detection and scan conversion). The solution can also include plane wave compounding in the future to realize a high quality imaging system with Wifi transfer of measurement data to commercially available tablets or smartphones with software beamforming.

Tue 11:45 Citadelle 1 Device technology: arrays and imaging

Preliminary use of ultrasonic tomography measurement to map tree roots growing in earth dikes – (Contributed, 000413)

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The aim is to elaborate non-destructive methods able to localize and map tree roots system, recognized as an environmental hazard when growing in hydraulic earth structures. Low frequency ultrasonic prospecting method has been used widely as a non destructive technique to assess wood properties, for instance to identify decays of tree stem.

Although complex, wood materials properties are well known. In contrast with soil which is fairly transparent to low frequency ultrasound, wood conducts ultrasound more efficiently. These properties motivated RINNTECH® to suggest a stress wave tomography methodology for mapping tree roots system with a special positioning of the receiver sensor directly on the trunk. The technique relies on measuring the travel time between two sensors respectively a mobile source defining a mesh all around the tree and fixed receivers on the tree stem.

In each following experiment, we studied spectral properties of propagation with wavelet processing method as an additional parameter for the discrimination of the root in the surrounding.
Our work has been first initiated during laboratory experiment with an ultrasonic transmission device to demonstrate relative differences between samples of soil and roots. The measurements were repeated to ensure statistical interpretation. An intermediate state device reproducing in-situ measurement in laboratory was performed at the soil surface in two plastics tanks containers one control of bare soil and another containing a root sample burried in homogeneous soil. Finally we reproduced RINNTECH® methodology in the field. Results from soil excavation will be soon compared to those obtained with tomography.
We shown with laboratory experiments that information provides by the velocity term seems relevant to localize roots in the soil. Unfortunately the signal at very low frequency is noisy and prevents an easy interpretation of spectral properties. Therefore efforts should be done for offers a better understanding of spectral properties.

Tue 10:30 ESAL 2 Physical acoustics: Inverse problem

Numerical Study of Mode Waves in a Deviated Borehole Penetrating a Transversely Isotropic Formation – (Contributed, 000038)

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A 2.5 dimensional method is developed to investigate the mode waves in a deviated borehole penetrating a transversely isotropic formation. The phase velocity dispersion curves of the fast and slow flexural mode waves excited by a dipole source are computed accurately at different deviation angles for both hard and soft formation. The sensitivity of flexural waves to all the five elastic constants are calculated. Numerical results show that for a soft formation, the fast flexural mode wave is dominated by C66 at high deviation angles and low frequencies, the slow flexural mode wave is dominated by C44 at the same condition. An inversion procedure is presented to prove the sensitivity analysis.

Tue 10:45 ESAL 2 Physical acoustics: Inverse problem

Curing and post-curing viscoelastic monitoring of an epoxy resin – (Contributed, 000039)

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This paper describes the monitoring of ultrasonic parameters of a thermosetting resin during an isothermal curing process. The ultrasonic properties are studied within the context of the monitoring of composite plate production by resin transfer molding (RTM). An experimental setup has been developed for the monitoring of ultrasonic parameters during polymerization. A monitoring of the phase transformation based on the ultrasonic measurement of the elastic constant and associated mechanical loss has been developed. An analytical approach is proposed based on the modeling of the elastic constant fitted by a (λ, k) Weibull distribution. The influence of the set-point temperature T on the ultrasonic parameters was investigated. The Debye series modeling (DSM) of the three layered structure allows to validate this approach when it is compared with experimental results. The ultrasonic monitoring of the cured epoxy is also performed after curing in order to study the temperature sensitivity and identify to glass transition temperature (T_g) compared with DSC measurements. The temperature sensitivity of the viscoelastic properties of the cured epoxy is estimated through the frequency dependence of the ultrasonic parameters. As a result, an approximated analytic frequency-temperature (f, T) model is proposed and fitted both for the attenuation and velocity frequency dispersions and temperature sensitivities.

Tue 11:00 ESAL 2 Physical acoustics: Inverse problem

Characterization of acoustical properties of a phantom for soft tissues (PVCP and graphite powder) in the range 20-45°C – (Contributed, 000274)

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Stability and duration of ultrasonic (US) Phantoms are still a subject of research. We present a study of acoustic and mechanical properties for polyvinyl chloride plastisol (PVCP) with graphite powder (at 2% in weight) used to construct tissue-like phantoms in the temperature range of 20-45°C. PVCP is a new material in the field of US phantoms and has longer duration and stability than the conventional organic mimicking materials. Longitudinal US velocity and attenuation were measured at 1 MHz by the standard transmission method. Shear velocity was obtained by 1-D transient elastography. The extreme values for each of the parameters were obtained at 20°C and 45°C. They are: 1501.5±0.7 m.s^{-1} and 1331.8±0.3 m.s^{-1} for longitudinal US velocity; 0.46±0.03 dB.cm^{-1} and 0.94±0.09 dB.cm^{-1} for attenuation; and 8.4±1.2 m.s^{-1} and 1.7±0.8 m.s^{-1} for Shear velocity. Specific heat measured with a calorimeter and thermal conductivity measured by the method of hot plates were, respectively, 2.65±0.51 J.(kg.°C) $^{-1}$ and 0.091±0.013J.(s.°C.m)$^{-1}$, both at 22°C. For 2% of graphite powder, the parameter ranges were compatible to biological tissue ones and therefore, the same phantom can simulate different conditions only by changing its temperature. Other graphite percentages are to be tested to simulate parameter values of pathological conditions like nodules, calcification, fibrosis, etc. The phantom did not suffer from dehydration and is easy to be built in several different geometries.

Tue 11:15 ESAL 2 Physical acoustics: Inverse problem

Marble ageing characterization by acoustic waves – (Contributed, 000400)

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In cultural heritage, statue marble characterization by acoustic waves is a well-known non-destructive method. Such investigations through the statues by time of flight method (TOF) point out sound speeds decrease with ageing. However for outdoor stored statues as the ones in the gardens of Chateau de Versailles, ageing affects mainly the surface of the Carrara marble. The present paper proposes an experimental study of the marble acoustic properties variations during accelerated laboratory ageing.
The surface degradation of the marble is reproduced in laboratory for 29mm thick marble samples by using heating/cooling thermal cycles on one face of a marble plate. Acoustic waves are generated by 1 MHz central frequency contact transducers excited by a voltage pulse placed on both sides of the plate. During the ageing and by using ad hoc transducers, the marble samples are characterized in transmission, along their volume by shear, compressional TOF measurements and along their surface by Rayleigh waves measurements. For Rayleigh waves, both TOF by transducers and laser vibrometry methods are used to detect the Rayleigh wave. The transmission measurements point out a deep decrease of the waves speeds in conjunction with a dramatic decrease of the maximum frequency transmitted. The marble acts as a low pass filter whose characteristic frequency cut decreases with ageing. This pattern occurs also for the Rayleigh wave surface measurements. The speed change in conjunction with the bandwidth translation is shown to be correlated to the material de-structuration during ageing. With a similar behavior but reversed in time, the same king of phenomena have been observed trough sol-gel materials during their structuration from liquid to solid state (Martinez, L. et all (2004). "Chirp-Z analysis for sol-gel transition monitoring". Ultrasonics, 42(1), 507-510.). A model is proposed to interpret the acoustical measurements.

Tue 11:30 ESAL 2 Physical acoustics: Inverse problem

Evaluation Of General Anisotropic Elasticity By Resonant Ultrasonic Spectroscopy And Surface Acoustic Wave Methods – (Contributed, 000404)

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Exact knowledge of the elastic coefficients of low-symmetry materials or materials with unknown elastic anisotropy (e.g. polycrystalline materials with complex microstructure) is important not only with respect to their further engineering applications, but also contribute to deeper understanding of material mechanics and development of theoretical tools for prediction of such properties (e.g. ab-initio calculation in single crystals, homogenizations in polycrystals). However, experimental methods that allow to determine full elastic tensor on a simple material specimen are still very rare. In this contribution, we present an approach for the determination of elastic coefficients of materials with unknown symmetry class and unknown orientation of the principal axes of this symmetry class. The proposed method utilizes laser-based contactless resonant ultrasound spectroscopy (RUS), including modal analysis of a simple-shaped small specimen [1]. The same theoretical framework (the Rayleigh-Ritz method) as for the RUS method can be also used for a mathematical model of surface acoustic waves (SAW) propagation in general directions on an surface of anisotropic media. This approach is applied for elasticity evaluation from angular scans of SAW velocities, performed on arbitrary cuts [2]. The similarity between the SAW and RUS forward and inverse problems is discussed and their applicability is shown on experimental examples.
[1]P. Sedlák, H. Seiner, J. Zídek, M. Janovská, M. Landa. Experimental Mechanics, 54 (2014) 1073-1085. [2]P. Stoklasová, P. Sedlák, H. Seiner, M. Landa, Ultrasonics 56 (2015) 381-389.

Tue 11:45 ESAL 2 Physical acoustics: Inverse problem

Non-contact Ultrasonic Techniques for Characterisation of Membranes and Single Crystals – (Contributed, 000446)

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Non-contact ultrasonic techniques using, for example, electromagnetic acoustic transducers (EMATs) and/or laser ultrasonic techniques, are starting to see applications in materials characterisation. Research has shown that determination of elastic constants, ultrasonic attenuation, and phase transitions (e.g. magnetic or structural) is possible using EMATs, with the lack of contact giving many benefits to the measurements. Similarly, it is possible to measure vibrations of very thin films using laser interferometry, without disturbing the vibration patterns. We present measurements in these two areas, illustrating the use of EMATs through phase transition measurements obtained on a set of magnetic rare-earth alloys ($Gd_xSc_{(1-x)}$). An analysis system has been developed using LabVIEW to perform time-frequency analysis and improve accuracy of the results. Laser interferometry vibration measurements are demonstrated for Ge membranes of various thicknesses, giving mechanical properties such as Q-factors, tensile stress, anisotropy, and robustness to shock. The benefits of non-contact measurement techniques are shown to overcome their drawback of reduced efficiency, for certain measurement situations.

Tue 12:00 ESAL 2 Physical acoustics: Inverse problem

Ultrasonic properties of the hexagonal boron nitride nanotubes – (Contributed, 000012)

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Using Lennard-Jones potential model, we have evaluated higher order elastic constants of hexagonal boron nitride (h-BN) nanotubes at room temperature. The temperature variation of the ultrasonic velocities is evaluated along different angles with unique axis of the crystal using the second order elastic constants. The ultrasonic velocity decreases with the temperature along particular orientation with the unique axis of crystals. Temperature variation of the thermal relaxation time and Debye average velocities is also calculated along the same orientation. The temperature dependency of the ultrasonic properties is discussed in correlation with elastic, thermal and electrical properties. It has been found that the thermal conductivity is the main contributor to the behaviour of ultrasonic attenuation as a function of temperature and the responsible cause of attenuation is phonon-phonon interaction. The mechanical properties of hexagonal boron nitride nanotubes at low temperature (100K) are better than at room temperature, because at low temperature it has low ultrasonic velocity and ultrasonic attenuation. Boron nitride nanotubes could serve as electrically insulating yet highly thermally conducting wires, efficiently removing heat locally and piping it away via nanotube-based phonon waveguides.

Tue 13:45 Citadelle 1 Device technology: energy harvesting, micro-devices and multiphysics

Analysis and optimization of piezoelectric energy harvesting on a car damper – (Contributed, 000440)

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With the increasing use of remote sensors embedded in the vehicles, one of the primary challenges is to propose potential clean sources for powering them. In this study, the aim is to design and analyse piezoelectric vibration harvesters located in a vehicle suspension for powering standalone systems, such as wireless transducers. The main advantage of using ambient energy converted by piezoelectric materials instead of batteries is to enable the decrease of the system size without changing the suspension behavior. Furthermore, ambient vibrations that are harvested and converted would be normally dissipated as heat in the mechanical parts of the suspension. As the piezoelectric conversion level according to the mechanical excitation is around some milliwatt for a piezoelectric transducer bonded onto the structure, the development of an associated low power electronics adapted to the piezoelectric characteristics is essential for the energy harvesting.

To obtain optimal configurations of our vibration-powered generators, an innovative approach based on Bond Graph modeling of the piezoelectric vibration harvester inside the vehicule suspension is presented and used to compare the performances of various piezoelectric ceramics associated with different power conditioning circuits. This model provides the voltage response of the harvester as well as the power estimation due to a mechanical excitation, i.e. vibrations which are usually available on a damping system

for vehicles. It shows that up to 0.5 milliwatt electrical power is harvested using such autonomous devices and this power could be easily optimized by varying key parameters of the harvester which are the location, the choice of material piezoelectric and the optimization strategy management and storage of recovered energy.

Tue 14:00 Citadelle 1 Device technology: energy harvesting, micro-devices and multiphysics

Magnetic Stoppers on Single Beam Piezoelectric Energy Harvesting – (Contributed, 000599)

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The single beam structure has been long used in piezoelectric energy harvesting to harvest the vibrations of the circumstances. One of the critical defects of the structure is its narrow band of operating frequency. Many propose mechanical stoppers, rigid or non-rigid, such as another beam, to create a non-linear broad band effect. Moreover, with a piecewise linear PEG (Piezoelectric Energy Generator) , or a simple cantilever beam with one or two mechanical stoppers laid on its sides, the constant driven amplitude of the beam displacement can be enlarged by a perturbation. It is also proposed that the stoppers prevents the piezoelectric pad from cracking due to over deformation. However, from a long-term point of view, the impact of the beam on the stoppers can also cause faster fatigue of the beam body, not to mention the noise that will hinder its practical application which maybe apparatuses nearby human. Therefore, this paper proposes a magnetic pair to serve as the stoppers for piezoelectric beam, so as to perform similar effects of bandwidth enlargement and also the amplification using perturbation. With no actual contacts, the single beam can be well protected, but also eliminated by the magnets. The magnetic force, which is distance dependent, can provide a smoother feedback to the beam, giving a greater displacement in comparison to the mechanical stopper.

Tue 14:15 Citadelle 1 Device technology: energy harvesting, micro-devices and multiphysics

Guided wave generation in laminated elastic substrates with piezoelectrical coatings and patches – (Contributed, 000279)

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The present paper deals with two kinds of electromechanical systems: surface acoustic wave (SAW) devices based on polycrystalline diamond layers covered by piezoelectric films, and structural health monitoring systems employing piezoelectric active wafer sensors (PWAS) for guided wave (GW) generation and registration.
Diamond films are considered as attractive substrates for SAW devices operating at gigahertz frequencies because they provide the highest acoustic wave velocities. Surface and pseudo-surface (PSAW) acoustic waves generated in AlN/Diamond and AlN/Diamond/Gamma-TiAl structures by an electric interdigital transducer source are analyzed in the mathematical framework based on the Green's matrix integral representations and GW asymptotics. The attention is focused on the effect of pseudo- surface-to-surface wave degeneration at certain discrete values of the film-thickness- to-wavelength ratio. Such optimal ratios were previously discovered and experimentally verified for the first pseudo-surface (Sezawa) mode (M. Benetti et al. Appl. Phys. Letter, 2005). With the model developed, this effect has been revealed and specified for higher PSAW modes. In addition to wave characteristics, which can be obtained by a conventional modal analysis technique, this model explicitly provides the amplitude and the power intensity of waves excited by a given source, i.e. the coupling coefficients.
In the second problem, an integral equation based model of coupled PWAS-substrate elastodynamic behavior has been developed. In this framework, wave energy coming from the source into the substructure and its distribution among the excited GW modes have been studied. Numerical results demonstrating selective generation of a particular fundamental or higher GW mode are presented and discussed.

Tue 14:30 Citadelle 1 Device technology: energy harvesting, micro-devices and multiphysics

Guided acoustic wave devices with in-plane c-axis ZnO films: Experimental and theoretical studies – (Contributed, 000455)

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ZnO piezoelectric films are widely used for guided acoustic wave devices including surface acoustic wave and Lamb wave devices. In most cases, the c-axis of the ZnO film was oriented out-of-plane. On the other hand, we have fabricated in-plane c-axis ZnO films[1] on different substrates such as glass and Si. The in-plane c-axis ZnO film has unique anisotropy of elastic properties enabling to excite guided acoustic waves with high electromechanical coupling coefficient K^2. This feature is of great interest for applications based on acousto-electric, acousto-optic and magneto-acoustic interactions.
In this study, we investigated theoretically and experimentally the Lamb wave properties in in-plane c-axis ZnO films.
First, K^2 values of Lamb waves in IDT/in-plane c-axis ZnO membrane structures were theoretically analyzed. Maximum K^2 value was found to be 10.5% in the first symmetrical Lamb wave (S_0) mode. We note that this K^2 value of the in-plane structure was higher than that of the out-of-plane structure (K^2=3.3%).
Next, we fabricated IDT/in-plane c-axis ZnO membrane structures. An in-plane c-axis ZnO film (2.3 μm) was grown on a Si substrate by RF magnetron sputtering[1]. Au/Ti IDTs with the wavelength of 8 μm were fabricated on the sample so that the c-axis direction corresponded to the wave propagation direction. Then, the Si substrate was etched. The insertion loss of the membrane sample was measured by a network analyzer. An acoustic wave excitation was observed at the center frequency of 606 MHz. An analysis of the displacement field using finite element method suggestted that the mode of the acoustic wave was a S_0 mode.
For an additional application, the high frequency magneto-elastic coupling in multilayered structure including the in-plane c-axis ZnO membrane and magnetostrictive thin film can be of great interest.

[1] S. Takayanagi, et al., *Appl. Phys. Lett.*, **101**, 232902 (2012).

Tue 14:45 Citadelle 1 Device technology: energy harvesting, micro-devices and multiphysics

Optimization of high frequency acoustic reflection on 45° mirrors for lab on chip applications – (Contributed, 000234)

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During the past decades, acoustic microfluidics have been developed intensely in the emerging lab-on-a-chip-based field applications, such as flow mixing, micro- pump and micro-valve, bio-sample detection because of the advantage of non-contact mode and nondestructive effect for living cells1-3. Ultra high frequency (∼1GHz) ultrasonic bulk acoustic waves (BAW) characterization has been already integrated in a lab-on-a-chip silicon platform4,5. Thanks to the fabrication of a microsystem, the acoustic wave guided in three dimensions (3D) was achieved via 45° mirrors in a silicon wafer4, and was successfully applied for the detection of chemical solution and particles in micro-channel5. It is well known that using silicon or silica 45° mirrors, a huge amount of incident longitudinal wave would be converted into shear wave after reflection. For this purpose we need to optimize the reflection on the 45° mirrors in order to maximize the acoustic energy of the longitudinal wave which is able to cross a microfluidic channel. We have studied and compared different acoustic matching layer on the 45° mirror which can be easily realized in the technological process. We demonstrated that shear wave transfer is limited in the mode conversion and longitudinal wave transmission is efficiently strengthened using metal coating (gain factor of 8 compared to reference case without mirror coating). We characterized the S21 scattering parameter between transducer emitter and transducer receiver. The frequency bandwidth of the transmitted wave is also analyzed thanks to an inverse Fourier transform. The results are in good agreement with the simulations.

Tue 13:45 ESAL 2 Physical acoustics: Inverse problem

Ultrasonic characterization of water saturated double porosity media – (Contributed, 000063)

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Wave propagation through a multilayered structure consisting of a water saturated double porosity medium in an aluminum rectangular box immersed in water is studied. By assuming a plane incident wave from water onto the structure, the reflection and transmission coefficients are derived by application of the boundary conditions at each interface. Numerical computations are done for two particular double porosity media, ROBU® and Tobermorite 11 Å, that are assumed to obey Berryman's extension of Biot's theory [Berryman 1995, 2000]. The influence of the thickness of double porosity medium is investigated. To compare experiments to computations, two comparison coefficients C_{num} and C_{exp} are introduced. The theoretical one C_{num} is defined as the ratio of the transmission coefficient of the structure to the transmission coefficient of the box filled exclusively with water. The experimental comparison coefficient C_{exp} is defined as the ratio of the Fourier transforms of the transmitted signals by the box filled with the double porous medium to that of the transmitted signals by the box filled with water. A method of minimization based on a gradient descent algorithm is used to optimize some of the parameters of the double porosity media such as the bulk moduli.

Tue 14:00 ESAL 2 Physical acoustics: Inverse problem

Contactless Monitoring of Conductivity Changes in Vanadium Pentoxide Xerogel Layers using Surface Acoustic Waves – (Contributed, 000181)

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Nanostructured vanadium oxide compounds attract much interest due to their chemical and physical properties and their great potential for applications in chemical industry, batteries, and bolometer and microbolometer arrays for thermal imaging. The hydrated form of the vanadium pentoxide (V2O5 ·nH2O) deserves special attention due to dependence of its properties on the number of the water molecules, n. Surface acoustic wave (SAW) sensing is a powerful technique for contactless monitoring of thin layer properties. In the present paper, we report on the observation of strong acoustoelectric interaction in V2O5 ·nH2O layers deposited on piezoelectric YZ lithium niobate (LiNbO3) substrates and using these measurements to monitor the changes in the vanadium oxide layer conductivity. The SAW transmission parameters S12 were measured with the radio-frequency network analyzer as a function of time passed from the moment of the layer deposition. The measurements were performed at the SAW frequencies of 57 MHz and 86 MHz. We observed the effect of strong variation in the SAW amplitude and phase with time, which we attributed to the acoustoelectric interaction in the conditions of the varying V2O5 ·nH2O layer conductivity after fabrication. This was confirmed by the disappearance of the effect when the vanadium pentoxide layer had been deposited on the LiNbO3 substrate surface with a pre-deposited thin metal film screening the SAW piezoelectric field. Using the theory of acoustoelectric interaction for a layer-substrate structure, we extracted the sheet resistivity of the V2O5 ·nH2O layer from the changes in the measured amplitude, phase, and amplitude-to-phase ratio. The results obtained by different methods are close to each other. Small discrepancies might be attributed to the relatively insignificant contributions of other mechanisms affecting the SAW parameters (for example, those of mechanical origin).

Tue 14:15 ESAL 2 Physical acoustics: Inverse problem

Ultrasonic Measurement of Tortuosity and Viscous Characteristic Length of Double-Layered Porous Absorbing Materials with rigid frames – (Contributed, 000291)

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We propose an indirect method for measuring simultaneously acoustic parameters describing the ultrasonic propagation in double-layered porous material. The porous media consist of two slabs of homogeneous isotropic porous materials with a rigid frame. Each porous slab is described by equivalent fluid model, in which the acoustic wave propagates only in the fluid saturating the material. The inverse problem is solved numerically using experimental transmitted waves in time domain. The direct problem is solved in frequency domains. Four parameters are inverted : tortuosity and viscous characteristic lengths of the two layers. Tests are performed using industrial plastic foams. Inverted values of acoustic parameters are close to those measured by conventional methods. Experimental and numerical validation results of this method are presented, which show the advantage of using the transmission for measuring the characteristic lengths, unlike the reflection.

Tue 14:30 ESAL 2 Physical acoustics: Inverse problem

Wave Speed Propagation Measurements on Highly Attenuative Heated Materials – (Contributed, 000138)

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Ultrasonic wave propagation decreases as a material is heated. Two factors that determine material properties are changes in wave speed and energy loss from interactions within the material. Relatively small variations in velocity and attenuation can detect significant variation in microstructures. This paper discusses ultrasonic wave speed tracking methods and signal analysis algorithms that can document the changes within highly attenuative materials as it is either being heated or cooled from 25°C to 90°C. The experimental set-up utilizes ultrasonic probes in a through-transmission configuration. The waveforms are recorded and analyzed during the thermal experiments. To complement the ultrasonic data, a Discontinuous-Galerkin Model (DGM) was also created which uses unstructured meshes to determine how waves travel in these anisotropic media. This numerical method solves particle motion travel using partial differential equations and outputs a wave trace per unit time. Both experimental and analytical data is compared and presented. Finally, the paper describes a series of additional instrumented tests that will aid the finite element code to adjust for density variations.
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Tue 14:45 ESAL 2 Physical acoustics: Inverse problem

Guided waves attenuation in water immersed corrugated plates – (Contributed, 000040)

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Influence of surface corrugations on the propagation of guided waves in an immersed elastic plate on both the real and imaginary parts of the wavenumbers are investigated. The effects of corrugations can be accounted for by means of a rheological model. The Finite Elements Method (FEM) is used to simulate the reflected and transmitted pressure fields for oblique incident plane harmonic waves in a selected frequency range, for several corrugations geometries. The corrugated surface is then modeled by an interface model of Jones, consisting of ideal springs at normal and tangent directions, which can replace the continuity boundary conditions at the liquid - corrugated solid-plate interface. The spring constants are obtained by a best fit procedure between the analytical solutions of modal resonance peaks and the FEM results for the corrugated plate. There were obtained quasi-constant values for the real parts of the reemission angles, but a relatively large variation of up to 30% of the imaginary parts, which are proportional the to width of the guided modes resonances. It is shown that the presence of corrugations on the plate surface can be modeled by computed spring constants used in the rheological model.

Tue 14:15 ESAL 1 Nanoacoustics and phonons: General

Picosecond Acoustic Experiments with Microcavity Lasers – (Contributed, 000564)

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Optical resonators of vertically emitting semiconductor lasers possess, besides a confined optical mode, also nanomechanical resonances in the GHz frequency range. These resonances may be of different origin: (i) in a planar vertical-cavity-surface-emitting-laser (VCSEL) with a microcavity between two distributed Bragg reflectors (DBRs), the resonances are due to acoustic stop bands emerging in the DBRs phonon dispersion with quality factors exceeding 1000 [1]; (ii) In electrically pumped VCSELs processed in the shape of micropillars (MPs) the resonances are governed by the equencies of the MP's extensional and breathing vibrational modes [2].
We perform picosecond acoustic experiments on these types of VCSELs and observe a long-lived modulation of the laser emission intensity of up to 50after the excitation of mechanical resonances. In an optically pumped VCSELs with quantum wells this modulation takes place at a frequency of up to 40 GHz at room temperature [3]. Experiments on electrically driven quantum dot MP lasers are carried out at cryogenic temperatures and demonstrate the different response of the laser emission on extensional and breathing modes. For various micropillars we observe a different laser emission modulation and explain this by the elastic contact between the micropillar walls and its polymer environment, which determines the spectrum of vibrational modes [4].

1. A. Fainstein et al., Phys. Rev. Lett. 110, 037403 (2013)
2. H. Sakuma et al., Appl. Phys. Lett. 100, 131902 (2012)
3. T. Czerniuk et al., Nat. Comm. 5 4038 (2014)
4. T. Czerniuk et al., Appl. Phys. Lett. (accepted)

Tue 14:30 ESAL 1 Nanoacoustics and phonons: General

What does see the impulse acoustic microscopy inside nanocomposites? – (Contributed, 000550)

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The paper presents results of studying bulk microstructure in carbon nanocomposites by impulse acoustic microscopy technique. Nanocomposite materials are in the focus of interest because of their outstanding properties in minimal nanofiller content. Usually uniform distribution of nanoparticles is assumed, but big area and high superficial activity cause strong interaction between nanoparticles that can result in formation of fractal conglomerates. The conglomerates are able to trap air and to form micron-sized aerogel clusters. Occurrence of fractal conglomerates in nanocomposites has been demonstrated indirectly by measuring fractal dimensions of scatterers by small-angle scattering X-ray methods. This paper involves results of the first direct observation of nanoparticle conglomerate distributions over the bulk of epoxi-carbon nanocomposites with diverse types of the carbon nanofiller using the impulse acoustic microscopy technique. The impulse acoustic microscope SIAM-1 (Acoustic Microscopy Lab, IBCP RAS) has been employed for 3D imaging bulk microstructure and measuring elastic properties of the nanocomposite specimens. The range of 50-200 MHz is optimum for observation of the microstructure inside the entire specimen bulk. Acoustic images are obtained in the ultramicroscopic regime - they are formed by the radiation scattered at components of the bulk fractal structure (Rayleigh type scattering). The technique provides layer-by-layer imaging of the 3D internal microstructure as a set of gray-scale raster images (C-scans) at any depth with the depth range up to 1-2 millimeters. Echo patterns at arbitrary points of the scanning area make it possible to measure local values of elastic wave velocities and elastic modules with micron resolution.

Tue 14:45 ESAL 1 Nanoacoustics and phonons: General

Acoustic Properties of Polyurethane Composition Reinforced with Carbon Nanotubes and Silicon Oxide Nano-powder – (Contributed, 000009)

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This article demonstrates the acoustic properties of added small amount of carbon-nanotube and siliconoxide Nano powder (S-type, P-Type) to the host material polyurethane composition. By adding CNT and/or nanosilica in the form of powder at different concentrations ,up to 2% within the PU composition, to improve the sound absorption. Sound absorptions were investigated in the frequency range up to 1600Hz. Sound transmission loss measurement of the samples were determined using large impedance tube. The tests showed that addition of 0.2 wt.%Silicon Oxide Nano-powder and 0.35 wt.% carbon nanotube to polyurethane composition improved sound transmissions loss (Sound Absorption) up to 80 dB than that of pure polyurethane foam sample.

Tue 15:00 ESAL 1 Nanoacoustics and phonons: General

Red Nile release from polymeric/PFOB nanocapsules triggered by collapse cavitation showed strong temperature dependence – (Contributed, 000602)

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The motivation of this work was to study and achieve by ultrasonic cavitation the Nile red release from nanocapsules known to be very stable as they didn't show significant release under mild sonication, temperature incubation and centrifugation.
The 140nm mean diameter nanocapsules were constituted of a perfluorocarbon core (PFOB) and a thick polymeric shell (PLGA-PEG) encapsulating a hydrophobic fluorescent dye (Nile Red). Samples at a nanocapsules volume fraction of 0.25% in water were introduced in a medical balloon placed at the focus of a 1.1MHz transducer emitting tone bursts (3min sonication: 4.4MPa-22MPa, 200Hz pulse repetition frequency, 5%-50% duty cycle). Experiments were performed in a controlled environment: tank with highly degassed water maintained at 25 or 37±0.2°C, medical balloon with a 35μm wall presenting tiny air/solution interfaces. Inertial cavitation was monitored using a broadband hydrophone. Nile red release was assessed by spectrofluorometry.
The variations of Nile red release percentage as a function of energy at the focus (Ispta*sonication duration in KJ/cm^2) presented a peculiar behavior for both tested temperatures compared to usual drug release profile from Caelyx liposomes. To begin with, less than 5.6% of Nile red was released under ultrasound in the absence of collapse cavitation. Once samples were irradiated above the collapse cavitation threshold (about 10Mpa), release increased up to 14-21%. Release toped out to 21% for a wide range of energy before achieving an abrupt release for a threshold of 1200KJ/cm^2 at 25°C and 550KJ/cm^2 at 37°C. High release profile was then strongly dependent of temperature but cavitation was mandatory to achieve it (as 3min incubation of nanocapsules solution at 60°C induced only 2% release). This behavior could be attributed to an increased fluidization and thinning of the shell above the nanocapsules glass transition (25°C to 35-37°C) rendering it more sensitive to cavitation effects such as shear stress.

Tue 16:00 ESAL 2 Physical acoustics: waveguides

Supersonic Surface Acoustic Waves - Discrete Eigenvalues Embedded in a Radiation Continuum – (Contributed, 000079)

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The subject matter of this paper pertains to systems displaying discrete eigenvalues embedded in a radiation continuum. This phenomenon was originally postulated by von Neumann and Wigner as a possibility in quantum mechanics, but to date has not been encountered in any real quantum mechanical system. However, it is known to exist in acoustics under the guise of supersonic surface acoustic waves (SSAW), and is currently attracting considerable attention in the field of photonics. We will present a broad overview of this phenomenon in the context of solid state acoustics. Conditions for the occurrence os SSAW, their structural stability and the role of symmetry, and realistic physical systems where they can be observed experimentally will be discussed. Then we will turn our attention to one particular example of embedded states, i.e. SSAW on cubic crystals. Normally SAW exist in the subsonic region of the dispersion relation, while in the supersonic domain there occur leaky- or pseudo-SAW, which correspond predominantly to evanescent wave components, but with a small bulk wave component into which they radiate. For a limited class of surface orientations and propagation directions the coupling to the bulk wave vanishes, so that

the mode exists as a non-leaky SSAW. This has observable consequences in surface Brillouin scattering and elsewhere. In some cases the vanishing of the coupling hinges on the symmetry of the situation. There also occur so-called secluded SSAW in non-symmetry directions, where the reason for the vanishing of the coupling lies deeped. This paper establishes existence criteria for SSAW of the two types in the (001) and (110) planes of cubic crystals

Tue 16:15 ESAL 2 Physical acoustics: waveguides

Supersonic Surface Acoustic Waves in a Fluid-Loaded Supported Layer – (Contributed, 000273)

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Guided waves localized at surfaces and interfaces are generally slower than bulk waves in adjacent media; otherwise they become "leaky" due to the radiation of energy into the bulk. However, there are isolated non-radiating modes termed embedded states in the radiation continuum. While the recent discovery of robust non-symmetry-protected embedded states in photonic crystals [1] attracted considerable attention, in solid state acoustics such states referred to as supersonic surface waves [2] have been well known to exist at anisotropic crystal surfaces. The question discussed in this report is whether supersonic surface acoustic waves can exist in isotropic systems without periodicity. We show that isolated non-symmetry-protected embedded states exist in a layered isotropic structure comprising a fluid-loaded elastic layer on an elastic half-space. Normally, loading by a "slow" fluid turns saggitally-polarized surface waves into leaky modes. However, for some combination of parameters, surface waves in a supported layer may become horizontally polarized [3]. When this happens, a pure surface mode completely decoupled from the bulk wave in the fluid emerges. The embedded states in this system are unique in that they do not involve any evanescent fields in the adjacent medium. We also show that these embedded states are structurally stable with respect to small variations of parameters. Our findings may have practical implications for acoustic microscopy.

[1] C. W. Hsu et al., Nature 499, 188 (2013). [2] V. I. Alshits et al., Phys. Scr. T 44, 85 (1992). [3] P. G. Malischewsky and F. Scherbaum, Wave Motion 40, 57 (2004).

Tue 16:30 ESAL 2 Physical acoustics: waveguides

Lamb Wave Propagation in Functionally Graded Piezoelectric Material Created by Internal Temperature Gradient – (Contributed, 000117)

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The study deals with the propagation of Lamb waves in a functionally graded piezoelectric material (FGPM) plate. The FGPM character imposes that the material properties, electrical and mechanical, change gradually with the thickness. This gradient is created by forming a temperature variation across the piezoelectric plate that has a relatively low Curie temperature. To describe the behavior of this system, an approach based on the state vector is used to write constitutive equations and motion equation. The ordinary differential equation system, in the frame of plane waves, leads to an Eigen value problem. The numerical studies have been carried on the basis of dividing the whole FGPM layer into N sub-layers then processing each one as a homogeneous layer. The obtained ordinary differential equations are written under the Thomson-Haskell parameterization of the Stroh formalism. To describe the propagation phenomena in the multilayer system, the recursive Stiffness matrix method has been applied. That allows us to overcome the numerical instabilities related to the conventional transfer matrix method in the high frequency range. The obtained deviations in comparison with the ungraded homogenous plate are plotted with respect to the dimensionless wave number. For illustration, the studied FGPM plate consists of Lead Zirconate Titanate (PZT-4D). This crystal, of 6mm class, is polarized such that the piezoelectric axis is perpendicular to the free surface. The internal temperature gradient has a significant influence on the phase velocity and on the electromechanical coupling factor with a change of 88% for A0 mode, 64% for S0 mode.

Tue 16:45 ESAL 2 Physical acoustics: waveguides

Numerical and experimental investigation of the excitability of zero group velocity Lamb waves – (Contributed, 000207)

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In isotropic and anisotropic plates a number of Lamb waves possess zero group velocity (ZGV) points in their spectrum. At these points not only the group velocity but also the energy propagation of the elastic waves is vanishing. The locally trapped acoustic energy shows a well-detectable resonance making them well-suited for non-destructive testing purposes, in particular to investigate local properties.
Previous investigations has shown that laser-ultrasonic techniques are well-suited for the study of these modes and in the presented work we investigate numerically and experimentally the excitability of ZGV modes by varying the ratio of the laser pulse diameter (D) to plate thickness (h). In the experiments a pulsed laser is used to excite elastic waves and the response of the plate is detected interferometrically on the epicentral axis. The experimental results are compared to numerical simulations based on the finite difference method. Within these numerical simulations we solved the coupled heat and wave equations in the time domain to obtain transient and steady-state responses.
In the experiments and simulations we have studied aluminum and tungsten plates with thicknesses in the sub-millimeter range and observed up to three ZGV points in the spectra. We investigated the transient response of the plates with Fourier-transforms and the obtained numerical and experimental results show how the ratio D/h influences the coupling of the excitation into the ZGV modes. Short-time Fourier-transforms of the numerical and experimental results indicate that the temporal decay of these modes are also influenced by this coupling and the D/h ratio.

Tue 17:00 ESAL 2 Physical acoustics: waveguides

Analysis of Rayleigh-Lamb Modes in Soft Solids With Application to Surface Wave Elastography – (Contributed, 000260)

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Extraction of elastographic parameters from surface wave (SWE) measurements is getting increasing interest among researchers of this field. In this work, we study experimentally the Rayleigh-Lamb modes in soft solids in order to study the conditions for SWE. The experiments were carried out in agar-gelatin phantoms. The low-frequency waves were excited at the free surface of the phantom using a 5 mm diameter piston attached to a shaker. The low-frequency excitation varies from 60 to 160 Hz in 20 Hz steps. The displacement field was acquired using an ultrafast electronics. A 256 element linear array of 7.5 MHz central frequency and 50 mm in length was positioned horizontally in the opposite surface of the piston. Surface displacements were acquired through the standard speckle tracking technique, and the group velocity was measured for each frequency. Three phantoms made from the same mixture of agar and gelatin but with heights of 60, 20 and 10 mm were used. Therefore we built a dispersion curve where the fh (frequency times height) parameter varies from 0.6 to 9.6 Hzm. The results show that both symmetric and antisymmetric modes are excited. The system allows to study transient behavior and mode resonances depending on the horizontal distance from the source. For distances closer to the source, the symmetric modes dominate the field whereas for longer distances the antisymmetric modes do. The A0 mode brings the group velocity closer to the Rayleigh wave speed. As a conclusion, better conditions for surface wave elastography are when antisymmetric modes are excited.

Tue 17:15 ESAL 2 Physical acoustics: waveguides

Supersonic Waves Guided by Crystal Edges – (Contributed, 000289)

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It is known that straight-crested solid wedges can guide elastic waves along the apex. Normally, the phase speeds of such waves lie below the Rayleigh velocity for the wedge material. In this work we present new effects induced by the anisotropy of the elastic solid. The first one is the existence of leaky supersonic wedge waves with phase velocities exceeding the surface acoustic wave velocity and even bulk wave velocity. Another interesting effect of anisotropy is that under certain conditions two wedges formed by the same crystallographic planes and having the same apex angle exhibit different properties of the wedge waves, such as phase velocities and polarizations. This work studies wedge waves in various wedges of silicon crystals, both experimentally and theoretically. Acoustic waves were excited by a laser-based selective transducer and detected optically. Experiments include accurate measurements of the phase speed and the spatial distribution of the wave field. Theoretically the problem was treated by the Laguerre function method, extended for the case of leaky waves. Several configurations with different degree of symmetry were considered, depending on the symmetry properties of the characteristic planes of the wedge: the side faces of the wedge, the plane normal to the apex line, and the mid plane of the wedge.

Tue 17:30 ESAL 2 Physical acoustics: waveguides

Investigation of Scholte and Stoneley Waves in Multi- layered Systems – (Contributed, 000392)

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Interface waves are elastic waves that can propagate at the interface between two solids (Stoneley wave) or between a solid and a liquid (Scholte wave). In this study, properties of generalized Stoneley and Scholte waves are investigated analytically in a multi-layer system with both liquid-solid and solid-solid interfaces. The interface waves are modeled using partial waves in layers with finite thicknesses to trace quasi- and non-dispersive modes. Dispersion curves of the propagating modes and corresponding particle displacement profiles are obtained using numerical solution techniques with the global matrix method. Limiting conditions of quasi-modes are evaluated analytically for thickness and material selection. Furthermore, interference of the two interface waves and plate modes are investigated for small frequency-thickness products in the multi-interface system using dispersion curves and particle displacement profiles. Preliminary sensitivity analyses are also performed for development of multi sensing physical quantities such as temperature, viscosity and density simultaneously using interface waves.

Tue 16:15 Citadelle 1 Bio-medical: Imaging process, beamforming and tomography

Comparison of Thresholds for Pulmonary Capillary Hemorrhage Induced by Pulsed-wave and B-mode Ultrasound – (Contributed, 000098)

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Pulsed ultrasound was found to induce pulmonary capillary hemorrhage (PCH) in mice about 25 years ago but remains a poorly understood risk factor for pulmonary diagnostic ultrasound. In early research using pulsed wave (fixed beam) ultrasound, thresholds for PCH appeared to have a frequency variation from 1-4 MHz similar to a Mechanical Index (MI) of 0.63. In this study, PCH was observed in rats after 1.5 MHz and 7.5 MHz exposure to pulse-wave (fixed beam) and B mode (scanned) ultrasound for 5 min in a heated water bath. PCH areas were measured on photographs of the surface of excised lungs. Measurements were made of peak rarefactional pressure amplitudes (PRPA) attenuated by rat chest-wall samples. Thresholds were based on the proportion of PCH occurrence in groups of 5 rats exposed at different PRPAs, and were calculated as the mean of the lowest PRPA with significant PCH and the highest PRPA without significant PCH. Pulsed wave exposure using 10 μs pulses at 40 pulses/s gave thresholds of 0.75 MPa at 1.5 MHz and 0.69 MPa at 7.5 MHz. B mode scanning at 1.5 MHz with 1.5 μs pulses and 36 frames/s and 7.6 MHz with 0.25 μs pulses and 39 frames/s gave higher thresholds of 1.03 MPa and 1.18 MPa, respectively. The PCH areas decreased with increasing ultrasonic frequency, but the PRPA thresholds remained constant. These findings were different from the $\sqrt{f}$ dependence of the MI and the earlier pulsed wave research, which would have predicted thresholds of 0.77 MPa at 1.5 MHz and 1.7 MPa at 7.5 MHz. These results suggest that the MI may not be directly useful as a dosimetric parameter for safety guidance in pulmonary ultrasound.

Tue 16:30 Citadelle 1 Bio-medical: Imaging process, beamforming and tomography

Realistic Simulations for the Evaluation of Monomodal Registration Algorithms of 3D Pelvic Ultrasound Images – (Contributed, 000277)

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Motivation: validating image processing algorithms from real medical data is an important issue since a ground truth is often missing. Recent developments in radiotherapy aims at using 3D ultrasound images to set-up the patient. To automate this procedure, automatic registration algorithms need to be validated. A simulation framework is proposed to answer this need.
Methods: the proposed framework is composed of 4 steps: (1) an ultrasound image is simulated from a real one, (2) the scatterers are displaced with a known transformation and (3) a new ultrasound image is generated from this transformed scatterer map. Finally, registration is performed between the images simulated at steps 1 and 3. Registration results are compared to the applied transform (step 2). The realism of the US simulations were first visually evaluated. The proposed framework has been used on images acquired with the transperineal Clarity® system (5Mhz ultrasonix model of bandwidth 2.6MHz) of 3 patients suffering from prostate cancer. Translations ranging from 0mm to 4mm and from 0mm to 2mm were tested in Anterior-Posterior (AP), Superior-Inferior (SI) directions, respectively.

Results: during the qualitative assessment of the simulated images, the experts mentioned that the borders of the organs could not be clearly identified. Once they knew they were simulations, they admitted they were highly realistic but often of poorer quality. The mean registration error was -0.6+-3.1mm, -0.7+-1.6mm in AP and SI directions, respectively. The proposed framework can be used to produce ground truth data and could be extended to other probes / organs / transformations.

Tue 16:45 Citadelle 1 Bio-medical: Imaging process, beamforming and tomography

Segmentation of inhomogeneous skin tissues in high-frequency 3D ultrasound images, Bhattacharyya distance compared with a Bayesian method – (Contributed, 000332)

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High-frequency ultrasounds (>20 MHz) are a promising tool for diagnosis and surgery of skin tumours, for the cosmetic industry and for the imaging of organs in small animals. To make quantitative studies, one often needs to extract boundaries in 3D images, a qualitatively and numerically challenging task [Pereyra et al. 2012].
We propose a multi-purpose region competition algorithm based on the statistics of the envelope signal. Whereas most proposed algorithms assume a specific (e.g. Rayleigh) distribution of the speckle noise [Alessandrini et al. 2009], we do not make such assumption. Instead, we use a non-parametric method where the cost function is the Bhattacharyya distance between the histograms of the region of interest and the outlying regions. Qualitatively, it tends to make the distribution of the two regions as different as possible. Thanks to the non-parametric nature of the method, it is capable of segmenting inhomogeneous tissues with arbitrary intensity distributions, a crucial property given the high variability of the structures found in the skin tissues.
We compare the results of our algorithm with the maximum likelihood method with the hypothesis of a Rayleigh distribution and demonstrate that our method performs equally well as the Bayesian methods in the case where distributions are Rayleigh, and better for handling inhomogeneous tissues. For this purpose, we use realistic simulated images and medical images made with the Dermcup 3D ultrasound scanner of Atys Medical company.

Tue 17:00 Citadelle 1 Bio-medical: Imaging process, beamforming and tomography

Detection of Solid Microspheres in Viscoelastic Medium by Their Response to Acoustic Radiation Force – (Contributed, 000337)

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Microcalcifications are an important diagnostic sign of breast cancer, highlighting tumor progression in the early stages, when the disease is asymptomatic. The size, form, and density of microcalcifications are varied significantly and can serve as characteristic signs of the disease. Sensitivity and resolution of conventional ultrasonic devices are not sufficient for detection of microcalcifications. We propose to induce a radiation force in a suspicious volume by focused ultrasound. The presence of solid microparticles increases the radiation force and results in more pronounced displacements of the medium. Radiation force on a rigid particle of arbitrary shape was calculated by FEM. Transient displacement of a solid sphere in the viscoelastic medium under the radiation force of 0.2 ms duration was evaluated numerically. Experiments were performed in tissue-like gel phantoms with embedded glass spheres with diameters of 50 - 450 microns. Verasonics system with linear probe L7-4 was used to apply the radiation force and to track the movement of the spheres. The spheres of 300 - 450 microns were visualized on ultrasound image, their coordinates were determined. The ultrasonic beam focused at the sphere resulted in its transient displacement, which was determined by the correlation of successive images obtained at a frequency of 5 kHz. For the spheres of 50 - 200 microns that are practically invisible on the B-scan the algorithm of detection was as follows. Area of the probable sphere location was scanned by the focused beam excited the transient displacements of the medium in the focal region. The position of a sphere was determined by the maximum displacement of the medium in the focus immediately after exposure. The results can be used to develop a method of ultrasound diagnosis of breast cancer by the detection solid microparticles - microcalcifications. This work is supported by grant 11.G34.31.0066.

Tue 17:15 Citadelle 1 Bio-medical: Imaging process, beamforming and tomography

Focused Shock Shear Waves in Soft Solids and the Brain – (Contributed, 000576)

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Shear waves in soft solids are extremely nonlinear and have nonlinear properties that are four orders of magnitude larger than in classical solids. Consequently these nonlinear shear waves can transition from a smooth to a shocked profile in less than a wavelength. We hypothesize that traumatic brain injuries (TBI) could be caused by the sharp gradients inshear shock waves. However shear shock waves are not currently modeled by simulations of TBI.
The objective of this paper is to describe shear shock wave propagation in a general model of soft solids that can model the brain with a source geometry that is determined by the skull. A 2D nonlinear paraxial equation with cubic nonlinearities is used as a starting point. We present solutions based on second order operator splitting which allows the application of optimized numerical methods for each term. We then validate the scheme with Guiraud's self-similarity law applied to caustic solutions at the focus. This validated numerical scheme is then used to determine injury criteria in a blunt trauma. A CT measurement of the human skull is used to determine the initial conditions and shear shock wave simulations are presented to demonstrate the focusing effects of the skull geometry. The simulations are then compared to experiments of focused shear shock waves in a homogeneous gelatin phantom. It is shown that when the focal gain and shock formation distance are the same there is a dramatic increase in brain injury criteria.

Tue 17:30 Citadelle 1 Bio-medical: Imaging process, beamforming and tomography

Assessment of liver viscoelasticity for the diagnosis of early stage fatty liver disease using transient elastography – (Contributed, 000585)

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Motivation
Nonalcoholic fatty liver disease (NAFLD) is characterized by accumulation of fat within the Liver. In the most severe cases, NAFLD can progress to nonalcoholic steatohepatitis (NASH) and subsequently to liver cirrhosis. In many cases NAFLD can be asymptomatic, hence a non invasive method for the measurement of fat concentration within the liver would very beneficial. The main objective of this work is to evaluate the feasibility of measuring in vivo the shear wave phase velocity dispersion cs(ω) in a 20Hz-100Hz bandwidth using vibration-controlled transient elastography (TE). In addition, a correlation of these measurements with the hepatic fat percentage measured with T1-weighted gradient-echo in-and ou-phase MRI sequence was carried out.
Methods

We use a research Fibroscan® platform with different consecutive transient vibrations at the same measurement point. The in vivo transient strain rate dVz(z,t)/dz is measured with 0.12mm axial and 0.43 ms temporal resolutions respectively. After segmentation and Fourier transform, the shear wavelength λs is estimated in the spatial domain for each known frequencies of the transient vibration bandwidth using an inverse problem algorithm based on a shear wave visco-elastic propagation model. Finally, shear wave dispersion curves are fitted by the classical Voigt model for visco-elastic parameter estimation.
Results

In vivo experiments were conducted on two volunteers at Tours Hospital. We repeated 10 successive measurements using the TE method at the same position without displacement of the Fibroscan's probe and we computed the median and IRQ. For the first volunteer who has 2% of fat in the liver, we obtained a shear elastic modulus μ=1.6 ±0.1 kPa and a shear viscosity η=1.4±0.3 Pa.s. For the second volunteer with 22% of fat, we obtained with our method μ=1.1±0.1 kPa and η=2.3±0.4 Pa.s.

In conclusion, we show in vivo measurement of fat concentration using TE.

Tue 17:45 Citadelle 1 Bio-medical: Imaging process, beamforming and tomography

Ex vivo **evaluation of an eye-adapted beamforming for axial B-scans using a 20 MHz linear array through experiments on a human isolated lens and an entire eye** – (Contributed, 000594)

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Motivation
In ophthalmic ultrasonography the crystalline lens is known to be the main source of phase aberration, as ultrasounds propagate about 10% faster than in the surrounding intra-ocular medium. Consequently, it impairs significantly both spatial and contrast resolution of axial B-scans and causes important distortions, especially on the ocular fundus. To deal with this serious issue, an adapted beamforming free from crystalline lens aberration has been developed in a previous work [Mateo et al., IEEE TMI 2014] and implemented on a custom US research scanner working with a 20 MHz linear array. The adapted BF lies on a ray tracing approach to compute focusing delays that take into account crystalline lens aberrations including refraction at the interface. Promising results were obtained in vitro using an eye phantom consisting of a synthetic gelatin lens anatomically set up in an appropriate liquid to reproduce the in vivo celerity ratio.

Method
Confirmation of the interest of this adapted BF is now presented through *ex vivo* experiments conducted on human eyes, by imaging first a wire phantom beyond an isolated crystalline lens that allows to quantify both spatial resolution and fidelity and then an entire eye. The adapted BF has been extended to take into account the velocity gradient that exists in the real lens *i.e.* a plateau in the nucleus followed by a gradual decrease toward the lens edges.

Results
Quantitative analysis shows a two-fold improvement of both axial and lateral resolution, a greater sensitivity (about 7 dB) and 84% reduction in spatial distortions (from 621 μm to 97 μm) compared to conventional BF. B-scan of the entire eye shows a significant improvement in the visualization of the fundus (better delineation of the vitreoretinal junction, interfaces between retina, choroid and sclera that become visible).

Tue 16:15 ESAL 1 NDE / NDT: Laser Ultrasound Techniques

ZGV resonances of three layer plates for bonding evaluation – (Contributed, 000488)

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Lamb waves in plates are strongly dispersive. For some branches of their dispersion curves ω(k), a minimum occurs at a non-zero wavenumber k, corresponding to a Zero Group Velocity (ZGV) mode. Such ZGV Lamb modes also exist in multi-layered plates and depend on the quality of the bonding. As the group velocity of these modes vanishes, the energy deposited by a local impact remains trapped under the source, resulting in sharp resonances. Laser based ultrasonic techniques offer a unique tool to observe these resonances. When the layer thickness is small compared with the plate thickness and the acoustic wavelength, the coupling layer can be modeled by normal and tangential springs to take into account the normal and shear interfacial stresses (Mezil et al., APL, 2014). For thicker layers, a three layer model was used (Vlasie and Rousseau,Wave Motion, 2003) taking into account normal and tangential springs at both interfaces. Theoretical results are illustrated through various experiments. The local impact was achieved by a 1064 nm, 20 ns, pulsed laser source and the ZGV resonances were detected by a heterodyne interferometer. Measurements were conducted on several samples made of millimeter thick plates (either glass or metal) bonded with different layers (salol or epoxy) of thicknesses varying from a few micrometers to hundreds of micrometers. The dependence of ZGV resonances with the layer thickness and their frequency variations during the couplant hardening were observed.

Tue 16:30 ESAL 1 NDE / NDT: Laser Ultrasound Techniques

Nondestructive Evaluation of Material Properties for Thermal Spray Coatings with Laser Ultrasound Technique – (Contributed, 000328)

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Abstract: - Motivation: The non-destructive characterization of thermal spray coating for mechanic components is important on industrial manufacturing. It provides the prediction of mechanical properties and increases the quality of coatings. However, this research focused on characterization of mechanical and geometrical properties in Nickel-Aluminum coating with different thermal technique and processing parameters at high temperature environment up to 295°C.
- Methods: With the laser ultrasound technique (LUT), guided acoustic waves are generated to propagate on the Ni-Al sprayed coatings. By measuring dispersive phase velocity followed by SCE-UA inversion algorithm. The inversed material properties can be obtained directly.
- Results: The results shows that both Ni-AL sprayed coating is fabricated by air plasma spraying (APS) or high velocity oxygen fuel (HVOF) technique, the surface wave velocity become fast while gas flow velocity of processing parameter is higher. On the other hand, Young's modulus for the Nickel- Aluminum alloy coatings with different environment temperature is inversed and shown in this study. It is founded that the Young's modulus decreases as the temperature increases. In addition, The Young's modulus of coatings which fabricated by HVOF technique is higher than APS technique. Moreover, if the gas flow velocity of thermal spray procedure were high, the Young's modulus will greater for both techniques.

Tue 16:45 ESAL 1 NDE / NDT: Laser Ultrasound Techniques

Characterization of 3D-Printed Parts with Lamb Waves Based on Laser Ultrasound Technique – (Contributed, 000356)

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A laser ultrasound technique (LUT) followed by an inversion algorism is reported for nondestructive characterization of mechanical properties of 3D printed, or additive manufacture (AM) parts. For traditional substation manufacture (SM) such as milling or drilling, parts machined from relatively uniform bulk materials are stable and naturally exhibit higher strength. AM produces parts with a layer-by-layer way. As a consequence, these AM- manufactured parts suffer from inhomogeneity across layers and relatively lower strength. While used as load supporting components in critical applications, the AM parts need to demonstrate their stable mechanical properties. The research demonstrates that the additive manufacture parts is non-homogeneous for elastic modulus across the thickness direction. Laser ultrasound technique is used to characterize the inhomogeneous elastic property in a nondestructive way.

Tue 17:00 ESAL 1 NDE / NDT: Laser Ultrasound Techniques

Evaluation of the elastic parameters of steel by all-optical monitoring of surface and pseudo-surface bulk acoustic waves – (Contributed, 000131)

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To allow for the non destructive evaluation models to predict accurately the influence of the metallurgical structure on the ultrasonic wave propagation, the material properties of polycristalline specimens must be determined. For instance, the influence of the cast stainless steel structure on ultrasonic wave propagation in nuclear power plants components remains a significant challenge. The physical characterization of such complex materials requires, before a macroscopic evaluation of the texture, the quantitative evaluation of the elastic behaviour of its composing microstructures on a microscopic scale. A laser ultrasound set-up composed of a sub-nanosecond pump laser combined with a continuous probe laser on a sample surface is implemented for the generation and the detection of acoustic waves after a propagation distance of tens of micrometers. This method, with a line source-point focused probe beam deflection approach, allows the measurement of the time of flight of propagating waves along the surface [1,2]. We were able to detect the acoustic pulses corresponding to surface, pseudo surface and surface skimming bulk acoustic waves that propagates along the surface of an individual or several neighbours individual crystals. We propose and discuss a new approach of the evaluation of elastic properties of the crystals composing a polycrystalline sample by the study of the value and probability of detection of surface wave speeds.

[1] N. Chigarev, P. Zinin, L.-C. Ming, G. Amulele, V. Gusev, Appl. Phys. Lett. 93, 181905 (2008).
[2] A. Zerr, N. Chigarev, R. Brenner, D. A. Dzivenko, V. Gusev, Phys. Status Solidi RRL 4, 353 (2010).

Tue 17:15 ESAL 1 NDE / NDT: Laser Ultrasound Techniques

Laser-Ultrasonic Measurement of Elastic Properties of Anodized Aluminum Coatings – (Contributed, 000061)

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Variations in anodizing process parameters strongly affect density, Young's Modulus, hardness and thickness of the anodized coating. For many industrial applications the properties of the anodized layer have to be optimized, e.g. in order to achieve greater wear resistance. However, a remaining issue is the lack of non-destructive measurement systems to determine the properties of anodized coatings. In this work the elastic material parameters of anodized aluminum were investigated using a laser-based ultrasound system. The laser-based ultrasound system consisted of a Q-switched Nd:YAG generation laser and a heterodyne Mach-Zehnder interferometer. The beam of the generation laser was focused on the surface of the sample to a diffraction-limited thin line, where broadband Rayleigh waves were launched. They were detected in the near field of the source by the Mach-Zehnder interferometer. The experimental dispersion relation of Rayleigh waves on the investigated sample was calculated using the phase-spectral analysis method. The thickness of the anodic layer was measured with a coating thickness gauge. Rayleigh waves were measured before and after the anodizing process to investigate the influence of the anodizing process on the dispersion of Rayleigh waves. A one-layer model was fitted to the experimental dispersion relations in order to determine variations in elastic parameters of the coating. It was shown that anodizing time and temperature strongly influence Rayleigh wave propagation. While anodizing time mainly influences the coating thickness, the electrolyte temperature has a great impact on the elastic parameters of the coating.

Tue 17:30 ESAL 1 NDE / NDT: Laser Ultrasound Techniques

Monitoring of acoustic waves inside and in close vicinity of elastic contact by sub-nanosecond laser ultrasonic technique – (Contributed, 000115)

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Sub-nanosecond laser ultrasonic (LU) technique, which provides excellent opportunities for non-destructive evaluation of elastic properties, has been applied recently for the probing of laser-induced crack closure [1]. The parameters of naturally produced cracks are usually unknown. For this reason, the use of a contact between light-transparent and light-absorbing materials could be proposed for the simulation of some properties of cracks and interfaces. The technique is based on the excitation of surface, interface and skimming bulk acoustic waves by a sub-nanosecond laser and their subsequent detection by a continuous laser beam using a deflection method. The automatic scan of photo-acoustic signals is obtained by the displacement of the excitation beam relative to the detection one. The value of sound velocity is obtained from the fit of arrival time of the acoustic pulse as a function of distance between the beams. The sample is installed on a displace-

ment stage, allowing the study of different parts of the contact and its surroundings.
In the simplest configuration, a contact between a cylindrical lens and a light absorbing plate has been studied. The amplitude and the profile of different acoustic waves propagating near the surfaces in contact provide information on the parameters of the contact, which can be modified using the variable static loading or an additional powerful heating laser beam. The technique provides an opportunity to study the transmission and the reflection of acoustic waves at the contact boundary. Possible nonlinear regimes of acoustic pulses propagation, when the distance between the surfaces of the contact is comparable with the mechanical displacement of the wave, are particularly interesting. The results of this work should find the applications in the area of the adhesion characterization and the mapping of damages and cracks in different materials.

[1] C. Ni, et al, J. Appl. Phys. 113, 014906 (2013).

Tue 17:45 ESAL 1 NDE / NDT: Laser Ultrasound Techniques

Elastic Modulus Measurement of Metal Thin Film Layers on Silicon Substrate using Laser Generated Guided Ultrasonic Waves – (Contributed, 000557)

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The accurate measurement of mechanical properties of thin films in MEMS/NEMS structures is very necessary to improve the reliability of their design and manufacturing. However, existing methods to measure them, such as a tensile test or a resonance test, cannot be applied to thin films because of its quite small thickness. In this work, the method of elastic modulus measurement using laser generated guided ultrasonic waves, which propagating through constant geometric boundaries, is concerns for noncontact and nondestructive measurement so guided wave excitation and detection system using a pulsed laser and a laser interferometry has been established. Also an elastic modulus extraction algorithm from the measured guided wave signal was developed to build dispersion relations between wave speed and frequency. Finally, it was applied to actual metal thin film structures of Al-Si and Ni-Si multilayers. From experimental results, we confirm that the proposed method has considerable feasibility to assess elastic properties of metal thin films on silicon substrate.

Tue 9:30 Main Hall Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics (Special Session in Honour of Professor Emeritus Oswald Leroy) (poster)

Acousto-optical imaging system for in-situ measurement of the temperature distribution in micron-size specimens – (Contributed, 000139)

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An acousto-optical imaging system for in-situ measurement of the high temperature distribution in micron-size specimens is described. It is based on image acquisition in narrow-band spectral intervals and reconstruction of the Planck law in each pixel. It contains the microscope objective lens, imaging acousto-optic tunable filter, optical coupler and CCD camera. The system is designed to measure temperature distribution inside minerals and functional materials phases subjected to high pressure and high temperatures in a diamond anvil cell heated by a high power laser which is required for studying phase transition and measurements acoustical properties of materials under high pressure in geophysics and materials sciences.

Tue 9:30 Main Hall Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics (Special Session in Honour of Professor Emeritus Oswald Leroy) (poster)

Peculiar Cases of Acoustic Wave Reflection in Acousto-optic Paratellurite Crystal – (Contributed, 000383)

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The presentation is focused on analysis of unusual cases of propagation and reflection of acoustic waves in the tellurium dioxide single crystal. The latter is known for being an efficient acousto-optic medium. Therefore the crystal has found numerous applications in devices controlling optical beam parameters. A strong anisotropy of acoustic properties of the crystal provides observation in the tellurium dioxide of a number of new effects. The effects are related to reflection of elastic energy from a free boundary separating the material and the vacuum. As found, in the XY plane of the crystal, there exists a particular angle of inclined acoustic incidence, at which energy flow of a reflected wave propagates exactly towards the energy flow of the incident wave. Moreover, in some specific cases of the acoustic incidence, Pointing vectors of the incident and reflected waves are located in one and the same quadrant, i.e., from one side with respect to the boundary normal. We also predicted that due to the elastic anisotropy, the angle of incidence may be included not only in the traditional limits from zero to 90 degrees but in a wider range of angles up to about 160 degrees. The general case of acoustic reflection from a free boundary in paratellurite was examined in details. We extended the analysis over arbitrary planes in the material and determined orientation of wave vectors, energy flows and directions of polarization in two acoustic waves reflected from the boundary. The effect of elastic modes transformation was also predicted and examined during the analysis. Finally, we briefly discuss possible applications of the studied effects in new devices for light beam control.

Tue 9:30 Main Hall Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics (Special Session in Honour of Professor Emeritus Oswald Leroy) (poster)

Contribution of elasto-optic and flexoelectric effects to the linear light diffraction on periodic domain structures in lithium niobate – (Contributed, 000528)

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Periodically poled structures created in lithium niobate crystals (PPLN) have attracted interest for applications in nonlinear optics and electro-optic modulations of laser beams. The light diffraction on such structure in the linear regime is the informative testing method of their quality. It is known that the periodical perturbations of the light-frequency dielectric tensor in PPLN are due both to the electric charges and to the intrinsic elastic fields of domain walls. In this report we study the light diffraction on an ideal poled structure with periodical along the X-axis of LiNbO3 alternation of domain walls free from electric charges. The intrinsic elastic fields of domain walls on the base of Landau-Ginzburg-Devonshire equation with taking into account the converse piezoelectric and flexoelectric effects are considered. In this approximation the spatial dependence of polarization can be represented as P3(x) $\sim$ tanh(ηx), where parameter η is inversely to the width of domain wall. We have obtained that converse piezoelectric and flexoelectric effects cause correspondingly the elastic strains with components S1(x) $\sim$ (P3)2 $\sim$ tanh2(ηx) and S5(x), S6(x) $\sim$ dP3/dx $\sim$1/cosh2(ηx). Due to elasto-optic effect these strains determine the changes in the components of dielectric tensor $\Delta\varepsilon$11, $\Delta\varepsilon$22, $\Delta\varepsilon$33, $\Delta\varepsilon$23= $\Delta\varepsilon$32$\sim$ tanh2(ηx) and $\Delta\varepsilon$21= $\Delta\varepsilon$12, $\Delta\varepsilon$31= $\Delta\varepsilon$13$\sim$ 1/cosh2(ηx). Thus, on the PPLN under consideration along with the conventional isotropic diffraction, the collinear and anisotropic ones can be also observed. We experimentally investigated the diffraction of light beams with the different wavelength on the structure with spatial period of 6.89 μm, which was developed in "Labfer Ltd" on the Z-cut MgO:LiNbO3 crystal using electric-field poling. The isotropic diffraction both with many maxima and with two Bragg ones as well as the collinear diffraction have been observed.

Tue 9:30 Main Hall Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics (Special Session in Honour of Professor Emeritus Oswald Leroy) (poster)

Multibeam Holographic Formation of the Polarization Photonic Structures in Polymer-Dispersed Liquid Crystals – (Contributed, 000567)

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Currently, polarization photonic structures holographically formed in polymer-dispersed liquid crystals (PDLCs) by the polarization holography methods are of great interest due to possibility to manage their optical properties dynamically. The purpose of this paper is to develop the theoretical model of holographic formation of the PDLC polarization photonic structures (PPS) for the case of multibeam recording. PPSs formation in PDLCs is possible due to the light-induced spatial inhomogeneity of the optical anisotropy of the material caused by the superposition of arbitrarily polarized recording beams on the sample plane, and stabilized as a result of phase sepa-

ration of PDLC components during photopolymerization process. In the multibeam case, the phase difference between the interfering waves leads to a polarization state changing and also to an intensity modulation of the resulting field. Due to liquid crystal's ability to orient in the direction of the electric field vector of the light field (photoinduced Fredericks effect) and photopolymerization and diffusion processes in material (caused by impact of modulated recording field), polarization photonic structures are formed in PDLC after exposure. The PPS' refractive index changing is caused not only by modulation of the material density, but also by the spatial distribution of the liquid crystal molecules orientation. According to the obtained relations, numerical simulation of the spatial changing of the dielectric tensor was made. The resulting mathematical model describes the multibeam holographic formation of polarization photonic structures in PDLC. Obtained results can be used to develop a model of light beams diffraction on them.

Tue 9:30 Main Hall Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics (Special Session in Honour of Professor Emeritus Oswald Leroy) (poster)

Influence of Acoustic Field Structure on Polarization Characteristics of Acousto-Optic Interaction in Crystals – (Contributed, 000112)

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Influence of acoustic field structure on polarization characteristics of acousto-optic interaction is investigated. It is shown that inhomogenity of acoustic field causes changes in values of acousto-optic figure of merit for ordinary and extraordinary light beams in comparison with theoretic values which were derived under assumption that acoustic wave is homogeneous. Experimental analysis was carried out in acousto-optic cell based on lithium niobate crystal where acoustic wave propagates at the angle 13 degrees to Z crystal axis. The acoustic wave was generated by two sets of electrodes placed on top of the crystal surface. First pair of electrodes was directed along X crystal axis, second pair of electrodes was directed orthogonally to X crystal axis and direction of ultrasound. Structure of acoustic field generated by these sets of electrodes was examined by laser probing. We performed an analysis of acoustic field intensity using acousto-optic method. A relation of diffraction efficiency of ordinary and extraordinary light waves was measured during each iteration of laser probing. The research was supported by RSCF grant 14-12-00380.

Tue 9:30 Main Hall Bio-medical ultrasound for therapy (poster)

Characterization of pressure fields produced by a focused transducer-a home made system design – (Contributed, 000573)

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The ultrasound field radiated by HIFU has been investigated by measuring its pressure field and mapping in 2-D and 3-D. A new ultrasound pressure measurement system has been designed and constructed at TÜBITAK UME (The Scientific and Technological Research Council of Turkey, the National Metrology Institute) Ultrasound laboratory. System consists of a water tank, positioning system, measurement devices and a controlling program. Water tank and positioning system have no mechanical contact to each other so that preventing any vibration throughout the movement in water. The signal was captured and analyzed by the commercially available LabVIEW 8.1 software (National Instruments). The measurements of the ultrasound field were carried out with a needle hydrophone (Onda Corporation). The hydrophone was attached to a 3-axis, computer-controlled positioning system for alignment with the ultrasound source. For each waveform, the following parameters have been calculated; p+, peak-compressional acoustic pressure max, p-, peak- rarefactional acoustic pressure, p(pp), peak-to-peak pressure. Wave behaviors in produced by the KZK (Khokhlov-Zabolotskaya-Kuznetsov) model and from experiments look like similar in general. In peak compressional pressure p+, p- the focal point, zero point after the primary peak (focus) and extremum points in the near field well matched.

Tue 9:30 Main Hall Bio-medical ultrasound for therapy (poster)

Power evaluation of high intensity focused ultrasound transducer based on acoustic field measurement in pre-focal region – (Contributed, 000210)

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A novel technique to the measurement of high intensity focused ultrasound output power is described. The method exploits a scanning device and a needle hydrophone, when fixed in the pre-focal region of a transducer, the distribution of acoustic pressures can be measured in both amplitude and phase, then its acoustic output power can be calculated. Since acoustic intensities in the pre-focal region are much lower than on the focus for a high power transducer, the damage to measurement devices, especially hydrophones, can be reduced, and results will become more reliable. In this paper, a scanning device for high intensity measurement is described and a number of properties of the method are investigated. Acoustic powers of a few focused transducers are evaluated and their uncertainties are presented. Implications of the work for the development of a portable device of acoustic power measurement, appropriate for high intensity focused ultrasound systems are discussed.

Tue 9:30 Main Hall Bio-medical ultrasound for therapy (poster)

An Intercomparison of Ultrasound Dose Measurements – (Contributed, 000149)

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The aim of this work is to evaluate the measurement methods and the models developed in the EMRP project Dosimetry for Ultrasound Therapy, DUTy, by validating the measurement results of national laboratories. In this work the methods are to be applied to a common set of ultrasound fields and tissue models. The general format is similar to a metrological comparison, with which the National Metrological Institutes, NMIs, are already familiar. The first step involved the agreement of the protocol that was to specify the set of transducers to be circulated and the measurement conditions. Two transducers were circulated: transducer 1 is a piston like device with a transducer frequency of 2,01 MHz, transducer 2 is a HIFU with central frequencies of 2 MHz and 6,38 MHz. Different drive voltage levels and pulsing regimes were defined and tissue mimicking materials characteristics were specified. Each lab was enabled to prepare the TMMs for their own measurements with the inclusion of formulations and preparation instructions specified in the protocol. Uncertainties of the input data are to be declared by the participating laboratories, the uncertainty of the reference value and the degrees of equivalence will be calculated according to the analysis method agreed between participants.

Tue 9:30 Main Hall Bio-medical ultrasound for therapy (poster)

Thermal ablation of the pancreas with intra-operative high-intensity focused ultrasound (HIFU): safety and efficacy in a porcine model – (Contributed, 000469)

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Background: Pancreatic ductal adenocarcinoma is the most frequent primary malignancy of the pancreas with a very poor prognosis. New treatments, as focal destruction technologies among them high intensity focused ultrasound (HIFU), are required to improve this prognosis. The fear of such technologies is that thermal destruction of pancreas expose to severe pancreatitis with dramatic consequences. The aim of this study was to demonstrate the safety and efficacy of intra-operative HIFU in an animal model. Methods: In a porcine model (n=24), a single HIFU ablation was performed either in the body/tail of the pancreas, distant to superior mesenteric vessels (n=12) or in the isthmus through contact with the superior mesenteric and hepatic vessels. All animals were sacrificed the 8th day for body/tail ablations and the 30th day for isthmus ablations. The objective was to obtain an HIFU ab-

lation of the pancreas measuring at least 1cm in all diameters without premature death. Results: In total, 24 HIFU ablations were carried out. These ablations were performed within 160 seconds and on average measured 20mm x 16mm. Neither premature death, nor severe complications occurred. Six pigs had an asymptomatic hepatic artery thrombosis. The HIFU treatment was associated with a transitory increase in amylase and lipase levels. The ablations were visualized with intraoperative ultrasound as hypoechogenic images. All HIFU ablations were well delimited at both gross and histological examinations. Conclusion: Intraoperative thermal destruction of porcine pancreas with HIFU is effective and safe and could offer a new hope in the treatment of pancreatic cancer.

Tue 9:30 Main Hall Bio-medical ultrasound for therapy (poster)

Iterative time reversal simulation for selective focusing in multi-target nonlinear media – (Contributed, 000165)

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In High Intensity Focused Ultrasound (HIFU), beam focusing can be achieved by multichannel arrays using time-reversal focusing. When multiple targets are present in a homogeneous medium, the time-reversal mirror needs to work in an iterative mode in order to focus on the strongest target and the effectiveness has been confirmed. However, the validation of iterative time reversal in layered nonlinear human tissue still needs to be investigated.
In the study, a layered biological model containing multiple reflective targets with different impedance is created. A finite difference method in two-dimension is used for the numerical simulation. During the simulation, the ultrasound wave is generated by one of the transducer elements, scattered by the reflective targets, collected by the transducer array, time reversed and re-emitted. The procedure iterates until the acoustic beam focuses on the strongest target. To evaluate the effectiveness of beam focusing, simulations are conducted for layered media with variable nonlinearity parameters and absorption coefficients.

Results from numerical simulations show that iterative time reversal works in both layered linear media and nonlinear human tissues. When the targets have similar reflectivity, it takes more iterative steps to focus most of the energy onto the strongest target. The nonlinearity parameter of the media affects only the focusing intensity, while the absorption coefficient affects both intensity and position of the focal spot.

Tue 9:30 Main Hall Bio-medical ultrasound for therapy (poster)

Uncertainty of Temperature Measurement during Therapeutic Ultrasound Sonication – (Contributed, 000639)

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Motivation
Ultrasound therapy has gained increasing attention to cure a growing number of diseases. Next to destroying tissue by the induced heat it is possible to aim at the protracted biological reactions of treated cells or the immune system. As ultrasound therapies get more common, safety concerns like the acoustical output of therapy devices or the accuracy of treatment plans do, too. Measuring the temperature differences in phantoms induced by intensive ultrasound sonication could meet those requirements. We compared two temperature calculation methods and evaluated the attainable accuracy.
Methods
A promising method of measuring temperature differences caused by the therapeutic ultrasound device uses diagnostic ultrasound and a phantom located in a waterbath. A change of temperature mainly causes a change in the speed of sound and therefore a time-shift in the measured backscattered RF-signal. The time-shift therefore can be used to calculate the difference to a baseline temperature. In our investigations it was once calculated as a discrete value to the preceding frame and was added to the previous shifts. Second it was calculated as a continuous value directly to the base-frame. To assess uncertainty the formulas where theoretically deduced and applied to the second time-shift calculation method.

Results

For accurate temperature assessment time-shifts should be calculated directly to the base-frame and continuously. Main influences on accuracy are filtering and fitting methods used during data processing as well as the accuracy of a conversion factor. The uncertainty of temperature calculation was less than 11% in the focus zone.

Tue 9:30 Main Hall Bulk wave NDT/E: modelling and simulation (poster)

Application of Waterman-Truell and the Dynamic Generalized Self-consistent Models to Concrete – (Contributed, 000194)

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The effects of water in immersed concrete structures can cause microfractures, this generally reduce the strength of the material, for this reason the concrete structures require a periodic evaluation of their structural integrity to ensure their optimal performance, the reason for using ultrasound to do that is due to its low cost and reliability. The concrete is a highly heterogeneous material which may be considered in a first approximation as a cement matrix with inclusions; when the concrete structures are immersed in water for a long time these inclusions can be saturated with water due to capillary which results in changes in the properties of the concrete. A simple model of the concrete saturated with water can be considered as the inclusions fill of water in a cement matrix. The propagation of an ultrasonic wave in concrete can be analyzed using the theory of scattering proposed by Waterman-Truell and the self-consistent dynamic generalized model proposed by Yang.

The effective phase velocity and attenuation are functions of the concentration of the inclusions in the matrix, the size of these and frequency of the ultrasonic wave,. In this work the phase velocity and the attenuation to several concentrations of inclusions are calculated, the changes in the phase velocity and attenuation due to the concentration of inclusions and the size of the them are shown in a graph. As a part of the results it is shown that the phase velocity increases when the frequency increases, besides, when the concentration of inclusions increases, and the size of the inclusions change it is noted that the phase velocity and the attenuation show changes.

Tue 9:30 Main Hall Bulk wave NDT/E: modelling and simulation (poster)

Research of Evaluation Method about Cement Bonding Quality of the Second Interface – (Contributed, 000228)

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How to evaluate cement bonding quality of the second interface has been a worldwide problem in acoustic logging field. This article researches measurement method of the second interface based on ultrasonic pulse echo by using the finite element method. The influence of different bandwidth and different acoustic impedance of formation on ultrasonic echo of the second interface is simulated numerically. With the increase of the bandwidth, echo amplitude of the second interface cement sheath decreases exponentially. With the increase reflection coefficient in the second interface, ultrasonic echo amplitude of the second interface increases gradually. The signal energy of the second interface can be effectively improved with the narrowband signal, so cement bonding quality of the second interface may be solved by this method.

Tue 9:30 Main Hall Bulk wave NDT/E: modelling and simulation (poster)

Analysis of transient acoustic radiation field from pulse-driven finite aperture piezoelectric transducer – (Contributed, 000330)

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Conventional analysis of the radiation filed from the finite aperture transducer has been conducted for the case when the plate was excited with continuous function such as Gaussian enveloped sine pulse. However, many of the piezoelectric transducer for the ultrasound devices are driven by the discontinuous function like unipolar rectangular pulse. To build an intended spatio-temporal acoustic field for the design of a device or a vibrator, it is important to analyze the transient radiation acoustic wave field under the actual discontinuous pulse excitation condition. Numerical analysis such as Finite Difference Time Domain (FDTD) method has a difficulty due to the requirement of extremely high amount of computer resources for the discontinuous transient field computation. To encounter the

problem, the analytical formula based on the Rayleigh integral was proposed assuming homogenous liquid medium. It is noted that diffusion process was incorporated into the conventional saptio-temporal impulse response of the transducer, considering the actual amplitude dependencies of radiation field in the far field. Using the method, behaviors of the spatio-temporal transient acoustic wave field were theoretically clarified. It is demonstrated that they are formed caused by the superposition of a primary plane wave and edge waves. They are much different from the conventional continuous wave excitation fields. Specifically, transient waves are propagating much longer distance, changing their waveforms dramatically with distance. In addition, they were compared to the experiment to show the validity of the proposed analysis.

Tue 9:30 Main Hall Bulk wave NDT/E: modelling and simulation (poster)

Parallel Computing for Real-time Topological Imaging – (Contributed, 000626)

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Recent developments of the topological imaging method that we developed are presented here. This imaging algorithm is close to adjoint-based inversion methods but relies on a fast calculation of the direct and adjoint fields formulated in the frequency domain. The radiation pattern of a the transducer array is computed once and for all, and then the direct and adjoint fields are obtained as a simple multiplication with the emitted or received signals, in Fourier domain. The resulting image represents the variations of acoustic impedance, and therefore highlights interfaces or flaws. Real-time imaging and high definition visualization both imply an expensive computation cost, that led us to implement this method on GPU (Graphics Processing Unit). Thanks to a massively parallel architecture and an high level programming language, like CUDA, GPUs have become for ten years a new way to implement high performance algorithms. We used interoperability between OpenGL and CUDA to avoid data transfers between CPU and GPU, and to enable a real-time visualization, showing a picture of the inspected medium meanwhile the next one is calculated. Experimental and numerical results obtained with scalar waves are presented. At this time, the method has been implemented for acoustic waves in fluids or longitudinal waves in solids, with an initial homogeneous medium, but it can be extended to elastic media and more complex configurations.

Tue 9:30 Main Hall Device technology (poster)

A multiplexed 2D-ring antenna for Ultrasonic Computed Tomography – (Contributed, 000043)

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This paper is focused on the development of a multiplexed 2D-ring antenna for Ultrasonic Computed Tomography (UCT) to assess the imaging of elastic tube (such as long bone). The crown of the antenna has an inner radius of 150 mm and supports first, 8 fixed transducers distributed in 360° ($\Delta\theta = 45°$), and second, a 128-element array. The object to be imaged is positioned in the supposed geometrical center of the antenna. The 8 transducers and the 128-element array are Imasonic® piezo-composite transducers with a central frequency of 1MHz, and 3MHz. Transducers and array have a cylindrical focusing in the plane of the slice, (Transducers: lateral x axial aperture 40 x 40mm, slice thickness 3mm, Array: lateral x axial aperture 10 x 50mm, slice thickness 3mm) adapted for ultrasonic tomography. The Mistras-Eurosonic® multiplexer excites 8-by-128 channel phased array, and permits the formation of arbitrary wave forms (such as pulse, chirp, wavelet), and beam forming over 8 independent channels. Transmitted and received ultrasonic RF-signals were digitized (12 bit, 40 MHz). By means of step-by-step motors and of an electronic set-up of the mechanical movements, the crown can turn 45° degrees in increments of (1/100) degrees and move vertically to carry out many slices (200mm). In this presentation, we present results obtained on rectified circular and non-circular cylindrical tubes, and on long bones sample.

Tue 9:30 Main Hall Device technology (poster)

Development of a multichannel pulser for acoustic scanning microscopy – (Contributed, 000062)

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Modern ultrasound imaging technics use arrays to manipulate an ultrasound beam and to gather additional information out of the reflected sound field by analysing the received signal of each channel. For further wide-ranging applicability it is required to achieve a higher resolution by increasing the frequency of excitation signals and improvement of the signal to noise ratio. Actually neither the electronic hardware nor high-frequency transducers are available that meet these requirements, so that a further development of the control-electronics is indispensable.
Therefor the ultrasound pulser presented in [1] was improved with respect to the generation of various excitation signals. A unit consisting out of 16 channels has been developed concluding the technology to control these channels as well as to record and to process the received signals. It provides different types of excitation-functions with an excitation-frequency up to 20 MHz. Additionally the modularised layout allows an extension to control much more elements.

All presented improvements are realised in a new ultrasound pulser that offers emission of arbitrary signals on each single channel. Of course the measurements raw data is accessible and different optional data processing functions are selectable.

[1] Norbert Gust, Falk Schellhorn: "High frequency 16 channel ultrasonic microscope for annular arrays", IEEE International Ultrasonics Symposium, 2012, 2435-2437

Tue 9:30 Main Hall Device technology (poster)

Evaluation of mechanical losses in piezoelectric plates using genetic algorithm – (Contributed, 000111)

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Characterization of piezoelectric ceramics is fundamental for the optimal design of ultrasonic transducers and for the understanding of losses process. A procedure based on genetic algorithm is applied to find elastic coefficient, dielectric permittivity, electromechanical coupling factor and mechanical losses of piezoelectric ceramics. These parameters are estimated from a minimum scoring of cost function defined as mean square error between experimental and computed electric impedances. Electric impedances are calculated from Mason's model including mechanical losses. The procedure has been applied for the characterization of piezoelectric ceramics (rings and disks) at frequencies around to the thickness vibration mode regarding two models: (a) mechanical losses constant and; (b) mechanical losses depending on frequency as a linear function. The results show that the electric impedance percentage error inside the investigated interval of frequencies decreases when mechanical losses depending on frequency is inserted in the model. In the studied cases, we have found some vibration modes where the decreasing is until three times. We have concluded that for a more accurate characterization of the piezoelectric ceramics mechanical losses should be considered as frequency dependent.

Tue 9:30 Main Hall Device technology (poster)

Electrical Interfacing Circuit Discussion of Galloping-Based Piezoelectric Energy Harvester – (Contributed, 000597)

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In this paper, the modeling, equivalent circuit and electrical interfacing circuit of the galloping-based piezoelectric flag energy harvester is proposed and discussed. The nonlinear synchronized switching technique SSHI (synchronized switching harvesting in Inductor) is used to increase the power efficiency and through the equivalent circuit model of the piezoelectric flag, the whole system can be simulated together to compare the different interfacing circuits results. In the past decade, energy harvesting from ambient is highly focused and by using a cantilever beam to be the host structure converted the vibration energy is the most popular topics. Except using cantilever beam be the host structure, during recent few years, piezoelectric flag or plate converted the flow energy has been widely invested. In previous studies, the piezoelectric patches are shunted with the resistors as the load to estimate the power output. As the interfacing circuit is the important design part to increase the power output, in this paper the SSHI technique is used with piezoelectric flag. Equivalent circuit of the piezoelectric flag and the interfacing circuit are simulated by Matlab and PSIM software. Several interfacing circuit including standard DC approach, SSHI technique and transformer-based SSHI technique are proposed and compared. Simulations and experimental results show the optimal interfacing circuit in piezoelectric flow energy harvester.

Tue 9:30 Main Hall Device technology (poster)

Study of Vertical Sound Image Control Using Parametric Loudspeakers – (Contributed, 000006)

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A parametric loudspeaker utilizes nonlinearity of a medium and is known as a super-directivity loudspeaker. The parametric loudspeaker is one of the prominent applications of nonlinear ultrasonics. So far, the applications have been limited monaural reproduction sound system for public address in museum, station and street etc. We had discussed characteristics of stereo reproduction with two parametric loudspeakers by comparing with those with two ordinary dynamic loudspeakers. In this paper, the sound localization in the vertical direction using the parametric loudspeakers was confirmed The direction of sound localization was able to be controlled not only when the acoustical axis was set to the right ear but also when it was set to rightward 5 degrees far from the right ear. The results were similar as in using ordinary loudspeakers. However, by setting the parametric loudspeaker the right ear, that is by setting it only 3 degrees rightward, the direction of sound localization moved about 10 degrees rightward. Moreover, by setting it 5 degrees rightward, the direction of sound localization moved about 20 degrees rightward. The measured ILD (Interaural Level difference) using a dummy head were analyzed. The reason of the interesting characteristics was clarified.

Tue 9:30 Main Hall Device technology (poster)

High power electromechanical characterization of piezoceramic elements and low frequency ultrasound transducers by using algorithm for tracking changes in resonant frequency and electrical impedance – (Contributed, 000073)

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Electromechanical and acoustical characterization of PZT piezoceramic elements and high-power ultrasound horn transducers has been done around resonance frequencies in order to determine the features of the models that describe the considered devices, both as equivalent circuits and as nonlinear oscillators. Several measurement methods have been compared, including the frequency- sweeping method with constant excitation voltage, the voltage magnitude- sweeping method at a constant excitation frequency and the method that uses impulse excitation. The parameters that describe the losses in a coupled nonlinear electro- mechanical-acoustical systems, like active piezoceramic elements and assembled ultrasound transducers, greatly depend on the type of excitation and its level. A novel algorithm is tested, designed for tracking the changes of the series and parallel resonance frequency and impedance magnitude and phase with the excitation level. It enables a more precise determination of the resonance frequency and impedance changes over different levels of excitation, which is especially important in high-power ultrasound resonant applications. The characterization based on frequency sweeping at different excitation levels is influenced by changing electrical parameters (current, voltage, power) due to different complex loading of the excitation amplifier and the changes of thermodynamic conditions. The characterization of horn transducers in loaded condition through frequency sweeping at higher signal levels gives no results when cavitation in front of the sonotrode tip appears, because the impedance magnitude changes significantly at higher excitation voltages. Using the tracking algorithm, the impedance magnitude at resonance frequency has been determined in a range of different excitation levels up to 50 V_{RMS}. After the onset of nonlinear effects like cavitation in front of horn transducers, the impedance magnitude increases significantly due to viscosity effects.

Tue 9:30 Main Hall Device technology (poster)

Introduction of an All-Optical, High-Sensitivity, Large-Bandwidth Ultrasound Sensor: From Lab to Market – (Contributed, 000637)

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Microphones have been around for more than one hundred years. Yet the fundamental principle of their functionality - to put it roughly - hasn't changed much over time. All transducers have in common, that the sound pressure acts on a mechanically movable or deformable part, such as a deflectable membrane, a bendable cantilever or a deformable piezoelectric material.
The presented membrane-free optical transducer exploits another, completely different property of sound: namely the fact that it can change the speed of light! The pressure-induced change of the optical refractive index proportionally changes the laser wavelength, which is detected by means of a very rigid, miniaturized multi-pass interferometer with 2mm optical path length. Refractive index changes below 10e-14 are detected with this technology. Due to the absence of mechanical resonances, the transducer has an outstanding frequency bandwidth (10Hz to 1MHz in air, up to 50MHz in liquids) with a (transduction-inherent) linear frequency response. A small sensor size (2mm by 4mm footprint) combined with a low a detection limit in the μPa/sqrtHz range could make this novel acousto-optic transducer an interesting option for cutting-edge ultrasound detection in gas and liquids.

The transducer currently is at the stage of commercialization. Target areas of application include ultrasound metrology, process control in industrial applications, air-coupled non-destructive testing and medical imaging, with a focus on photoacoustic imaging.

Tue 9:30 Main Hall Physical acoustics (poster)

Full characterization of rigid porous material through ultrasonic reflected waves at oblique incidence – (Contributed, 000236)

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An improved method is proposed for measuring porosity, tortuosity, viscous and thermal characteristic length of porous materials having a rigid frame via reflected ultrasonic waves at oblique incidence. The conventional ultrasonic approach can be used to determine all the parameters via transmitted waves [1] or using the first and second reflected waves at normal incidence[2] (the ratio between the viscous and thermal characteristic lengths is fixed as in classical acoustic methods [3,4]). The advantage of the proposed method is that the four parameters are determined simultaneously just using reflected experimental waves for a porous material saturated by air. In addition, no relationship is assumed between the two characteristic lengths. The inverse problem is solved based on the least-square numerical method using experimental reflected waves in time domain. Tests are performed using industrial plastic foams. Experimental and numerical validation results of this method are presented.

Reference: [1] ZEA Fellah, M Sadouki, M Fellah, F. G Mitri, E Ogam, C Depollier." Simultaneous determination of porosity, tortuosity, viscous and thermal characteristic lengths of rigid porous materials" J. Appl. Phys, 114, 204902 (2013). [2] Z. E. A. Fellah, M. Fellah, W. Lauriks, and C. Depollier, ëëDirect and inverse scattering of transient acoustic waves by a slab of rigid porous material" J. Acoust. Soc. Am. 113, 61-73 (2003). [3] C. Ayrault, A. Moussatov, B. Castagne'de, and D. Lafarge, ëëUltrasonic characterization of plastic foams via measurements with static pressure variations" Appl. Phys. Lett. 74, 3224-3226 (1999). [4] A. Moussatov, C. Ayrault, and B. Castagne'de, ëëPorous material characterization-ultrasonic method for estimation of tortuosity and characteristic length using a barometric chamber" Ultrasonics 39, 195-202 (2001).

Tue 9:30 Main Hall Physical acoustics (poster)

Lamb Type Surface Wave in Piezomagnetic Layer – (Contributed, 000246)

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In this paper we considered the elastic SH waves coupled with electromagnetic wave of TM polarization in a layer with piezomagnetic properties of the orthorhombic 222, mm2. Wave dispersion equations are obtained. Demonstrated the existence of similar modes symmetric and antisymmetric Lamb modes in piezomagnetoelastic plate. Boundaries of layer metallised. Wave components of elastic and electromagnetic wave vectors along Z axis. By using matricant method [1-3] for piezomagnetic media the cases of the metallized surfaces and the free (vacuum) surfaces of layer are considered. The interaction between elastic and electromagnetic waves in piezomagnetic is considered on a joint equation set of motion of elastic media and the Maxwell's equations for electromagnetic field. An analytical solution of matrix equation and dispersion equation by using matricant method in explicit analytical form are obtained. The existence a symmetric and an anti-symmetric modes of this coupled waves are shown. Analytical form of this expression is analogical with equation for Lamb waves modes. There are shown the limiting cases as attention is focused on the analysis of situations where the modes of plane wave conversion derived on the basis of the electromagnetic theory differ significantly from the calculated within the frame of the quasi-electrostatic approximation. [1] Tleukenov S.K. A method for the analytical description of coupled-field waves in various anisotropic media // Acta Mechanica. 2014. Vol. 225. N°4-5. - P. 1-12. [2] Tleukenov S.K., Wave processes and method matricant//Scientific journal of L.Gumilyov Eurasian National University, 2011.no.4, p. 68-74. (in Russian) [3] Tleukenov S.K., Dosanov T.S. On the propagation of waves in an infinite piezomagnetic anisotropic medium orthorhombic classes 222, mm2, mmm with piezomagnetic effect//Proceedings of the National Academy of Sciences of Kazakhstan - 2009 - N°5.

Tue 9:30 Main Hall Picosecond laser ultrasonics (poster)

Fully passive femtosecond time-resolved common-path interferometer in reflection mode – (Contributed, 000405)

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Femtosecond time-resolved interferometry has been developed since teh 80's in nonlinear optics, laser-dielectric interaction, THz optical switching and THz acoustics. Up to now, double-path interferometers (Michelson or Mach-Zehnder) or common-path interforemeters (Sagnac) have been broadly used. An innovative method is proposed here to perform femtosecond time-resolved interferometry in reflection mode. The reflection mode is ideally suited to study opaque samples or to perform time-resolved Brillouin spectroscopy. The technique we present relies on the combined use of a pump-probe setup and a fully passive femtosecond common-path interferometer in reflection mode. Originality of this interferometer rests on the use of a single birefringent crystal first to separate the reference and probe pulses and second to combine them to get intereferences. We first present here the principle of operation of the interferometer. Then, through the analytical modeling of the interferometer with the Jones formalism, we show how can be inferred the temporal derivative of either the real part or the imaginary part of the reflectivity coefficient of the sample. We finally illustrate the performance of the interferometer by detecting longitudinal acoustic waves bouncing back and forth in a thin film.

Tue 9:30 Main Hall Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" (poster)

Traveling Surface Acoustic Waves Microfluidics – (Contributed, 000127)

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In a microfluidic system, standing surface acoustic waves (SSAWs) have been used to manipulate micro-objects. A pair of interdigitated transducers (IDTs) is usually used to generate SSAWs, however, a single IDT has also been reported to produce a similar effect. In a parallel domain, traveling surface acoustic waves (TSAWs) produced by a single IDT have been used to efficiently actuate (mix, pump, nebulize) fluid on a microfluidic platform. Recently, TSAWs have shown promising potential in dexterous handling (separation, sorting, trapping) of micro-objects in a micro-sessile droplet or inside a microchannel. The present study is focused on the use of TSAWs for micro-object manipulation and micro-fluid actuation inside the microchannel. The actuation of micro-fluids via TSAWs is dependent on the acoustic streaming flow (ASF) generated by the dissipation of acoustic waves in the fluid, whereas the manipulation of micro-objects depends on the acoustic radiation force (ARF) derived from TSAWs' frequency, particles' diameters and relative densities of the fluid and particles. The ASF is produced in conjunction with the ARF. A κ factor, directly proportional to the diameter of the particle and TSAWs' frequency, is used to characterize the different behaviours of the particles under the effect of TSAWs. For $\kappa>1$, the ARF on the particles dominates the drag force induced to the particles via ASF. For $\kappa<1$, the particles are so small to be effected by the ARF and the effect of ASF dominates. We have taken advantage of these promising effects to separate microparticles and controllably actuate fluids inside the microchannel.

Tue 9:30 Main Hall Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" (poster)

ultrasonic enrichment of flowing blood cells in capillars: influence of the flow rate – (Contributed, 000296)

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Red Blood cells subjected to standing waves collect at the pressure nodes during their flow motion. Blood is a non-newtonian fluid, whose density and other properties are defined by its flow velocity. Depending on their concentration, the red cell drift motion is governed not only by the radiation forcé acoustically induced, but also by the hydrodynamic conditions established in the sample, defined by the cell concentration and the cell-cell interactions. This work presents a study of the red cell enrichment performed by ultrasounds in a rectangular capillar as a function of their flow motion. Very low flow rates don't favor the cell collection to achieve good results of plasmapheresis. On the contrary, the cell enrichment at the pressure node is enhanced with the flow raise. The cells collect to form a long chain of red cell aggregates along the capillar length in very few seconds of acoustic treatment.

Tue 9:30 Main Hall Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" (poster)

Ultrasonic Microfluidic Actuation with Secondary Bjerknes Forces on Bubbles – (Contributed, 000417)

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In the last decade, the development of microfluidics has motivated the search of new actors that could help handling small objects in laminar flows. Combining various force fields has proved to be a good strategy in classical issues such as particles detection and sorting, drop coalescence, mixing, etc. In the area of physical acoustics, the Bjerknes force, that occurs when an immersed compressible medium undergoes a pressure fluctuation, appears as a potential nominee for microfluidic actuation. In this talk, we will present an original experiment that allows us to follow the trajectory of a free bubble attracted or repelled by one or several fixed bubbles, under the action of an external acoustic field. The role of the frequency of the acoustic excitation and the radii of the bubbles will be emphasized. We will discuss a potential application for guiding bubbles through a microfluidic device.

Tue 9:30 Main Hall Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" (poster)

Surface Acoustic Wave Based Cell Measurements in a Disposable Chamber – (Contributed, 000484)

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Biophysical properties of tumor cells are important for biomarkers, informing medical diagnostics, as well as biology research. In particular mechanical properties of cells have been linked to tumour aggressiveness. Existing methods to measure these mechanical properties, including atomic force microscopy, are bulky, invasive and require time consuming analysis. Here, we demonstrate a technique to investigate mechanical properties such as compressibility and bulk modulus of human breast cancer cells (MCF-7) in a disposable chamber using surface acoustic waves (SAW). This system was implemented on disposable microchips in a non-invasive fashion. When the commonly used techniques usually give access to the Young's modulus, this technique provides access to the compressibility of the cells (or bulk modulus). We used slanted interdigitated transducers (SIDTs) patterned on a lithium niobate ($LibNO_3$) substrate to generate a wide range of acoustic excitation frequencies (3MHz - 6MHz) using a signal generator (TG5011 TTi) and a power amplifier (Mini Circuits ZHL-5W-1). The waves were coupled with a glass coverslip superstrate, using water as the coupling agent and sample was loaded in a 3D printed microfluidic disposable chamber. The system was first characterized using polystyrene beads, enabling us to locate the pressure nodes of the standing wave field created by the reflected waves. We then introduced MCF-7 cells in phosphate buffer in the system. By adjusting the SAW wavelength (400μm to 1000μm) and the power of the excitation (0.252W to 1.585W) the cells were positioned onto the pressure node of standing wave. Tracking the cells under a microscope with a 10x/20x objective lens and camera (Zeiss Axio Observer), enabled us to extract viscous and acoustic force applied to the particles. We found the compressibility of MCF-7 cancer cells of density 1,068 Kg/m^3 to be $4.124 \pm 3.24\% x 10^{-10} Pa^{-1}$ or the bulk modulus $2.41 \pm 3.97\%$ GPa. These results are in close agreement of published works ($\pm 2\%$). The system developed offers a disposable system which can easily be integrated within lab-on-a-chip technologies for studying biophysical properties of cells through non-invasive methods.

Tue 9:30 Main Hall Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" (poster)

Acoustic separation of cells and particles in a single laminar flow stream – (Contributed, 000427)

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A novel acoustophoresis-based method has been developed that allows for continuous separation of cells and particles in a single flow-stream without the use of hydrodynamic pre-positioning of the sample before separation. The method is characterized demonstrated by separation of 5-μm and 7- μm particles. The usefulness of the method is demonstrated by separating prostate cancer cells from white blood cells.
Acoustophoresis for separation of cells has previously necessitated the use of a cell-free liquid to pre-position the sample before the separation. In this work, cells are instead pre-positioned using two-dimensional pre-alignment into two pressure nodes, allowing for particle separation within the initial suspending medium. In addition to simplifying the fluidic setup, the method eliminates the need for acoustically matched fluids. The extension of this zero-dilution approach holds promise of an increased throughput since the flow velocity in the sorting channel is reduced.
The chip consists of a pre-alignment channel (300 μm by 150 μm) operated at 5 MHz and a separation channel (375 μm by 150 μm) operated at 2 MHz. The sample flow rate was kept at 100 μL/min and the outlet flow rates were 25 μL/min in the centre and 75 μL/min in the sides outlet, as simulations indicated this to be the optimal ratios.
Using this microchip $99.6 \pm 0.2\%$ 7-μm particles could be collected though the centre outlet while $98.8 \pm 0.5\%$ of the 5-μm particles were collected though the sides outlet. $86.5 \pm 6.7\%$ of the cancer cells could be recovered with a contamination of only $1.1 \pm 0.2\%$ of white blood cells.

Tue 15:00 Main Hall Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics (Special Session in Honour of Professor Emeritus Oswald Leroy) (poster)

Acousto-optical deflector with great angular aperture on new $KLu(WO_4)_2$ crystal – (Contributed, 000408)

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With the progress of laser technologies, new crystalline materials are synthesized and utilized. The crystal $KGd(WO_4)_2$ (short: KGW) is one of the most famous due to a very high threshold of laser damage: up to 170 GW/cm^2. It is widely used in laser technics as lasing material. Moreover, it has rather good acousto-optical properties, as well as the group of double potassium rare-earth tungstates $K\mathit{RE}(WO_4)_2$, where RE = Yb, Lu, and Y. It has been demonstrated that their AO figure of merit M_2 is comparable with that of $LiNbO_3$ and better than M_2 of SiO_2. Moreover, these monoclinic crystals are optically biaxial, transparent in visible and infra-red ranges (0.4-5.5 μm), and demonstrate significant anisotropy.
The fact that K*RE*W crystals are biaxial materials makes possible the development of new kinds of AO units on their base, which can not be made with use of uniaxial crystals usually utilized in acousto-optics. For example, the acousto-optics deflector with angular aperture up to 2° for incident light could be maid on $KLu(WO_4)_2$ (short: KLuW) crystals. For this purpose, the diffraction geometry with ultrasound wave vector being a tangent to wave surfaces of two optical modes should be used. In this case beams with wide angular spectrum can be diffracted efficiently while the deflection angle is proportional to acoustic frequency. Such deflector can operate with angular-extended beams, in particular, profiled laser beams, focused radiation, etc. And also, the switching time of a high-speed AO modulator is approximately equal to the acoustic transit time through the waist of the focused beam, estimated as 20 ns or less.
A promising AO element is suggested, which can control high-power profiled laser beams. It is capable to operate with more intensive laser beams than the existing TeO_2 deflectors, though it requires somewhat higher driving frequency.

Tue 15:00 Main Hall Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics (Special Session in Honour of Professor Emeritus Oswald Leroy) (poster)

Acoustooptic Figure of Merit Search – (Contributed, 000306)

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Acoustooptic (AO) devices launch an acoustic wave into an optically transparent crystal to diffract optical light. The diffraction efficiency of the device depends on the propagation direction and polarization of the acoustic wave and the incident and diffracted optical waves. We present a method for searching for Bragg matched AO geometries that provide large optical diffraction efficiencies of specific materials.
Our search method sweeps in spherical coordinates the propagation directions of the acoustic waves. For each propagation direction, there are three acoustic eigenmodes. For each acoustic wave we solve all possible Bragg-matched AO geometries including ordinary-to-ordinary, extraordinary-to-extraordinary, and ordinary-to-extraordinary optical polarization diffraction. We calculate an AO figure of merit M_2 to determine the diffraction efficiency of an AO geometry. From our search method, we can appraise the various possible geometries for AO applications in a crystal.

We have applied our search algorithm to known AO materials such as Te_2 and KDP and have discovered novel, efficient geometries. In addition we have explored new, in regards to acousto-optics, crystals including α and β-Barium Borate and have analyzed their potential for AO devices.

Tue 15:00 Main Hall Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics (Special Session in Honour of Professor Emeritus Oswald Leroy) (poster)

Discrete Diffraction of Light in 1D Photonic Lattice Induced in Lithium Niobate by Means of the Pyroelectric Effect – (Contributed, 000257)

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Light propagation in nonlinear medium may result in conversion of its spatiotemporal structure due to the self-action effects. As the result of the self-action spatial solitons may form in experiments including those in periodic optically induced photonic lattices (PL‘s). In some ferroelectric materials the spatial soliton regimes can arise at very low optical intensities due to both, the photorefractive and pyroelectric mechanisms of their nonlinear optical response. In this work we experimentally demonstrate the formation and the storage properties of pyroelectrically induced waveguide elements and 1D PL‘s within lithium niobate samples and the discrete diffraction of light within such PL‘s. 1D PL‘s with spatial periods from 12 to 20 micrometers are induced in crystal samples of various cuts using either, holographic two-beam coupling or optical projection schemes. In the projection method we image the 1D amplitude grating pattern onto the crystal input or top surfaces. The PL parameters are studied with light beam diffraction when it propagates as along waveguide layers as in the direction normal to the PL plane. In various experiments we compare the parameters of PL‘s formed with and without the pyroelectric effect contribution to the crystal nonlinear response. The discrete diffraction of light within PL‘s is studied both, in linear and nonlinear regimes with single-element excitation of light within the waveguide systems. The light wavelength of 633 nm (He-Ne laser) or 532 nm (YAG:Nd laser) are used in these experiments. The effect of gap soliton formation in pyroelectrically induced 1D PL‘s in nominally undoped lithium niobate samples is demonstrated in the experiments.

Tue 15:00 Main Hall Acousto-Optic Interactions and Wave Phenomena in Optics and Acoustics (Special Session in Honour of Professor Emeritus Oswald Leroy) (poster)

Acousto-Optics as an Efficient Method for Physical Measurements – (Contributed, 000641)

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In addition to acousto-optic information processing and manufacturing of such devices, the interaction between optical and acoustic waves are an efficient method for physical measurements. The paper analyses the potential of the acousto-optic method for measurement and investigation of crystal properties. It also presents some examples of this method applied to such measurements and investigations. As the acousto-optic interaction is essentially a diffraction of a flat light wave by a diffraction grid created by an acoustic wave, the main diffraction relation determines the potential and features of acoustic measurements. Each parameter of the main relation can be detected and measured provided that the other parameters in the main relation are determined. Optical and acoustic sources together with a medium of efficient interaction are required to use the acousto-optic method. The following measurements are possible for physical field characteristics: of the electro-magnetic nature, of the mechanical nature, properties of the interaction medium and its orientation parameters for the experimental device, and parameters of complex RF signals. For the acoustic fields, the following measurements are possible: acoustic mode velocities for selected propagation directions and crystal planes, conditions for acoustic mode attenuation, reflection, refraction, and transformation, their diffractional effects. The acousto-optic implementation of the pulse-phase method is used for acoustic velocity measurements. Velocities in an arbitrary directions can be measured using the Shaeffer-Bergman method together with the pulse-phase method. The matrices of crystal elastic coefficients can be evaluated using the Shaeffer-Bergman patterns, using the minimum number of tested samples. The Schlieren image method can give information both on the characteristics of acoustic and optical fields. An accurate estimation of sample optical homogeneity can be performed using those images. This estimation is very important when investigating the quality and growth features for multi-component crystal samples.

Tue 15:00 Main Hall Cardiovascular ultrasound image and signal analysis: a powerful tool toward valid, non-invasive and low-cost disease diagnosis (Poster)

Effect of occlusions on cerebral blood flow in an anatomical replica of the circle of Willis – (Contributed, 000636)

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The Circle of Willis (CoW) is the main collateral route in the cerebral circulation in the event that one of the arteries supplying it becomes blocked or narrowed. Many anatomical variations exist in the CoW which reduce its compensatory capacity and increases the risk of stroke and TIA, Henderson et al, (2000).Vascular phantoms provide a research tool for investigating blood flow under normal physiological conditions. They can also enhance our understanding of flow distribution under pathological conditions. This experiment aims to Ï Implement a steady flow in a physical model of CoW Ï Test theoretical predictions of flow in the open replica by timed collection from the replica outlet (middle cerebral artery (MCA), posterior cerebral artery (PCA) and anterior cerebral artery (ACA) outlet). Ï Test the effects of occlusion of the ICAs and VAs on cerebral blood flow in the open model. Our model Circle of Willis was incorporated into a flow-rig producing a steady flow at a rate of ∼454 ml/min, with a flow division between internal carotid arteries (ICAs) and basilar artery (BA) of 75:25% respectively. Common carotid arteries input pressure were adjusted to be ∼100 mmHg, to investigate flow rates in the anterior, middle, and posterior cerebral arteries and to investigate the effects of occlusion of the supplying arteries in comparison to theoretical predictions. Our results show that the total cerebral blood flow and contribution flow rates of the anterior, middle, and posterior cerebral arteries were consistent with alastruey's theoretical predictions. The Right MCA flow rate was lower than from the Left MCA .Our results suggest that the ICA occlusion is more critical than the basilar artery occlusion and that the greatest reduction in the mean cerebral outflows happened when the RT ICA and contralateral anterior cerebral artery A1 were occluded

Tue 15:00 Main Hall Device technology (poster)

Quasi-field Method For Calculation of Surface Acoustic Wave Device's Characteristics – (Contributed, 000054)

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Nowadays for accurate design of microwave surface acoustic wave (SAW) devices rigorous but resource-intensive coupled finite element/boundary element methods or field methods based on the Green's function are used. For fast calculations equivalent circuit, P-matrix and coupled-of-modes methods are usually applied. However, for these methods several phenomenological parameters must be defined, such as average SAW velocity, the reflection coefficient and others.
We propose a quasi-field method for calculation of SAW device's frequency responces (S_{21}) based on the accurate determination of the elastic displacements and electric potential of SAW and on simple and physically consistent equivalent circuit. This method allows modeling of arbitrarily complex shape device with interdigital transducer's (IDT) electrodes on the piezoelectric crystal surface or on the layered structure. In the proposed equivalent circuit, each gap between adjacent electrodes corresponds to the ideal current source. The calculation of the current in the electrodes based on the definition of the charge on electrode, induced by propagating SAW. The charge density is determined from the rigorous solution of the boundary problem on free and metalized surfaces of the substrate. Thereby, frequency response of IDT is defined as a ratio of released on the load electrical power, calculated by equivalent circuit approach, and modulus of strictly calculated Poynting vector of SAW.
The described method has been tested on several variants of filters and delay lines, and the calculation results are in good agreement with the experimental measurements. In contrast to mentioned modeling approaches, proposed quasi-field method doesn't contain any phenomenological parameters and doesn't require large computational resources.

Tue 15:00 Main Hall Device technology (poster)

Orthogonal wavelet deconvolution based-on system identification of electronic transfer function for ultrasonic signals in pulse-echo mode – (Contributed, 000161)

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Ultrasonic inspection techniques are widely used in medical imaging and non- destructive evaluation of materials especially the ones with optical opacity due to their quantitative and qualitative characteristics. Pulse-echo mode is privileged over the transmission mode as it is cost efficient and offers simple experimental set-up. However, it suffers from poor resolution. It could be improved using deconvolution techniques.
System identification method dedicates experiments to find a compact and accurate mathematical model of a dynamic system. Identification algorithm was used to identify the electro-acoustic transfer function of an ultrasonic system in pulse-echo mode. The algorithm used a recursive least squares to identify the model parameters of the transfer function. The input-output time domain series of the wavelet signals and their responses from the system were used. Once the transfer function was identified, a following deconvolution step was done using the same excitation wavelet signal to extract the supposed signal to be sent in the system in order to obtain the reconstructed wavelet. The algorithm was able to predict the response of the system for several input signals with robust performance. Simulation results using MATLAB© Simulink and experimental validation of results are presented.
The reconstructed wavelet signal obtained after the convolution with the whole electronic system shows a 98.7% fit with the original wavelet signal. Result manifests the conservation of the orthogonality when decomposed on dyadic grid corresponding to the scale J of non-zero coefficients. The method was validated for two transducers with central frequency of 1 and 2.5 MHz.
This modeling method provides an input-output black-box model for the whole electronic system including ultrasonic transducers, wave generator and signal routing multiplexers. The model was built without a priori knowledge of the manufacture characteristics and offers a robust transfer function to the electro-acoustic performance of the system.

Tue 15:00 Main Hall Device technology (poster)

Distributed force sensing using frequency response of acoustic waveguide made on a rubber substrate – (Contributed, 000304)

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Motivation Recently, demand for flexible and distributed load sensor is increasing in various fields such as tactile sensing in robot. However, conventional sensors have problems in lack of flexibility, complex wiring, and discrete position of measurement since they are based on electrical/electronic devices. We have developed a one-dimensional distributed load sensor utilizing acoustic frequency responses of an elastic tube. In this report, we newly propose a two-dimensional load sensor by fabricating an acoustic waveguide on a rubber substrate.
Experiment We made a 5-mm trench on a rubber substrate (50 mm x 50 mm x 5 mm), and attached a thin rubber film to cover the trench. The total length of the acoustic waveguide was approximately 160 mm. An earphone and a microphone were attached to the one of the ends of the waveguide. Continuous waves swept from 20 to 40960 Hz were applied with the earphone. The sound waves traveled along the waveguide, and a part of them is reflected at the load positions and other end of the waveguide. We estimated the load position by applying FFT for the power spectrum of the frequency response obtained with the microphone. The experimental procedure was repeated for 11 different load positions.

Results As a result, we successfully identified the load positions with the error of approximately 4 mm along the acoustic waveguide. This method provides a distributed load sensing without metal part, and is compatible to human skin. Thus, the proposed sensor would be useful for robotics and other human- related applications.

Tue 15:00 Main Hall Device technology (poster)

Short Lag Spatial Coherence Ultrasound Imaging Optimization by Reduction of 'Lag' Dependency – (Contributed, 000358)

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Speckle reduction in ultrasound images was extensively studied using various methods. It was shown that some reduction can be obtained by applying simple signal filtering or diffusion-based filtering. Another approach is based on the van Cittert - Zernike theorem. Although the theorem's applicability to the pulse-echo ultrasonic imaging was proved, we observe that short lag spatial coherence (*SLSC*) in its original form is characterized by low contrast in the area near the transducer, as well as time-consuming processing.
Modifications of the *SLSC* method to reduce these drawbacks are presented and analysed. The proposed approach removes dependency on the "lag" parameter between correlated signals and allows to implement the method without loss of the image quality (comparing signal to noise ratio and other image quality parameters in the resulting images obtained from tissue mimicking phantom measurements). Additionally, the results show contrast improved by 6dB in the upper part of resulting images in comparison to classical *SLSC*. The proposed algorithm implementation on General Purpose Graphical Processing Units (*GPGPU*) allows to efficient use of massive parallel execution paradigm and increase the reconstruction speed with this method over 10 times in comparison to the original one. Utilization of *GPGPU* allowed to achieve 25fps for a resulting image with the resolution of 128×512 pixels.

Tue 15:00 Main Hall High power ultrasound in materials engineering (poster)

Effects of High Power Ultrasonic Irradiation on the Microstructures and Mechanical Properties for Al-Si Alloys – (Contributed, 000198)

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Al-Si alloys are widely used in automobile industry due to their excellent castability, high weight-to-strength ratio, good corrosion resistance and good resistance to wear. The mechanical properties of the Al-Si alloys greatly depend on the microstructural features such as á-aluminium dendrites, primary Si, eutectic Si and intermetallic phases. Many efforts towards modification and refinement of the solidification structure have been made in order to improve strength and ductility of the Al-Si alloys. Among the various techniques, irradiation of high power ultrasonic into molten aluminum is one of the most effective means to refine the grain structure and intermetallic compounds and accordingly to improve the properties. In the present investigation, the effect of ultrasonic melt treatment (UST) on the microstructures and mechanical properties of a commercial hypereutectic Al-Si alloy (A390) was investigated. UST was applied directly to a melt at a temperature range of 750 $\sim$ 800oC with the input power of 1 kW at a frequency of about 19 kHz. The results showed that the irradiation of ultrasonic significantly refines the primary Si and also increase the strength by 20-40%. The refinement of the primary Si is explained by the well-known mechanism based on cavitation induced heterogeneous nucleation. However, the improvement of the strength is not explained simply by the refinement of the microstructures. Extensive microstructural analysis was performed to elucidate the enhancement of mechanical properties via irradiation of ultrasonic.

Tue 15:00 Main Hall Physical acoustics (poster)

Prediction of the Group and Phase Velocities of Acoustic Circumferential Waves by Fuzzy logic and neural network – (Contributed, 000007)

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In this work, a fuzzy logic system and an Artificial Neural Network (ANN) are developed to predict the velocity dispersion curves of the symmetric (S0) and antisymmetric (A1) circumferential waves propagating around an elastic cooper cylindrical shell of various radius ratio b/a (a: outer radius and b: inner radius) for an infinite length cylindrical shell excited perpendicularly to its axis. The group and phase velocities, are determined from the values calculated using the eigenmode theory of resonances. These data are used to train and to test the performances of these models. These techniques are able to model and to predict the group and phase velocities, of the symmetric and the anti-symmetric circumferential waves, with a high precision, based on different estimation errors such as mean relative error (MRE), mean absolute error (MAE) and standard error (SE). A good agreement is obtained between the output values predicted using the propose model and those computed by the eigenmode theory.

Tue 15:00 Main Hall Physical acoustics (poster)

Imaging of Geological Conditions Ahead of Drill Bit Using a Drilling Hole Dipole Source – (Contributed, 000143)

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In order to ensure a safety and effective drilling strategy, it is vital to get geological conditions ahead of drill bit in real-time. Current techniques, such as Drill Bit Seismic(DBS) and Seismic Measurement While Drilling(SMWD) have shortcomings in providing accurate information due to technical deficiencies such as long travel signal attenuation and noise aliasing. In the study, suppose that both the transmitters and receivers are located inside the drilling hole, the capability of waves excited by a dipole source inside a fluid-filled drilling well with surrounding and front formations in detecting geological reflectors is evaluated. Using a 3-dimentional staggered grid Finite Difference Time Domain (FDTD) method with a Convolution-Perfectly Matched Layer (CPML) absorbing boundary condition, a parallel computation scheme based on Message Passing Interface(MPI) on computer cluster is proposed to simulate wave propagation in different geological models. Propagation mechanism of compressional (P) wave and two types of shear wave(i.e., SH and SV waves) in the borehole, through the surrounding formation and on the reflectors ahead of the drill bit are studied in detail.The analyses show that SH wave has an advantage over P and SV waves in detecting reflections because of the wide energy coverage and good reflection sensitivity. The signals gathered inside the borehole can be used in indentifying shear wave velocity of the surrounding formation, the dip angle and the distance of the reflector ahead, etc.. It is indicated that dipole acoustic sources has the capability of detecting geological conditions ahead of the drill bit.

Tue 15:00 Main Hall Physical acoustics (poster)

Study of Elastic constants of Porous Silicon by using Two Different Methods – (Contributed, 000224)

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The investigation of the propagation characteristics of the surface acoustic wave in the porous silicon, using first, the acoustic microscopy and second the model of Biot, undergoes a great demand in scientific research. The objective of this work is to study the structure of porous silicon (Psi) by determining the elastic properties via acoustic microscopy and Biot theory. For non destructive testing via acoustic microscopy, the study of the basic parameters characterizing the elastic properties of materials (propagation velocities of different modes, elastic constants, etc.) occurs through acoustic signatures or V (z), which are recovered by the transducer, V, as a function of the defocus distance, z signal, when the sample is moved vertically to the acoustic lens. These signatures show a periodic oscillatory behavior. Thus, spectral analysis by fast Fourier transform (FFT: Fast Fourier Transform) allows the determination of the spatial period and therefore the velocity of propagation of the most dominant mode. In Biot's theory, the modeling domain requires the introduction of codes of digital simulation by finite differences or finite elements to determine the sensitivity of ultrasound parameters to the geometric, microstructural or material characteristics.

Tue 15:00 Main Hall Physical acoustics (poster)

Analytical Characteristics of SH-SAW in Orthorhombic Piezoelectrics Beyond Quasi-static Approximation – (Contributed, 000243)

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The conditions of existence the shear-horizontal surface acoustic wave (SH- SAW) and it's characteristics in explicit analytical form is successfully used in technological applications such as resonators, filters, sensors, and nondestructive evaluation of materials. Also known the ultrasonic methods for the measurement of the viscosity of liquids under high pressure by the Bleustein-Gulyaev SAW. This surface wave velocity and attenuation strongly depend on the boundary conditions on the waveguide surface which is viscoelastically properties. Usually for describe processes of SH-SAW high symmetry crystal models are used. Explicit analytical form for SH-SAW modes limited either to propagation in special directions, to the case where the free surface of the substrate is metallized and by using quasi-static approximation. Present study describes conditions of existence of SH-SAW on plane of orthorhombic crystals and it's characteristics in analytical representation. Main results carried out by using the matricant method [1]. The description of coupled elastic and electromagnetic wave propagation process based on the analysis of the joint solutions of equation of motion and Maxwell's equations beyond quasi-static approximation. Objective is to determine the cuts of anisotropic media where possible existence the Gulyaev-Bleustein SAW. Conditions for determine, decay factor into depth of elastic and electromagnetic waves for free surface case are obtained. Anisotropy of velocities of Bleustein-Gulyaev SAW for orthorhombic piezoelectric crystals of mm2 class are calculated for KNbO3 and KTA crystals. For considering SH-SAW a (4×4) dimentional matrix equation with W= (Uz,Txz,Ey,Hz) state-vector was used, wich describes the propagation of coupled SH waves and electromagnetic waves. An analytical fundamental solution of this matrix equation (matricant) by using matricant method in explicit analytical form are obtained for any cut.

[1] Tleukenov S.K. A method for the analytical description of coupled-field waves in various anisotropic media//Acta Mechanica.2014. Vol.225. #4-5.P.1- 12.

Tue 15:00 Main Hall Structural Health Monitoring (poster)

A gas leak and structural damage detector for spacecraft on- orbit based on two-staged acoustic sensors array – (Contributed, 000133)

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The probability of spacecraft on-orbit colliding with the space debris increases as the space trash in the earth orbit increases sharply. This project aims to distinguish the weak signal from the complex acoustics environment of spacecraft on-orbit, and to locate the sound source of broadband continuous acoustic emission signal. Meanwhile, it bases on the manufacture of two-staged acoustic sensors array and distributed A/D conversion and parallel data transmission. This project tries to put forward a new method to distinguish of weak leak signal from complex environment based on chaos method,to locate the leakage source based on the improved Beam Forming algorithm ,to assess the spacecraft damage used nonlinear ultrasonic method and to make a prototype at last.

Tue 15:00 Main Hall Structural Health Monitoring (poster)

Structural Health Monitoring of hollow cylinder using cross-corrélation of ambient noise field – (Contributed, 000604)

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On this article we focus on the development of a method to control the integrity of the tubular structure. The passive Structural Health Monitoring by the cross-correlation of the ambient noise field is studied. The method uses the induced vibrations by the fluid flow in pipes to extract information about the integrity of the structure. Results show convergence of cross- correlation function and sensitivity to the presence of an inhomogeneity between the two transducers. The cross-correlation of the noise field can be used for the control of tubes.

Tue 15:00 Main Hall Structural Health Monitoring (poster)

Structural Health Monitoring in Hollow Cylindrical Structures Using Helical Guided Wave Propagation – (Contributed, 000633)

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Defect detection and characterization are critical tasks for structural health monitoring of pipe-like engineering structures. Propagation and detection of ultrasonic helical Lamb waves using macro fiber composite sensors (MFC) is studied. Experiments for defect detection and characterization on an aluminum hollow cylinder (114 mm in outer-diameter and 6 mm of wall thickness) were carried out. An experimental setup using MFC sensors coupled to the cylinders surface in a pitch-catch configuration is presented. Time-frequency representation (TFR) using wavelets is employed to accurately perform mode identification of the ultrasonic captured signals. Also, a signal regeneration method is used to minimize the dispersion phenomena which allows implementing the regenerated signals in a proposed damage localization algorithm. The initial results indicate that the use of helical waves could let monitoring damage in difficult-to-access critical areas by locating the sensors only on a small region of the periphery of the cylindrical structure under inspection.

Tue 15:00 Main Hall Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" (poster)

Acoustic sorting and concentration of cancer cells – (Contributed, 000429)

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This abstract presents an acoustophoresis chip capable of sorting cancer cells (prostate cancer cell line DU145) from white blood cells (WBCs) and subsequently concentrating the recovered cells. The system aims to facilitate the handling and analysis of rare cell or dilute samples.
Circulating tumor cells are rare cancer cells that shed from a tumor into the blood stream and migrate to other tissues where they may form metastases. The number of circulating tumor cells is correlated to the aggressiveness of the tumor and isolation of them may also provide information of the primary tumor that can lead to more specialized treatments. Most isolation attempts today use antibodies targeting specific cell surface markers. No universal cancer cell marker has been found and the use of tissue specific markers involves the risk of losing subpopulations that do not express this marker. The label-free separation method acoustophoresis may thus provide information of new subpopulations otherwise undetected.
The chip, is composed of a pre-alignment channel (300 μm by 150 μm), a separation channel, and a concentration channel (375 μm by 150 μm). The pre-alignment channel was operated at 5 MHz and the separation and concentration channels at 2 MHz. The sample inflow rate was kept at 100 μL/min and the outflow rates were varied to modulate the final concentration of cancer cells.
Using this multifunctional chip 92 % of the cancer cells could be recovered and simultaneously concentrated 24 times with a contamination of only 0.6 % of the WBCs.

Tue 15:00 Main Hall Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" (poster)

Polymer-Shelled Ultrasound Contrast Agents in Microchannel Acoustophoresis – (Contributed, 000036)

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The aim of this work is to demonstrate the fundamental physical behaviors of stable micro-sized gas bubbles covered by polymer molecules under the presence of ultrasound standing wave (USW).
The experimental set-up consists of microfluidic chip coupled to the piezoelectric crystal (PZT) having the resonance frequency of about 2.8 MHz. The microfluidic channel consists of rectangle sono-cage and the width, w, of the cage was equal to one wavelength, λ ($\sim$535 μm) of USW. The superposition of horizontal and vertical standing waves in perpendicular to fluid flow resulting in formation of two pressures nodal at w/4 and 3w/4, and three anti-nodal planes at 0, w/2 , and w. The peak-to-peak voltage (Vpp) across the PZT was incrementally increased from 1 and 10.
Experimentally, the particles were translated and focused at the pressure anti-nodal planes under USW as similar to oil droplets. When the particles were dragged to the close vicinity to the pressure anti-nodal planes then the secondary radiation forces actively brings them to clusters at different spots along the channel. At 10 Vpp, the particles were accumulated at the pressure anti-nodal plane of about 0.46 seconds, while 5 μm blood phantom microbeads were accumulated at the pressure node of about 26 seconds. Theoretical prediction of the acoustic contrast factor, ϕ , of these particles was found to be negative and equal to -60.7.
Overall, the polymer-shelled gas bubbles are negative acoustic contrast particles and can be trapped at the anti-nodal plane. This phenomenon could be utilized to explore the future applications, such as bio-affinity and cell interactions studies.

Tue 15:00 Main Hall Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" (poster)

A Numerical Analysis of Phononic-Assisted Control of Ultrasound Waves in Acoustofluidic Devices – (Contributed, 000428)

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Motivation
The ability to precisely sort individual microparticles/cells/droplets in suspension is important for various chemical and biological applications such as cancer cell detection, drug screening etc. The past decade, label- free particle handling of particle suspensions by ultrasonic radiation forces and streaming has received much attention, since it relies solely on mechanical properties such as particle size and contrast in density and compressibility. We present a theoretical study of phononic-assisted control of ultrasound waves in acoustofluidic devices.

Methods
Our analysis is based phononic crystals diffraction gratings (PnC diffractors) [1]. These are artificial spatially periodic structures that lead to the formation of band gaps in the acoustic frequency spectrum, for which ultrasound cannot propagate through the crystal. We use a finite element method to design PnC diffractors near a microfluidic channel, and then using our previous methods [2], we calculate the influence of the these diffractors on particle acoustophoresis in the channel.

Results
We propose the use of PnC diffractors, which can be introduced in acoustofluidic structures. These diffractors can be applied in the design of efficient resonant cavities, directional sound waves for new types of particle sorting methods, or acoustically controlled deterministic lateral displacement. The PnC-diffractor-based devices can be made configurable, by embedding the diffractors, all working at the same excitation frequency but with different resulting diffraction patterns, in exchangeable membranes on top of the device.

References
[1] R. P. Moiseyenko, S. Herbison, N.F. Declercq, V. Laude, J Appl Phys **111**, 034907 (2012).
[2] P. B. Muller, R. Barnkob, M.J.H. Jensen and H. Bruus, Lab Chip **12**, 4617 (2012) .

Tue 15:00 Main Hall Ultrasonic particle and fluid manipulation as the "Acoustofluidics 2015" (poster)

Planar acoustic nodes in large format Acoustofluidic chambers for high flow rate sample processing applications – (Contributed, 000463)

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Acoustic Biosystems has succeeded in producing a uniform single acoustic node focus region in wide (>15mm) rectangular channels. This capability allows acoustophoretic sample processing at high (>10ml/min) flow rates with quantitative recovery of cells and particles in the focused streams. The resonant acoustic cell enrichment (RACE^{TM}) technology is used for automated sample processing in a continuous flow system that is capable of concentrating and washing cells. RACE will be applied as a cost effective, low power, continuous flow replacement to a centrifuge. This will enable automation of processing and analysis protocol that currently require centrifuge concentration to be deployed in continuous flow systems.
Additional applications for optical imaging of cells focused into the planar acoustic node will be discussed.

Tue 15:00 Main Hall Ultrasound in Food science, Pharmaceutical and Cosmetics (poster)

Impact of power ultrasound on the quality of fruits and vegetables during dehydration – (Contributed, 000086)

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To date, most of dehydrated vegetables and fruits are obtained by convection preceded or not by a pre-treatment. In general, their quality is low due to the physical modifications, loss of vitamins, polyphenols and carbohydrates and Maillard reaction (MR). MR can originate a remarkable loss of nutritional value due to the involvement of lysine. To improve the final quality of these products, one of the alternatives is the application of power ultrasound (US). US produces mechanical effects, such as cavitation, microstream and formation of microscopic channels which facilitate the mass transport and so, the removal of water from the food. The synergistic effect of US and temperature allows carrying out dehydration at low temperatures and short times. In the present work, the influence of power US on the quality of fruits and vegetables during the pre-treatment and drying was evaluated. Chemical indicators such as pectinmethyl esterase and peroxidase enzymes, vitamin C, carbohydrates, proteins, polyphenols and 2-furoylmethylamino acids was studied. In addition, rehydration capacity, leaching losses, shrinkage and organoleptic characteristics of the final product was assessed. During blanching, similar leaching losses and enzyme inactivation were found in low temperature and prolonged conventional treatments and in US processes, but with a significant reduction in the time for the latter. Application of US in the drying of carrots and strawberries provided high-quality end-products. The quality was better as compared to marketed products and superior or equivalent to samples obtained in a convective dryer, and, in some indicators, similar to that of freeze-dried samples.

Tue 15:00 Main Hall Ultrasound in Food science, Pharmaceutical and Cosmetics (poster)

Exploring the use of low-intensity ultrasonics as a tool for assessing the salt content in pork meat products – (Contributed, 000099)

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Achieving a homogeneous final salt content in salted meat products with anatomical integrity, such as loin or ham, represents a milestone due to salting is influenced by multiple product and process factors. Therefore, meat industry demands non-destructive techniques for quality control purposes in the salting process. The main aim of this work

was to evaluate the feasibility of using low- intensity ultrasound for characterizing the salting process of pork meat products. Individual muscles (Biceps femoris and Longissimus dorsi) and whole pieces (ham) were salted by brining (20% NaCl, w/w) and/or dry-salting at different times (up to 16 days) and 2 °C. Moreover, samples with preset salt content were formulated from minced Biceps femoris. The ultrasonic velocity (1MHz) was measured before and after salting by through-transmission method. In addition, the salting process was on-line ultrasonically monitored by conducting through-transmission and pulse-echo measurements. Salting involved an increase of the ultrasonic velocity due to the coupled water loss and salt gain, being the influence of salt gain larger than that of the water loss. For all the tested products, salting involved a similar increase of the ultrasonic velocity, approximately 13.6 m/s per 1% salt content increase (wet basis). The salt gain in Biceps femoris and Longissimus dorsi was estimated with an average prediction error of 0.48% (wet basis). The ultrasonic on-line monitoring of the salting process by only computing the time of flight could be considered a reliable tool for quality control purposes of individual muscles and whole meat pieces.

Tue 15:00 Main Hall Ultrasound in Food science, Pharmaceutical and Cosmetics (poster)

Ultrasonic Shear Reflectometry to Monitor the Isothermal Crystallization Behavior of Cocoa Butter – (Contributed, 000582)

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Determining and applying the correct crystallization procedure of cocoa butter in chocolate is crucial to obtain the desired quality characteristics, such as a glossy appearance, a pleasant texture and mouthfeel and a stable shelf life. However, most of the currently used techniques to monitor fat crystallization are off-line techniques, while in-line techniques could have important advantages. Here, we propose a shear ultrasonic wave reflection technique based on low intensity ultrasound, and we show that this technique has the potential to measure the crystallization behavior in-line. The implementation involves normally incident shear wave reflectometry and measures a averaged shear wave reflection every 10s while the data is processed in real-time. Furthermore, the measurement is nondestructive and can be performed under shear stirring conditions. An inverse wave propagation model allows to deduce relevant ultrasonic parameters that provide information about the crystallization kinetics and the microstructure development by analyzing the behavior of the measured shear reflection coefficient. In this study, the isothermal crystallization behavior of cocoa butter has been monitored and compared using three techniques: ultrasonic shear reflectometry, Differential Scanning Calorimetry and Polarized Light Microscopy. In order to understand the impact of the crystallization on the measured ultrasonic parameters, limonene was added to cocoa butter and the isothermal crystallization behavior was monitored for different doses. The results suggest that shear reflectometry especially monitors the microstructure development, which makes the technique particularly interesting as a complementary monitoring tool to other techniques that monitor primary crystallization.

The research leading to these results has gratefully received funding from the Research Coordination Office KU Leuven (internal funds: STRT1/10/015) and the Research Foundation - Flanders (FWO).

Tue 15:00 Main Hall Ultrasound in Food science, Pharmaceutical and Cosmetics (poster)

High Power Ultrasound Intensification of SuperCritical CO2 Processes: Assessment of Scale-Up – (Contributed, 000603)

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Supercritical processes with CO2 have gained wide acceptance in the last decades, because of its advantages compared to conventional solvents (inert, non toxic, nonflammable, worldwide available at reasonable prices, and its critical point makes possible to extract thermolabile substances, recyclable...).

Since SCF processes imply high pressures, it is difficult to apply traditional mechanical stirring to intensify them. An interesting alternative is the use of high power ultrasounds (HPU) to enhance mass transfer as a result of combined mechanisms. Previous works of this research group pointed out the feasibility of integrating an ultrasonic field inside a supercritical extractor without losing a significant volume fraction (1), giving rise to a non-antecedent patent.

Although a new self-controlled and robust prototype was achieved, further research pointed out that scale up required to develop a new transductor concept. In order to approach the most realistic industrial conditions, a bench scale installation was developed taking into account

AINIA's industrial-scale multipurpose ALTEX facility features.
The aim of this work was to assess this scale-up of HPU application to SuperCritical Extraction (SCE). The effect of HPU on SCE kinetics under different processing conditions were studied using the first system in a 5L-vessel and the new system designed to stand higher pressures (up to 50 MPa) at larger vessels (20 L). Extraction curves showed in both cases a clear enhancement of kinetics when applying HPU, confirming the scalability of this intensification alternative.
The authors are grateful to Instituto Valenciano de Competitividad Empresarial IVACE for its support through the ESCUALO project.
(1) E. Riera, Y. Golás, A. Blanco, J. A. Gallego Juárez, M. Blasco, A. Mulet, 2004. Mass transfer enhancement in supercritical fluids extraction by means of power ultrasound. Ultrasonics Sonochemistry, 11, 241-244.

Tue 15:00 Main Hall Ultrasound in Food science, Pharmaceutical and Cosmetics (poster)

Investigating Noodle Dough Using Air-Coupled Ultrasound – (Contributed, 000192)

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The goal of this work is to develop a non-contact on-line quality control technique for use in food processing of sheeted products such as Asian noodles. Current commercial production has no meaningful way of controlling product quality other than ensuring uniform sheet thicknesses between lamination rolls. Ultrasound is a good way of assessing the mechanical properties of food materials, which are important because they affect texture - a crucial quality determinant. Since, non-contact control during production is important to avoid risks of contamination or damage, our technique uses air-coupled ultrasound transducers in a transmission setup, enabling the texture of Asian noodle dough to be characterized. Noodles are a staple of the Asian diet, but their production presents significant optimization challenges due to intrinsic ingredient variability. During production, quality is largely determined by the work input and gluten development, which must be optimized during processing.

Our experiments have shown the feasibility of the technique to measure dough mechanical properties. Moreover, we are able to detect changes in the macroscopic properties of the dough samples associated with changes in composition (water quantity and types of salt) and process conditions (different work inputs). The next step is to develop an on-line prototype system to apply this non-contact transducer technique in a real production environment, and to establish its feasibility and adaptability for processing control beyond the laboratory context. We envisage that this approach will become a powerful way of implementing non-invasive quality control measurements of Asian noodles in industry.

Wed 8:30 Grande Salle Plenary lecture IV

Permanently Installed Ultrasonic Monitoring Systems – (000512)

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Ultrasonic inspection has traditionally been carried out with manual or automated equipment that is taken to the required test point(s) and removed after the test has been carried out. This inspection (NDT) mode is the only feasible option if the transducers and instrumentation are expensive and bulky, but modern electronics has radically reduced the size, cost and power consumption of the system so permanent installation is now increasingly attractive. This enables a move to monitoring (SHM) mode, enabling the condition of the structure to be tracked with time. The Imperial College NDE group has developed both bulk wave and guided wave ultrasonic monitoring systems that are commercially available. A key issue with permanently deployed systems is that they can take readings very frequently so the data must be handled automatically with reliable procedures for separating defects from random changes. Methodologies for achieving this will be discussed and practical examples of field applications of both bulk wave and guided wave systems will be given.

Wed 13:30 Grande Salle Keynote lecture I

Elastic wave processes in complex solids containing internal contacts – (000568)

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For ultrasonic waves propagating in solids, the presence of internal solid contacts or interfaces induces signatures of strong and often nonclassical nonlinearities. This is for instance the case in unconsolidated granular media, cracked solids, concrete... This presentation will review a selection of results obtained in three research directions, acoustic waves in granular media, nonlinear laser ultrasonic methods in cracked solids and nonlinear ultrasonic waves in complex solids, where these specific nonlinear elastic wave effects take place and can be used for characterization purpose or for designing wave control devices. The concepts, models and experimental manifestations shared between these research directions will be highlighted.

Wed 13:30 Esplanade Keynote lecture II

Ultrasound Enhanced PAT (Process Analytical Technology) - from Vibrational Spectroscopy By-pass Measurements to In-line Probes – (000589)

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During the last decade we have pursued the improvement of vibrational spectroscopy methods by ultrasonic standing waves.
A MHz ultrasonic standing wave exerts certain forces, which can be utilized to control the spatial concentration of micrometre-range particles. More specific these radiation forces collect the solid fraction of a suspension within the pressure nodes of the standing wave. A technical fluid like this exists for instance in a bio-reactor - cells in nutrient medium. Another example would be found in the production environment for crystals.
The spectroscopic means for aqueous suspensions like used in bio-technology is the mid-IR attenuated total reflection (ATR) spectroscopy delivering specific chemical information of organic compounds. Only a thin film of some micrometres in the proximity of the sensitive element is analysed, the said radiation forces can be used to populate or depopulate this volume with suspended particles. This makes an independent measurement of the chemical composition of particles (cells) and suspending medium (supernatant) possible.
This talk shall give an overview over our effort aiming on the improvement of PAT to gain better control over fermentation by assessment of the physiological status of the production culture.
In the beginning we used an on-line measurement scheme in a by-pass device, namely a stopped flow ATR set-up. Ultrasound was shown to enhance long-term stability and time-resolution of the measurements. Recently, in-line micro-imaging and laser scattering devices were tested in addition to the mentioned ATR technique.
The provisional endpoint of the development was the in-line monitoring with a close-to-series prototype. Data of the carbohydrate composition of a fermenting yeast culture was assessed with an US enhanced ATR probe within the bio-reactor. This was to our knowledge the first time, that the IR spectrum of cells was measured in-situ and in real-time.

Wed 13:30 Gouv Keynote lecture III

Advances in Acoustic Metamaterials Based of Sonic Crystals – (000526)

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A sonic crystal is a periodic distribution of sound scatterers embedded in a fluid like air or water. This presentation will review the properties of sonic crystals and a few of their recently proposed applications in different domains. At low frequencies, the behavior of sonic crystals is particularly fascinating since they behave like uniform materials whose effective acoustic parameters (bulk modulus and mass density) are unusual in comparison with that of the materials found in nature. The corresponding artificial structures are named acoustic metamaterials and can be design to behave as fluid-like materials with anisotropic mass density, negative bulk modulus, negative mass density or density-near-zero. Particularly, effective parameters with negative values are obtained when the

scatterers contain embedded resonances. The exploitation of these new properties has created novel acoustic devices like gradient-index refractive lenses, omnidirectional absorbers, acoustic cloaks, focusing devices based on negative refraction or devices allowing perfect transmission through narrow channels and sharp corners.

Wed 10:30 Saint Pierre Biomedical Imaging and Therapy through the Interaction of Light and Sound

Dual Frequency Band Annular Probe for Volumetric Pulse- Echo and Optoacoustic Imaging – (Contributed, 000121)

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Motivation
Optoacoustic imaging (OA) measures the shape and amplitude of the broadband laser induced pressure pulse as a function of optical fluence, wavelength and optical properties of the medium. When integrate with the ultrasonic Pulse-Echo(PE) technique, it can provide physiological and morphological information which facilitate the abnormality detection based on optical contrast. Conventional backward imaging transceivers however are limited in inter-element spacing and acceptance view angle.
Methods
We propose a dual frequency band annular probe for backward mode volumetric PE/OA imaging. The suggested geometry not only has the property of lower periodicity which allows designing larger element size and larger effective aperture but inherently provides a lumen for the optical probe to deliver the laser pulse for Optoacoustic mode. The propagated pressure field and point spread function of the system are calculated based on the spatial impulse response method. Optimum settings for number of elements in each ring, number of channels and maximum steering are suggested. The transducer design and synthetic array beamforming simulation are presented and compared with other classical algorithms. We also incorporated the optical effects within the reconstruction algorithm by employing the previously proposed analytical model for the optical fluence.
Results
The dual frequency band annular ring can offer improvement in both axial and lateral resolution while preserving a good capability of steering. The extended effective aperture size increases the lateral resolution while the dual bandwidth coverage ameliorates the lateral resolution, SNR and thus defines the size of resolved structure. The resolution performance and reconstruction capabilities are shown with the in-silico measurements.

Wed 10:45 Saint Pierre Biomedical Imaging and Therapy through the Interaction of Light and Sound

A Portable Scanner for Real Time dual Modality Ultrasound/Photoacoustic in vivo Imaging – (Contributed, 000411)

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Last few years, photoacoustic imaging has become an important field of investigation triggering tremendous interest among researchers and clinical physicians. The ability of photoacoustics to harmlessly reveal and distinguish different optical chromophores with ultrasound resolution at several centimeters depth has given it an advantage over other imaging techniques. However, unlike ultrasound which has gone a long way in clinical use, photoacoustics yet encounter difficulties to enter the clinic due to limitations such as lack of real time imaging, heavy costs and impracticability caused by the imposing dimensions of used lasers. These constrains are preventing the widespread use of photacoustics and prevent it from being a standard imaging modality for point of care diagnosis. To break through these hindering limitations we developed a real time photoacosutic/ultrasound portable scanner. To this end, we drastically shrank the size of the imager by designing an ultra-compact laser probe based on efficient and inexpensive laser diode stack providing 0.6 mJ per pulse at 800nm wavelength. The beam was carefully shaped by designing an optical system allowing a rectangular beam of 18 mm X 2.2 mm which provides a fluence of about 1.5 mJ/cm2 at front-end. The use of laser diode allows an imaging rate of 210Hz under maximum permissible exposure which in turn permits a real time imaging. In this oral presentation we will describe the newly developed scanner and we will demonstrate the performance of the imager for real time in-vivo imaging.

Wed 11:00 Saint Pierre Biomedical Imaging and Therapy through the Interaction of Light and Sound

Radial-Looking Endoscopic Probe based on Annular-Ring Transducer Arrangement for Optoacoustic and Ultrasound Imaging – (Contributed, 000460)

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Ultrasound is an imaging modality that is easily applicable and cost effective. Unfortunately the impedance differences between tissues are often very small. This leads to low contrast images and the problem that harmful changes of tissue are often not detectable. On the other hand, optical imaging modalities show a higher sensitivity for differentiation of tissues. It therefore is our intention to combine the optoacoustic effect with ultrasound imaging in an endoscopic probe for non-invasive diagnostics and surgery.
For this reason we have developed a combined probe consisting of an ultrasound ring-array and a laser fiber placed in the center axis of the rings. Laser light and ultrasound are emitted to a mirror rotating in front of the aperture and reflected radially through an optical and acoustical window that is forming the outer wall of the catheter probe. The annular ring array consists of 5 rings of same active area at a frequency of 5 MHz. The transducer is based on piezocomposite material that is able to produce short pulses of ultrasound. It is also able to receive the reflected ultrasound and the optoacoustic signals produced by the tissue. The annular ring array allows to focus the ultrasound dynamically within the near field of the probe. The imaging window is about 300° around the center axis of the catheter. The instrument can provide a 2-dimensional radial image. The 3rd dimension is observed by moving the instrument manually. A special optoacoustic phantom was built and a DiPhAS-beamformer was adapted to drive the probe.

In this work we present the basic concept of the probe and the first measurement results.

Wed 11:15 Saint Pierre Biomedical Imaging and Therapy through the Interaction of Light and Sound

Quantitative Optical Imaging in Diffuse Media by Pressure-contrast Acousto-optic Sensing – (Contributed, 000380)

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Acousto-optic (AO) imaging is a dual wave sensing modality that utilizes the interaction of light and sound to image optical contrast at depth with the spatial resolution of ultrasound. The quantitative measurement of contrast using AO is complicated by spatial variability of local light intensity. To circumvent this limitation, we employ a modified processing scheme in which we measure the ratio of the AO signal level generated at two different acoustic pressure amplitudes and thus normalize out (to zeroth-order) the contribution of local light intensity. The resulting pressure ratio, once calibrated, yields a direct measure of the average optical transport mean free path within the interaction volume. Proof of concept results are reported using optically diffuse gel phantoms. (Work supported by the Center for Subsurface Sensing and Imaging Systems [NSF ERC Award No. EEC-9986821].)

Wed 11:30 Saint Pierre Biomedical Imaging and Therapy through the Interaction of Light and Sound

Optoacoustic spectral features of coagulation in laser heated tissues ex vivo – (Contributed, 000598)

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Laser Thermal Therapy (LTT) is a minimally invasive technique for destroying diseased tissue, including solid tumours. Optoacoustics (OA) is being investigated as a tool to detect and monitor the progress of induced thermal damage (coagulation) during LTT. Optoacoustics involves exposing tissues to nanosecond pulsed laser light, which generates acoustic waves that are detected using wideband transducers. In this work, OA data for sixteen liver samples were obtained using a reverse-mode optoacoustic imaging system (Seno Medical Instruments Inc., San

Antonio, TX). The system consists of a Nd:YAG pumped Ti:Sapphire laser operating at 775 nm (8 ns pulse) and an 8 element annular array piezo-electric transducer with a nominal central frequency of 5 MHz. Each sample was heated for 5 minutes using an 810 nm laser at 4 W. OA signals were acquired 2 minutes prior to, 5 minutes during, and 7 minutes post heating. The spectral features of the OA signals were obtained using a spectrum analysis technique commonly performed on ultrasound backscatter data. It involves a linear fit of the average power spectrum to obtain the spectral midband fit, slope, and intercept. When comparing post-heating to pre-heating spectral features, the average midband fit and intercept increased by factors of 2.8 (7dB) and 4.3 (9 dB), respectively. While the average slope decreased by 18 % (0.3 dB/MHz). The OA signal amplitude increased continuously with temperature as the heat was applied. During the cooling phase, the tissue temperature returned to its pre-heated value, while the OA spectral features remained fixed at their heated values, indicative of a permanent change in tissue properties. The results of this study demonstrate that OA spectral feature analysis may prove to be a more direct measure of tissue thermal damage, than temperature, and as such, offer an improved approach to therapy guidance.

Wed 11:45 Saint Pierre Biomedical Imaging and Therapy through the Interaction of Light and Sound

Acousto-optic Monitoring of Thermal Lesions from High Intensity Focused Ultrasound Exposure Ex Vivo – (Contributed, 000360)

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Acousto-optic (AO) sensing has been shown to non-invasively detect, in real time, changes in the optical properties of ex vivo tissue exposed to high-intensity focused ultrasound (HIFU). The technique is particularly appropriate for monitoring non-cavitating lesions that offer minimal acoustic contrast. This presentation summarizes a larger body of work done on HIFU lesion monitoring using a photorefractive-crystal-based interferometer to measure changes in AO signal intensity induced by lesions of varying size and location. We will also report on direct measurements of optical contrast changes in thermally lesioned tissue, and briefly introduce a multi-physics numerical model developed to interpret the experimental results and assess the technique's viability and robustness in a clinical setting.

Wed 15:30 Saint Pierre Biomedical Imaging and Therapy through the Interaction of Light and Sound

Seeing HIFU lesions with sound – (Invited, 000354)

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Real-time acousto-optic (AO) sensing can detect changes in ex vivo tissue optical properties during high- intensity focused ultrasound (HIFU) exposure [Lai et al, UMB 37: 239, 2012] by modulating the HIFU beam. The AO signal correlates well with resulting lesion volumes. Here a numerical simulation of the AO sensing process is presented which captures the relevant acoustic, thermal, and optical transport processes. The angular spectrum method was used to model the acoustic field from the HIFU source. The thermal field was modeled using a finite-difference time-domain solution to the Pennes bioheat equation. The thermal dose model was then used to determine optical properties based on the temperature history. Finally the diffuse optical field in the tissue was calculated using a GPU-accelerated Monte Carlo algorithm, which accounts for light-sound interactions and AO signal detection. The robustness of the system to source-receiver geometry, tissue thickness, and optical contrast was considered. In order to reliably detect the generation of multiple lesions a specific geometry of HIFU source and optical sources and receivers was found. Based on signal to noise estimates AO sensing was determined to be feasible in the breast and prostate.

Wed 16:00 Saint Pierre Biomedical Imaging and Therapy through the Interaction of Light and Sound

Theoretical Modeling of Photoacoustic Generation by a Gold Nanosphere: Nonlinearity and Effects of Silica Coating and Interfacial Thermal Resistances – (Contributed, 000366)

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Photoacoustic imaging provides a unique and high optical-absorption contrast in biological tissue. To selectively map anatomical or physiological feature, one alternative to endogenous absorption is to use contrast agents. Gold nanoparticles have emerged as excellent candidates because they are biocompatible, readily functionalizable, and have a particularly high effective absorption cross section. The photoacoustic signal generation from these particles is however not yet fully understood and can be affected by their surrounding environment. In particular several recent experimental studies have shown that adding a layer of silica on the particles tends to enhance the generated photoacoustic signal. To better understand the photoacoustic generation in the case of a gold nanoparticle, we model and solve both the thermal and thermo-elastic problems in the case of a gold nanosphere. Specifically, we study the influence of a silica coating of controlled thickness and of the interfacial thermal resistances between the different materials (gold, silica, water). The thermal problem was first solved analytically. The spatio-temporal temperature field was then used as a source term in a thermo-elastic model solved by a FDTD approach to compute the photoacoustic signals. We also studied the nonlinearities in the thermoelastic regime, which are due to the dependence of the coefficient of thermal expansion on temperature. We report quantitative estimates of how the temperature fields and the photoacoustic signals are affected by the interfacial thermal resistances and the silica coating.

Wed 16:15 Saint Pierre Biomedical Imaging and Therapy through the Interaction of Light and Sound

Light Control in Deep Tissue via Photoacoustic-guided Wavefront Shaping – (Contributed, 000146)

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In biological tissue, light scattering limits the penetration depth of most optical imaging techniques to a few hundred micrometers. In the last few years, wavefront shaping appeared as a powerful tool to compensate light scattering and focus light in deep tissue. However it requires a feedback signal that monitors the light intensity on the target. In most practical scenarios, one cannot directly place a photodetector at the target position. Photoacoustic imaging has been investigated to provide such a feedback and to perform controlled focusing deep inside scattering media. We recently demonstrated light focusing using photoacoustic feedback from an ultrasound array and a transmission-matrix approach [Chaigne et al, Opt. Letters 39(9), 2014; Chaigne et al, Nat. Photonics 8, 2014]. The first challenge to apply this technique in practical situation is the millisecond decorrelation time in tissue. The second challenge is the mismatch between the acoustic resolution (tens of micrometers) and the speckle grain size inside tissue (fractions of micrometers): the modulation of the photoacoustic feedback signal vanishes when too many speckle grains are contained within one acoustic resolution cell. We report on the use of improved instrumentation to address these issues. We use a 100Hz repetition rate laser, which is able to almost follow the decorrelation of the scattering sample. We also use a Spatial Light Modulator with both high-resolution and high damage threshold, in order to benefit from a large number of input modes and increased SNR.

Wed 16:30 Saint Pierre Biomedical Imaging and Therapy through the Interaction of Light and Sound

Advances in Multispectral Optoacoustic Tomography – (Invited, 000513)

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Optical imaging is unequivocally the most versatile and widely used visualization modality in the life sciences. Yet it is significantly limited by photon scattering, which complicates imaging beyond a few hundred microns. For the past few years however there has been an emergence of powerful new optical imaging methods that can offer high resolution imaging beyond the penetration limits of microscopic methods. These methods can prove essential in cancer research. Of particular importance is the development of multi-spectral opto-acoustic tomography (MSOT) that brings unprecedented optical imaging performance in visualizing anatomical, physiological and molecular imaging biomarkers. Some of the attractive features of the method are the ability to offer 10-100 microns resolution through several millimetres to centimetres of tissue and real-time imaging. In parallel we have now achieved the clinical translation of targeted fluorescent probes, which opens new ways in the interventional detection of cancer in surgical and endoscopy optical molecular imaging. This talk describes current progress with methods and applications for in-vivo optical and opto-acoustic imaging in cancer and outline how new opto-acoustic and fluorescence imaging concepts are necessary for accurate and quantitative molecular investigations in tissues.

Wed 17:00 Saint Pierre Biomedical Imaging and Therapy through the Interaction of Light and Sound

Development of a reflection-mode raster-scan optoacoustic mesoscopy (RSOM) in the 20-180 MHz frequency range – (Contributed, 000239)

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Motivation: We developed a reflection-mode raster-scan optoacoustic mesoscopy (RSOM) system for imaging of mesoscopic scale biological specimen; these are specimen which are larger than what optical microscopy can image efficiently, yet smaller than where tomographic methods become relevant, i.e. where the depth to resolution ratio becomes around 50, which we call the mesoscopic gap. In this gap several interesting applications exist; such as imaging of model organisms, like zebrafish, and imaging of tumor development.
Methods: The design of the system is based on a custom-made ultrasonic detector, our detector enables coupling of light from the same side as the detector, thus enabling reflection-mode operation. The detector has a wide bandwidth of 20 180 MHz, i.e. a relative bandwidth above 100%. To optimally use this bandwidth, we implemented multi-bandwidth reconstruction, where the detection bandwidth is divided into smaller sub-bands, each sub-band is processed separately, and at the end all the sub-bands are combined into a single image using different colors. This reconstruction scheme improves the resolution of the system, and enhances the visibility of small structures.
Results: System characterization shows that the system achieves a resolution of 4 μm axially, and 18 μm laterally, at penetration depths reaching up to 5 mm. After characterization, we showcased the system's performance in imaging a zebrafish ex-vivo, and an excised mouse ear. From the zebrafish image, several anatomical features such as the melanocytes are seen, on the mouse ear image, we can see the vascular network, where both large vessels, and small microvasculature are seen simultaneously; the small microvasculature, could only be seen by applying the multi-bandwidth reconstruction.

Wed 17:15 Saint Pierre Biomedical Imaging and Therapy through the Interaction of Light and Sound

A Multi-Angle Approach for Photoacoustic Imaging Enhancement – (Contributed, 000466)

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Introduction : Photoacoustic is a fast growing biotechnological field which exploits optically excited acoustical phenomena for visualization of a variety of molecules, including in living organisms.To effectively address the needs of biological research it is essential to understand where the signals come from with respect to microscopic anatomy. We use the VevoLAZR that inherently co-registers photoacoustic signals with ultrasounds in a single angle reflection mode. This mode is advantageous for its ease of use and direct clinical translation possibility but it sins by its image quality and sensitivity. We are investigating the feasibility of improving these two parameters by using a rotational compounding imaging (RCI) approach. Methods : The RCI method consists in acquiring multiple images over different angles in the same plane. This approach was evaluated and compared to the single angle reflection mode and also to pure optical imaging. Agarose phantoms were filled with decreasing concentrations of ICG and were imaged by photoacoustic and 2D fluorescence imaging. For in vivo experiments in mice, ICG were mixed with matrigel and introduced under the renal capsule. Results : Phantoms and in vivo imaging demonstrated a great improvement in image quality with an important decrease of noise and reflection artifacts. The sensitivity limit of the single angle mode was 0.02 μM which was higher than the one of 2D fluorescence imaging (1 μM) but the RCI approach did not improved this parameter. Conclusion : The RCI approach enhanced photoacoustic imaging quality and should facilitate biological interpretation in vivo in physiopathological contexts.

Wed 17:30 Saint Pierre Biomedical Imaging and Therapy through the Interaction of Light and Sound

Adaptive Spatial Filtering with Principal Component Analysis for Biomedical Photoacoustic Imaging – (Contributed, 000255)

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Photoacoustic (PA) signal is very sensitive to noise generated by peripheral equipment such as power supply, stepping motor or semiconductor laser. Band-pass filter is not effective because the frequency bandwidth of the PA signal also covers the noise frequency. The objective of the present study is to reduce the noise by using an adaptive spatial filter with principal component analysis (PCA). A microchip laser with the wavelength of 532 nm, the pulse width of 1 ns and the repetition frequency of 50 Hz was used to generate PA signal. A concave PVDF transducer with the central frequency of 50 MHz and the diameter of 4.5 mm was used as the PA sensor. PA signal was digitized at the sampling rate of 1 GHz with 8-bit resolution. PA signal from chicken embryo, which was considered as the signal from the vasculature, was obtained by the 2D scanning of the PA transducer above the object. On the assumption of the spatial continuity of the vessels, obtained PA signal was able to be separated into desired PA signal and noise by PCA. By using this adaptive spatial filter, the noise level was reduced with - 4.12 $\pm$ 0.87 dB, S/N ratio was increased with 2.66 $\pm$ 0.87 dB and the spatial resolution was increased with 2.5 %. The adaptive spatial filter with PCA can extract the desired PA signal from the obtained signal, maintaining the spatial resolution.

Wed 10:30 Grande Salle Guided wave NDT/E: modelling and simulation I

Interaction of a Guided Wave with a Crack in an Embedded Multilayered Anisotropic Plate: Global Matrix with Laplace Transform Formalism – (Contributed, 000056)

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The modelling of the diffraction of an elastic wave by a defect located inside a multilayered waveguide is an active topic of investigation. It is challenging to develop methods capable of dealing with 3D anisotropic embedded waveguides, which would be numerically less expensive than the finite element solution. In this work, we present a method based on the numerical approximate evaluation of the Green tensor. We use the Global Matrix formalism in a Fourier-Laplace transformed domain, which is the most efficient way to obtain the near and transient field radiated by a given source. We focus on the case of a horizontal crack, although the method would allow us to deal with any shape. The crack is replaced by many small secondary sources, which amplitudes depend on the incident field and are obtained by solving a linear system. As an example, we present simulations of a cracked Carbon-Epoxy plate immersed in water and insonified by a transient source. Comparisons with a finite element model shows excellent convergence of the method, including in the neighbourhood of the crack. Calculations are performed in 2D, but the method is still valid for 3D cases.

Wed 10:45 Grande Salle Guided wave NDT/E: modelling and simulation I

Inspection of Pipelines Using the First Longitudinal Guided Wave Mode – (Contributed, 000065)

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Abstract-Inspection of cylindrical structures using the first longitudinal Ultrasonic Guided Wave (UGW) mode has so far been predominantly neglected. This is due to its attenuative and dispersive behaviour at common operating frequencies (20-100 kHz) of UGW inspection. The behaviour and properties of the first longitudinal guided wave mode and its potential of use in pipeline inspection have been explored and method of achieving higher resolution by using

this wave mode for inspection have been investigated using numerical modelling. An experimentally validated Hybrid Time Reversal Focusing (HTRF) technique has been applied and the performance of first longitudinal guided wave mode has been compared with that of the other axisymmetric modes at 20-100 kHz. The results show that first longitudinal guided wave mode has around 5 times more resolution than the second longitudinal guided wave mode and around 2.5 times more resolution than first torsional guided wave mode.

Wed 11:00 Grande Salle Guided wave NDT/E: modelling and simulation I

Detection of sub-surface delamination based on the spatiotemporal gradient analysis over the A0-mode Lamb wave fields – (Contributed, 000116)

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This paper proposes a novel non-destructive inspection method independent of frequencey and phase-velocity changes over the guided wave field. The proposed method has an ability to characterize the phase velocity of the Lamb-wave propagation through the linearity among the 4-dimensional vector which is composed by following components: (1)a vertical (z-directional) displacement, (2)its vertical particle velocity, (3)x-directional and (4)y-directional out-of-plane strains.
Structural flaws such as disbonds, corrosion and fatigue cracks represent changes in effective thickness and local material properties, and therefore measurement of variations in Lamb wave propagation can be employed to assess the integrity of these structures. Hayashi and Kawashima showed that the A0-mode Lamb wave is sensitive to the delamination at all through-thickness locations. In addition, because the A0-mode Lamb wave has shorter wavelength than S0-mode Lamb wave at the same frequency, it is potentially more sensitive to delamination damage. Due to the above reason, A0-mode Lamb waves measurement has been utilized as one of the promising structural health monitoring techniques for detecting hidden damage in composites. Whereas the above merits, the variation of phase velocity causes difficulties for interpretation of observed signals. Therefore, it is important to establish the delamination detection criterion independent of local wave numbers.
In this paper, the computational process of the local velocimetry is discussed and their physical meanings are investigated through numerical and acoustical experiments.

Wed 11:15 Grande Salle Guided wave NDT/E: modelling and simulation I

A Generic Hybrid Modelling Tool for Guided Ultrasonic Wave inspection – (Contributed, 000215)

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An understanding of modal characteristics in structures is essential for the application of existing and new guided ultrasonic wave Non Destructive Evaluation (NDE) technologies and methods. Analysis of guided wave phenomena is challenging because of their complex dispersive and multi-modal nature and fully numerical solution procedures often impose a large computational cost. Although hybrid models combining numerical models for wave scattering with rapid calculations for wave propagation have long been considered to address this problem, typically such models require modification of the base code of the solution procedure.
This paper discusses the development of a generic hybrid model that combines the advantages of analytical calculations and numerical models. This is achieved within the framework of the 'pill-box' approach that connects incoming and outgoing fields in the wave propagation and scattering models using generic bridge-codes. The concept and implementation of the hybrid model as applied to low-frequency guided wave propagation and scattering from canonical defects in flat plates are presented. The implementation relies on decomposition of multi-modal fields into constituent modes and is hence currently limited to the far-field in the scattering models.

Wed 11:30 Grande Salle Guided wave NDT/E: modelling and simulation I

Analytically based simulation of piezoactuator-generated guided wave propagation and diffraction in composite plates – (Contributed, 000225)

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Mathematical and computer simulation of wave processes in composite structures is a challenging task due to complicate waveguide properties induced by their anisotropy and lamination. Various mesh-based techniques, such as finite element or finite difference methods, became widespread for guided wave (GW) simulation. However, for lengthy plate-like waveguides, analytically based methods may serve as an alternative computational tool allowing efficient and physically evident parametric analysis.
In the present talk, recent advances in semi-analytical GW simulation within 3D anisotropic elasticity are presented and discussed. The wave fields generated in anisotropic laminate structures by surface or buried sources are explicitly expressed via integrals of Green's matrix of the structure considered and the source load. Far-field asymptotics of the excited cylindrical GWs are derived from these integrals. The wave fields scattered by local obstacles are approximated in terms of such integral and asymptotic expressions within the laminate element method (LEM). On this basis, a set of meshless low-cost computer models for a reliable quantitative near- and far- field analysis has been developed and experimentally validated.

Their abilities are illustrated with examples of structural frequency response and radiation pattern diagram evaluation for GWs generated by piezoelectric wafer active sensors (PWAS); the reconstruction of effective elastic moduli of fiber-reinforced composite plates based on laser vibrometer measurements; PWAS frequency tuning with accounting for the radiation directivity caused by the plate's anisotropy; and resonance GW transmission through deep surface notches.

Wed 11:45 Grande Salle — Guided wave NDT/E: modelling and simulation I

Interaction of Lamb waves with an imperfect joint of plates: reflection, transmission and resonance – (Contributed, 000312)

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Lamb waves are expected to provide an efficient tool for the nondestructive evaluation and the structural health monitoring of plate-like structures due to their ability of propagating long distances. However, the characterization of imperfect joints, such as closed cracks and adhesive joints, is still a challenging topic because of the complicated behavior of Lamb waves at a joint. Although the reflection and transmission characteristics of the lowest-order symmetric (S0) and antisymmetric (A0) Lamb modes at an imperfect joint have been investigated in the frequency domain (Mori et al., J. Appl. Phys. 113 (2013), 074901), the dynamic behavior of Lamb waves at the joint has not been fully clarified. In this study, the elastodynamic finite integration technique (EFIT) is utilized to analyze the transient behavior of Lamb waves at an imperfect joint, which is modeled as a linear spring-type interface characterized by normal and tangential stiffnesses. Not only the reflection and transmission but also the resonance behavior in the time domain is revealed by performing numerical calculations for several joint conditions. In particular, it is shown that the vibrations last at the resonance frequencies of the joint in the reflected and transmitted waveforms. Furthermore, imperfectly jointed aluminum plates are employed for measuring the Lamb waves transmitted through the joint. The obtained results are discussed in the light of the characterization of various joint conditions using Lamb waves.

Wed 10:30 Claude Lefebvre — Sonic and phononic crystals

Stress- and Phononic- Induced Changes in GHz Phonon Propagation in Thin Si Membranes – (Contributed, 000370)

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Tuning the acoustic phonon dispersion relation provides a means of controlling related properties such as group velocity and, ultimately, phonon propagation, with deep implications in engineering hypersound and heat transport in nanoscale phononic structures and metamaterials. An artificial periodic modulation of elastic properties in phononic crystals, external stress field or reduction of the characteristic dimensions as in thin membranes lead to acoustic phonon propagation which differs substantially from that in the bulk. We consider experimentally and theoretically the mentioned methods of acoustic phonon engineering. The dynamics of hypersonic phonons was measured by means of Brillouin light scattering and ultrafast asynchronous optical sampling. The confinement- and stress- induced changes in the dispersion relation were investigated in 27 nm thick single crystalline Si membranes with static biaxial tensile stress. The dispersion relations were calculated with the elastic continuum approximation taking into account the acousto-elastic effect. The influence of confinement and periodic modulation of elastic properties were studied in solid-air and solid-solid phononic crystals made of square lattices of holes in and Au pillars on 250 nm thick Si membrane, respectively. The volume reduction (holes) or mass loading (pillars) accompanied by a second-order periodicity and local resonances are shown to significantly modify the propagation of GHz phonons. The experimental data was analysed theoretically using the finite element method. The obtained results provide novel insight regarding the hypersonic phonon dynamics, dispersion relation, and thermal conductivity in stressed and patterned Si membranes.

Wed 10:45 Claude Lefebvre Sonic and phononic crystals

Confinement and interaction of elastic and electromagnetic waves in phoxonic crystal cavities – (Contributed, 000542)

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Phoxonic crystals are periodic structures that can exhibit dual phononic and photonic band gaps, thus allowing the simultaneous confinement of both acoustic and optical waves inside the same defect such as a cavity or a waveguide. Then, one can expect an enhancement of the phonon-photon interaction for the purpose of novel optomechanical devices, in particular for the modulation of light by acoustic waves. We study the optomechanic interaction in different (2D [1], slabs [2], and strips phoxonic crystals cavities. We take into account both mechanisms that contribute to the acousto-optic interaction, namely the photoelastic and moving interface effects. The strength of the acousto-optic coupling is evaluated for each phonon-photon pair by calculating either the modulation of the photonic frequency by the acoustic mode or the so-called coupling rate. The contributions of the photoelastic and moving interfaces effects can have similar or very different magnitudes. Moreover, they can be in phase and add together or be out of phase and partly cancel each other. We can notice that, due to symmetry reasons, only acoustic modes having a specific symmetry can couple to photonic modes. Finally, we discuss the influence of the material properties as concerns the photoelastic effect [1] since the latter strongly changes when the optical frequency approaches the energy of the direct band gap. [1] S Eljallal et al, JPCM 26, 015005 (2014) [2] S Eljallal et al, PRB 88, 205410 (2013)

Wed 11:00 Claude Lefebvre Sonic and phononic crystals

Imaging phonon propagation in phononic crystal slab waveguides and cavities – (Contributed, 000346)

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Phononic crystals (PCs) are materials that have a spatially periodic variation in their elastic properties. They exhibit dispersion relations with complicated band structures, producing effects such as negative dispersion and band gaps. Introducing defects in the periodicity provides possibilities such as waveguiding and confinement.

Here we present time-resolved imaging of optically-induced Lamb waves in PC slab structures. The acoustic energy is confined to the slab and gives rise to Lamb modes, for which the dispersion relation can be calculated. In particular, we investigate confinement in cavities and waveguides by introducing defects into the PC structure. The acoustic mode shapes are investigated using finite element numerical simulations.

The samples consist of microscopic honeycomb lattices of circular holes in (111) silicon-on-insulator wafers. Honeycomb lattices exhibit wide, complete band gaps[1,2]. The Si slabs are 6.5 μm thick, with hole spacing 6.6 μm. The first complete band gap for this structure is calculated to lie between 230 and 320 MHz.

Excitation and detection was performed using an optical pump-probe set-up with an ultrafast laser[3], detecting the out-of-plane surface velocity of the propagating waves. Fourier analysis reveals that at some frequencies the waves propagate freely through the sample, whereas at others the energy is confined to the cavity and waveguide defects. The simulations show the cross-sectional deformation associated with the wave propagation. Several Lamb modes contribute to the pattern at each frequency. We also derive the Q factor as a function of frequency for the phononic cavity.

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Wed 11:15 Claude Lefebvre Sonic and phononic crystals

Theoretical and experimental study of Love and Rayleigh waves interaction with surface Phononic Crystal (PnC) – (Contributed, 000495)

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Micro-machined phononic crystals with operation frequency in hundreds of MHz to GHz range have attracted significant interest for applications ranging from radio-frequency signal processing, sensing and microfluidic actuation. The interest in these materials stems from their useful wave guiding, trapping acoustic energy in high-Q resonators, and transmission properties. Phononic crystals for surface acoustic waves and lamb waves are typically created from drilling holes and deposition of pillars in/on a solid substrate and in/on a free standing membrane. They exhibit a well-known series of band-pass and band- stop frequencies, originating from Bragg interference of scattered waves and local resonances The purpose of the present study is investigate both theoretically and experimentally the interaction of surface acoustic wave - Love waves in Si02/Quartz AT cut, and Rayleigh wave in LiNBO3 Y128 cut- with 1D and 2D PnCs Crystal composed of Ni lines and pillars. First, The complete phononic band structures was calculated using the finite element method (FEM, COMSOL MULTIPHYSICS). In this work, the 2D PnC is composed of units cell arranged in different lattices symmetries (square, triangular and honeycomb lattices) with various filling factor. Because of simultaneous mechanisms of the local resonances and Bragg scattering, the structures exhibits band-stop frequencies that can be controlled by changing the pillars geometry as well as the lattice symmetries. Secondly, We have calculated the transmission spectrum through the PnCs involving modes with different polarization states -Rayleigh and love waves-. The numerical calculation was performed in frequency and time domain, this enables to understand the interaction mechanism between incident waves and PnCs . Finally, We have fabricated various devices of PnCs based on the two configurations, numerical simulations and electrical measurements are compared and discussed.

Wed 11:30 Claude Lefebvre Sonic and phononic crystals

Numerical simulation of in-plane elastic wave motion in layered phononic crystals with cracks, damaged layers and interfaces – (Contributed, 000311)

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Periodically layered composites, also known as one-dimensional phononic crystals, could be imperfectly manufactured or become damaged during their service. For instance, fatigue loading may lead to distributed delaminations between layers, while a local debonding or crack may occur due to an impact loading. In this case, the periodicity of layered phononic crystals is disturbed and the cracks act as disorders, which may lead to resonance phenomena. In addition, the periodicity violation due to single or distributed cracks may change the wave reflection and transmission properties of a phononic crystal. In the present study a numerical model for in-plane wave motion in layered phononic crystals with strip-like cracks or a periodic array of cracks is developed and the related wave phenomena are investigated. For a prescribed incident wave field, the transfer matrix method is applied to calculate the reflected and the transmitted wave fields and to estimate the elastic wave band-gaps. The cracks are dealt with using the integral approach, which represents the scattered wave field by a boundary integral containing the convolution of the Fourier transform of the Green's matrix of the corresponding layered structures and the crack-opening-displacements (CODs). The CODs are calculated by applying the Bubnov-Galerkin scheme along with the boundary integral equation method. The typical wave characteristics describing the wave propagation phenomena related to the elastic wave scattering by a periodic array of cracks are analysed. Resonance wave scattering by delaminations is investigated, and the corresponding streamlines of the wave energy flow are demonstrated and discussed.

Wed 11:45 Claude Lefebvre Sonic and phononic crystals

Micro Phononic Superlattices: Controlling Ultrasound Like Heat – (Contributed, 000264)

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The concept of a phononic superlattices is commonly used across different disciplines in physics and engineering. The basic principle involes the stacking of layers with a mismatch in their characteristic impedance. If the wavelength of incoming elastic-waves, or phonons, is in the order of the stacking period interference between the incoming and reflected waves occurs and yields a band gap in the frequency spectrum. In this work we exploit the analogy between phonons in atomic superlattices and the propagation ultrasound in micro scale superlattice, to create a novel material for ultrasound control. We demonstrate the creation of band gaps in the spectrum. These band gaps can be tailored to a specific frequency between 1 and 20 MHz. We use the specific lattice geometry of Si/Ge superlattices to guide the design of a micro phononic superlattice. Moreover we employ a 2PP 3D-Lithography method to create fully 3D polymeric lattice geometries with minimum feature sizes of less than 10 μm. The overall mechanical properties are controlled by means of varying the independent trusses that constitute the unit cell. We use a numerical model including fluid structure interaction to predict the occurrence of band gaps. Finally, the numerical model is validated using an experimental setup with high frequency ultrasonic transducers.

Wed 15:30 Claude Lefebvre Sonic and phononic crystals

Bloch wave properties in a 2D solid phononic crystal – (Contributed, 000288)

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1.Background, Motivation and Objective Phononic crystals (PC) exhibit unusual properties conveyed by Bloch waves, which are the eigenmodes of periodic structures. The knowledge of the effective acoustic impedance of the modes is a useful information for application purpose. For instance, a mode matched to the surrounding medium is suitable to imaging if using a PC-based flat lens [A. Sukhovich, et al, Phys. Rev. Lett., 154301 (2009)]. The properties of the Bloch modes can be highlighted by direct probing for surface waves. However, the inner sensing is impossible in volumic structures. The goal of the paper is to present the indirect measurement of the properties for a 2D PC.
2.Statement of Contribution/Methods The PC of interest is a triangular array of steel rods in an epoxy resin matrix. In a previous study [C. Croënne et al, Phys. Rev. B 83, 054301 (2011)], it was verified that a quasi-longitudinal wave with negative phase velocity can propagate across the sample. In the present study, the PC is placed in water whose index is not matched. The measurement of refracted waves reveals the multimodal propagation within the sample.

3.Results, discussions and conclusions The paper presents the data on this structure in the MHz range. The Bloch modes are identified using a prism PC shaped. In support to this experimental study, the effective impedances are evaluated using a theoretical model [M. S. Kushwaha et al, Phys. Rev. Lett. 71, 2022, 1993]. A flat lens has been fabricated which cannot achieve unique focalisation of all the modes. The previous results furnish the interpretation of the complex transmitted field.

Wed 15:45 Claude Lefebvre Sonic and phononic crystals

Propagation of Intense Acoustic Waves in Sonic Crystals – (Contributed, 000222)

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The propagation of intense acoustic waves in a periodic medium (often referred as a sonic crystal) is numerically studied. The medium consists in a structured fluid, formed by a periodic array of fluid layers with alternating linear acoustic properties and quadratic nonlinearity coefficient. The spacing between layers is of the order of the wavelength; therefore Bragg effects such as band-gaps appear. We show that the interplay between strong dispersion and nonlinearity leads to new scenarios of wave propagation. The classical waveform distortion process typical of intense acoustic waves in homogeneous media can be strongly altered when nonlinearly generated harmonics lie inside or close to band gaps. This allows the possibility of engineer a medium in order to get a particular waveform. Examples of this include the design of media with effective (e.g. cubic) nonlinearities, or extremely linear media (where distortion can be cancelled). In two dimensions, the situation is more complex but the same ideas introduced in 1D case remain valid. As an example, we report the propagation of an intense acoustic beam in a sonic crystal under self-collimation conditions. The presented ideas open a way towards the control of acoustic wave propagation in nonlinear regime.

Wed 16:00 Claude Lefebvre Sonic and phononic crystals

Sound Redirection and Absorbing Properties of Lattices of Perforated Shells – (Contributed, 000532)

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In this work we present a comprehensive study of the acoustic properties of sonic crystal slabs made of perforated shells arranged in a square lattice. Due to the perforation ratio and the size of the holes, the shells are almost acoustically transparent although they still show non negligible absorption. Numerical simulations have been performed in order to obtain the transmission, reflection and absorbing properties of finite slabs using the multiple scattering theory. It is found an unusual enhancement of the absorption and reflectance when the wavelength of the impinging sound approaches the lattice parameter of the crystal, which is associated to a redirection of the impinging energy along the axis of the slab. Then, the redirected waves travel through a long lossy path and produce an enhancement of the absorption. This behavior is associated to the excitation of a guided mode which is the responsible of the Fano-like profile experimentally observed in the transmission spectrum. The case of sonic crystals made with lossless shells is also theoretically analyzed for comparison purposes.

Wed 10:30 Gouv Ultrasonic transducers in harsh environments

Ultrasonic Transducers for Extreme Conditions – (Invited, 000134)

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Ultrasonic methods are often used for measurements and non- destructive testing in extreme conditions- in high temperature and corrosive environments, under a high pressure and a strong nuclear radiation. In this presentation a review of ultrasonic transducers developed at the Ultrasound Research Institute and suitable for operation in harsh environments is given. Various types of ultrasonic transducers suitable for high temperature and pressure environments and their properties are discussed. As an example of application of such transducers ultrasonic imaging of the interior of the accelerator driven sub-critical fission reactor is presented. The last case is extremely complicated because the core of such nuclear reactor is cooled by means of a heavy liquid metal, for example, lead-bismuth eutectic alloy. A special attention is given to the materials suitable for such purpose including various piezoelectric materials. Manufacturing technologies of high temperature transducers are presented. For a reliable bonding of piezoelectric elements with protective layers and backing a thermo sonic gold-to-gold diffusion bonding technology has been proposed. The quality of the bonding was tested up to 450oC. Additional problems are

caused by the requirement that the measurements on-line sometimes must be carried out through a relatively narrow access standard port. In this case wave guide type ultrasonic transducers may be used. The waveguides enable to reduce temperature from the melt temperature down to the temperature suitable for piezoelectric elements. Various designs of such transducers including matching layers suitable for harsh environments are discussed. In order to reduce trails in the signals caused by multiple reflections and mode transformation the geometry of the waveguide was optimized using a finite element modelling.

Wed 11:00 Gouv Ultrasonic transducers in harsh environments

Nuclear Radiation Tolerance of Single Crystal Aluminum Nitride Ultrasonic Transducer – (Contributed, 000509)

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For practical use in harsh radiation environments piezoelectric materials are proposed for Structural Health Monitoring (SHM), Non-Destructive Evaluation (NDE) and material characterization. Using selection criteria, piezoelectric Aluminum Nitride is shown to be an excellent candidate. The results of tests on an Aluminum Nitride based ultrasonic transducer operating in a nuclear reactor are presented. The tolerance is demonstrated for a single crystal piezoelectric aluminum nitride after a gamma dose and a fast and thermal neutron fluence, respectively. The radiation hardness of AlN is most evident from the unaltered piezoelectric coefficient after a fast and thermal neutron exposure in a nuclear reactor core for over several months in agreement with the published literature value. The results offer potential for improving reactor safety and furthering the understanding of radiation effects on materials by enabling structural health monitoring and NDE in spite of the high levels of radiation and high temperatures known to destroy typical commercial ultrasonic transducers.

Wed 11:15 Gouv Ultrasonic transducers in harsh environments

High Temperature Ultrasonic Transducer for Real-time Inspection – (Contributed, 000066)

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Conventional ultrasonic transducers are composed of multiple layers: piezoelectric disc, backing element, quarter-wave matching layer(s) and a protective wear plate, all acoustically coupled together. At high temperatures, individual components of the transducer may lose their functionality due to thermal or chemical instability. Also, the bonding between transducer layers may become stressed and damaged.
A broadband ultrasonic transducer with a novel porous ceramic backing layer is introduced to operate at 800°C. 36° Y-cut lithium niobate (LiNbO3) single crystal with a Curie temperature of 1200°C was selected for the piezoelectric element. The 1D KLM model yielded the approximate acoustic properties of matching and backing elements to obtain the desired signal-to-noise ratio (SNR) and signal bandwidth. By appropriate choice of constituent materials, porosity and pore size, the acoustic impedance and attenuation of a zirconia- based backing layer were optimized, and an associated manufacturing procedure was developed. An electrically-conductive adhesive with high temperature and chemical stability was selected to bond the transducer layers together; all transducer materials had similar thermal expansion coefficients.

Prototype transducers have been tested at temperatures up to 800°C. Backwall echoes from a steel plate were compared with those obtained at room temperature, and also with echoes predicted by finite element simulation of the entire system in polar coordinates. The experiments also confirmed that transducer integrity was maintained, while SNR and bandwidth varied only slightly with increasing temperature.

Wed 11:30 Gouv Ultrasonic transducers in harsh environments

Effect of Thermal Shock on High Temperature Ultrasonic Transducer Performance in Small Modular Reactors – (Contributed, 000190)

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Previous studies to demonstrate NDT measurements for small modular reactors have shown that the signal to noise ratio (S:N) becomes a critical issue for fully immersed in-coolant ultrasonic transducers operating at elevated temperature (∼250°C). Thermal expansion is one potential parameter which can pose a complex problem in the design of such transducers. The backing layer, the piezoelectric element and the matching layer with diverse aspect ratio and thermal expansion coefficient can undergo different rates of thermal expansion and cause thermal strains at interfaces and in the piezoelectric material. This strain and temperature can affect the response of the piezoelectric material and hence the performance of the ultrasonic transducer. Moreover, with high thermal strain the backing material can lose contact with the piezoelectric element causing loss of damping, adversely affecting S:N ratio and hence, the defect detection capability. The current work presents results of a numerical case study of such a high temperature ultrasonic transducer operating in pulse-echo mode which experiences thermal shock during measurements in a liquid sodium coolant. The study uses a finite element method to model the effect of changes in properties with temperature, thermal shock and hence the thermal strain on the piezoelectric response. The computational model takes into account the change into the thermo-physical properties of liquid sodium up to ∼250°C. Two examples of combinations of typical high temperature piezoelectric elements with suitable backing and matching layers are modelled. The impact of temperature on the pulse-echo responses is compared and the differences reported in dB.

Wed 11:45 Gouv — Ultrasonic transducers in harsh environments

Acoustic sensors for fission gas characterization in MTR harsh environment – (Contributed, 000018)

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Our group has been working for more than 15 years, in collaboration with CEA, on the development of advanced instrumentation for in-pile experiments in Material Testing Reactor. More precisely, our researches deal with the development of acoustic sensors devoted to the characterization of fission gas release. We will present the main principle of the method. A piezoelectric transducer, driven by a pulse generator, generates the acoustic waves in a cavity that may be the fuel rod or a chamber connected to an instrumented rod. The composition determination consists in measuring the time of flight of the emitted acoustic signal. This acoustic method was tested with success during a first experiment called REMORA 3, and the results were used to differentiate helium and fission gas release kinetics under transient operating conditions. This experiment was lead at OSIRIS reactor (CEA Saclay, France). As a first step of the development program, we performed in-pile tests on the most sensitive component, i.e., the piezoelectric transducer. For this purpose, the active part of this sensor has been qualified under gamma and neutron radiations and at high temperature. Next, a specific sensor has been implemented on an instrumented fuel rod and tested in the frame of a REMORA 3 Irradiation. It was the first experiment under high mixed, temperature neutron and gamma flux. A first irradiation phase took place in March 2010 in the OSIRIS reactor and in November 2010 for the second step of the irradiation. It was the first time that the composition of fission gas has been monitored online and in-situ in a fuel rod, all along an irradiation experiment in a MTR, giving access to the gas release kinetics. New researches involve thick film transducers produced by screen-printing process in order to propose piezoelectric structures for measurements under harsh temperature and irradiation.

Wed 15:30 Grande Salle — Guided wave NDT/E: modelling and simulation II

Guided waves in a plate-like structure with functionally graded coating – (Contributed, 000313)

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Functionally graded coating has been widely used in aerospace, nuclear and automobile industries. One of the superior properties of the functionally graded coating is that the continuous gradation in material properties can overcome the interfacial problem for better bonding strength. Characterization of mechanical properties of the functionally graded coating is important for testing the structural integrity. The objective of this paper is to investigate the ultrasonic guided waves based technique for evaluating the damage states of functionally graded coating in Nickle based alloy. The wave propagation behavior in an inhomogenous media with material properties varying along the depth direction is firstly studied. The variations of ultrasonic coefficients for guided waves in the specimens with different damages of the coating are obtained for quantitatively evaluating the functionally graded coating. It is found that mode conversions and change of wave amplitude are the two main features for guided waves in specimens with damages. The investigation provides a basis for optimizing and developing guided wave approach for evaluation of functionally graded coating.

Wed 15:45 Grande Salle Guided wave NDT/E: modelling and simulation II

Calculation of Guided Waves in Layered Fluid/viscoelastic/poroelastic Media using Semi-Analytical Finite Element Method – (Contributed, 000352)

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Understanding of the ultrasound transmission in multilayer systems containing multi-physical and multilayer materials is of great interest in many engineering applications such as geophysics, biomedical diagnostics, aircraft and automobile. Recently, the need for computational tools predicting the acoustical behaviors of such media is considerably increasing. This paper will present a numerical procedure to calculate the wave transmission through multilayer structures made from a combination of fluid, anisotropic viscoelastic and poroelastic materials. The poroelastic material is described by using the Biot theory. The presented approach is based on the semi-analytical finite element method (SAFE), which only requires the discretization of the cross-section of the structure. For the finite element solver, high-order spectral element method has been used, showing a significant improvement of the computational efficiency compared to the use of conventional high-order elements. Numeral tests in both time and frequency domains show that the proposed approach is efficient to investigate the transient response as well as the dispersion of layered media.

Wed 16:00 Grande Salle Guided wave NDT/E: modelling and simulation II

A model to predict modal radiation by finite-sized sources in composite plates with account of caustics – (Contributed, 000537)

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Nondestructive testing (NDT) can be performed in plate-like structures thanks to elastic guided waves. These waves are generated by transducers whose finite size generates diffraction effects, leading to complex field radiation characteristics. In order to optimize testing configurations for such plates, it is necessary to predict the guided wave field radiated by a transducer. Modal description of wave fields is known to be very helpful to ease the interpretation of typical signals measured in the industrial practice of NDT. In the case of isotropic and homogeneous plates, Fraunhofer-like approximations can be found in the literature. These allow fast computations of typical diffraction effects for typical transducer geometries. Similar approximations fail at predicting diffraction effects when the plate is anisotropic, typically, for composite multilayered plates used in the aircraft industry. To solve this problem a new calculation method is proposed. It is based on the computation of the approximate Green's tensor describing modal propagation from a point source. The overall principle of the method, which allows us to take in account caustics, is to proceed to an angular integration over the transducer surface as seen from the calculation point, based upon the energy paths involved, which are mode-dependent. To validate this computationally efficient method, some comparisons are made between our results and those obtained using a full convolution integral of the Green's tensor over the surface of the finite-sized source. Examples given concern disk and rectangular shaped transducers which are the most commonly used sources in the NDT practice.

Wed 16:15 Grande Salle Guided wave NDT/E: modelling and simulation II

Excitation of guided modes and energy transfer inside helical multi-wire structures with prestress – (Contributed, 000548)

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Ultrasonic guided waves are of interest for cable inspection. These waves are by nature multimodal and dispersive. In practice, modeling tools are required for interpreting and optimizing measurements. The modeling of cables must yet face various difficulties:

- cables are generally made of individual wires that are helical,
- contact between wires forms a multi-wire coupled system,
- high prestress is applied,
- cables are often embedded into a solid matrix used for protecting steel.

Based on a semi-analytical finite element method, this work shows how to overcome these difficulties. It is restricted to seven-wire strands (one cylindrical wire surrounded by six peripheral helical wires), widely encountered in civil engineering cables.

First, the elastodynamic equations must be written in a non trivial helical coordinate system satisfying translational invariance. The interwire coupling is then handled provided simplified contact conditions. Next, prestress effects are included in the elastodynamic equations. The static prestressed state is obtained from a helical homogenization method. A PML technique eventually allows to account for an unbounded embedment.

Numerical dispersion curves are computed. Each modeling step is validated by reference results (analytical, numerical or experimental). Prestress turns out to act on wave propagation mainly through the increase of interwire contact area. The latter is validated with available analytical solutions on cylinders. Finally, some simulations under excitation are performed thanks to a biorthogonality-based modal formalism. This allows to analyze the interwire energy transfer and to identify a local compressional mode of potential interest for non-destructive evaluation.

Wed 16:30 Grande Salle Guided wave NDT/E: modelling and simulation II

Interaction of the Shear Horizontal Bend Guided Mode (SHB) with Transverse Cracks – (Contributed, 000574)

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Recent research by the authors has revealed the presence of shear horizontal- type of feature-guided (SHB) waves in plates with 90° transverse bends. The SHB mode is non-dispersive and has low attenuation over a range of higher frequencies (500 kHz - 1 MHz). This mode is attractive for Non-destructive Evaluation (NDE) of bends in practical structures such as aerospace spar joints. Here the interaction of the SHB mode with transverse small-width notches (cracks) running across bends in plates is studied using 3D finite element simulations and validated by experiments. For through-thickness cracks, the influence of transverse crack length on SHB mode reflection is studied. For part-depth but long cracks (transverse length greater than operating wavelength), influence of crack depth on mode reflection is studied. The results demonstrate the potential of the SHB mode for NDE of bent plate structures

Wed 16:45 Grande Salle Guided wave NDT/E: modelling and simulation II

Guided Waves Modeling in Composite Structures to Optimize an NDT System – (Contributed, 000592)

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A simplified 2D finite element model is developed to describe guided wave propagation in a multi-layer cylinder along the axial direction. Understanding the interaction of guided waves with expected defect types can give insight into the optimal excitation configuration, e.g. frequency and transducer geometry. Due to the dispersive nature of the guided waves as well as the limited accessibility to the outer surface of the cylindrical structure, damage detection and sizing is accomplished via modal reflection, transmission and conversion coefficients. To this end, comb-array type transducers are modelled and are used both as emitters and receivers. These multi-element devices allow for the modal decomposition of wave packets in the wavenumber-frequency domain. A study is carried out to determine optimal excitation parameters for a given defect type. A bi-layer carbon-epoxy over-wrapped pressure vessel is used as an example case. However, the methodology presented is applicable to a wider-range of planar and cylindrical multi-layer structures. It is demonstrated that the mode with relatively high exterior boundary displacement should be used as an excitation mode when detecting and sizing surface-originating crack type defects. Transducer geometry is chosen to support a strong excitation of this mode at optimal frequencies, namely near 180-200 kHz for the structure in question. This frequency range is shown to be optimal by virtue of its high conversion coefficients to other modes in the reflection and transmission fields, i.e. after the excited wave packet interacts with the defect.

Wed 17:00 Grande Salle Guided wave NDT/E: modelling and simulation II

Simple finite element algorithm to determine propagating modeshapes in a multi-layer waveguide – (Contributed, 000610)

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A simple algorithm for determining the modeshapes constituting a wavepacket propagating in a waveguide is presented. The method uses the solution of the Helmholz equation in commercially available finite element software. A two-dimensional example is chosen to illustrate, and the two planar directions are monitored in a regular rectangular grid. Modal decomposition is achieved via the Fast Fourier transform (FFT). The amplitude of the modeshape as a function of thickness of the waveguide is determined by local maximums of the FFT as a function of position. Special consideration needs to be given to the angle of the solution to the FFT in the complex plane to inform the given modeshape's amplitude with respect to the mid-plane. Solutions are compared with commercially available dispersion curve software for single and multilayer cases.

Wed 17:15 Grande Salle Guided wave NDT/E: modelling and simulation II

Influence of the numerical dispersion effects in the modelling of ultrasonic measurements – (Contributed, 000387)

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The modern structures in aerospace, transport, wind energy and other industries contain components manufactured of composite materials. One of the advanced techniques used for inspection and monitoring of such structures are based on application of ultrasonic guided waves. The dispersive character of guided waves complicates the analysis of the signals propagating in large complex structures. Numerical simulation is one of the most efficient tools enabling adequate interpretation of the signals.. However, the necessity to relate the sampling steps in time and space domains with frequency and wavelength of the ultrasonic waves propagating within the object under investigation often leads to unacceptably long simulation time. Employment of coarser meshes tend to create additional problems caused by the numerical dispersion effects. They may individually affect the propagation velocities of different harmonic components of the wave pulse. The final result is the distortion of the shape of the simulated signal and mismatches against the experimental results. The objective of this work was to investigate the numerically caused distortions in simulated ultrasonic waves and to develop the technique enabling to minimize their influence. The analysis has been carried out by investigating the propagation of wideband ultrasonic waves in materials with known elastic properties by using the finite element model. The signals along the wavepath have been calculated and numerical dispersion could be estimated by means of two dimensional Fourier transform. The same calculated signals have been used for the estimation of the propagation velocity, which has been compared against the corresponding wave velocities obtained by the analytical formulae and against signal velocities measured experimentally. As a result of the investigation, the rules enabling to determine a well-balanced set of modelling parameters have been developed. It was demonstrated that the models developed on the base of this set of parameters enable to reduce the numerical dispersion errors , as well as, the simulation time.

Wed 16:15 Claude Lefebvre Acoustic Metamaterials: fundamentals, applications and emerging topics I

Cloaking and transformation elastodynamics for elastic plates – (Contributed, 000250)

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Broadband cloaking via transformation elastodynamics is considered. It is shown that, in contrast to Maxwell's equations and the Helmholtz equation, the fourth-order differential operator governing the flexural deflection of Kirchhoff-Love plates is not invariant under a general coordinate transformation. As such, the metamaterials required to create invisibility cloaks for thin plates cannot be understood in terms of a simple Kirchhoff-Love plate. Nevertheless, we demonstrate that a consistent physical interpretation for transformation elastodynamics as applied to thin elastic plates can be found in terms prestressed inhomogeneous anisotropic plates.
The primary result of the work presented here is the analysis of the transformed differential operator and its interpretation in the framework of the linear theory of pre-stressed plates. We provide a formal framework for transformation elastodynamics as applied to elastic plates and demonstrate that it is possible to create a regularised invisibility cloak for Kirchhoff-Love plates by applying an appropriate combination of pre-stress and in-plane body forces to an anisotropic plate. The rigorous theoretical framework is accompanied by an illustrative example, involving a regularised square push-out transformation, with numerical examples demonstrating the efficacy of the broadband invisibility cloak In particular, we use a flexural analogue of the classical Young's double split experiment in order to demonstrate the quality of the cloaking effect.
The proposed physical interpretation of the transformed differential operator may lead to a refinement of experimental implementations.

Wed 16:30 Claude Lefebvre Acoustic Metamaterials: fundamentals, applications and emerging topics I

Theory and applications of perforated acoustic metamaterials – (Contributed, 000037)

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In this talk we focus on a wide range of wave phenomena in perforated metallic and non-metallic metamaterials. Aided by a simple theory we show how these structures can be modeled to get insight into highly absorptive panels [1], negative refractive materials [2] and focusing of sound beyond the diffraction limit [3]. These numerical techniques are verified by experimental proofs. Beyond these achievements we also address the outlook and outstanding challenges in the field of acoustic and elastic metamaterials.

[1] J. Christensen, V. Romero-Garcia, R. Pico, A. Cebrecos, F. J. de Abajo, N. A. Mortensen, M. Willatzen, and V. J. Sanchez-Morcillo, Sci. Rep. 4, 4674 (2014). [2] J. Christensen and F. J. Garcia de Abajo, Phys. Rev. Lett. 108, 124301 (2012); V. M. Garcia-Chocano, J. Christensen, and J. Sanchez-Dehesa, Phys. Rev. Lett. 112, 144301 (2014). [3] J. Zhu, J. Christensen, J. Jung, L. Martin-Moreno, X. Yin, L. Fok, X. Zhang, and F.J. Garcia-Vidal, Nature Phys. 7, 52 (2011).

Wed 16:45 Claude Lefebvre Acoustic Metamaterials: fundamentals, applications and emerging topics I

Acoustic Fresnel lenses with extraordinary transmission – (Contributed, 000595)

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Building acoustic lenses with high transmission efficiency is challenging due to the lack of materials with high refractive index and low impedance mismatch with the host medium. In this work we investigate the design of highly efficient acoustic lenses based on the principle of extraordinary acoustic transmission. We study circular, flat lenses composed of perforated air channels, similar to Fresnel zone plates. The transmission through the lens is maximized through the excitation of Fabry-Perot resonances in the channels and cavity resonances on the lens surface. The lenses are built experimentally using 3D printing. The transmission and focusing properties of the lenses are de-

termined using modal expansions and finite elements simulations. The proposed lenses are able to transmit more than 80% of the incident energy and generate sharp focusing with very high amplification (up to 16 dB experimentally). Furthermore, the resulting lenses are several times thinner than other designs providing similar performance, making them ideal candidates for application in acoustic imaging and medical diagnostics.

Wed 17:00 Claude Lefebvre Acoustic Metamaterials: fundamentals, applications and emerging topics I

Sound Propagation above a Soda Can Array: Extraordinary Focusing Without Time Reversal – (Contributed, 000458)

A. A. Maznev[a], G. Gu[b], S.-Y. Sun[b], J. Xu[c], Y. Shen[b], N. X. Fang[d] and S.-Y. Zhang[b]

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In the past decade, a significant effort has been put into attempts to focus light or sound into a sub-diffraction-limited spot. In an elegant experiment [1], time reversal was used to focus sound above an array of soda cans into a spot much smaller than the acoustic wavelength in air. In this report, we aim to answer two questions: (i) Is time reversal essential for achieving the extraordinary focusing demonstrated in [1]? (ii) Does the observed effect truly beat the diffraction limit with respect to the wavelength of the acoustic wave propagating in the metamaterial medium formed by soda cans? We arrange soda cans into a nearly circular array and focus monochromatic sound into the center of the array. The size of the focal spot is made progressively smaller as the frequency approaches the Helmholtz resonance frequency of a can from below, and, near the resonance, becomes as small as 1/40 of the wavelength in air. We show that a locally resonant metamaterial formed by a periodic array or a random assembly of soda cans supports a guided wave at frequencies below the Helmholtz resonance frequency. The small focal spot results from a small wavelength of this guided wave near the resonance in combination with a near field effect making the acoustic field concentrate at the opening of a can. We conclude that the observed sharp focusing, albeit impressive if compared to the wavelength in air, does not beat the diffraction limit.

[1] F. Lemoult et al., Phys. Rev. Lett. 107, 064301 (2011).

Wed 17:15 Claude Lefebvre Acoustic Metamaterials: fundamentals, applications and emerging topics I

Dynamic homogenization of acoustic metamaterials with coupled field response – (Contributed, 000483)

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Acoustic metamaterials are heterogeneous materials with dynamic subwavelength structures that can generate behavior of interest to ultrasonic imaging applications such as negative refraction and zero index. However, traditional effective medium models fail to properly capture the frequency dependent response of these materials. Recent work on homogenization schemes for wave propagation in heterogeneous electromagnetic (EM) and elastic materials indicate that EM bianisotropy and elastic momentum-strain and stress-velocity field coupling is required to correctly describe the effective behavior of the medium [Alù, Phys. Rev. B, **84**, 075153 (2011); Milton and Willis, Proc. R. Soc. A, **463**, 855-880, (2007)]. Further, the determination of material coupling terms in EM resolves apparent violations of causality and passivity which is present in earlier models [A. Alù, Phys. Rev. B, **83**, 081102(R) (2011)]. This work derives expressions for effective properties of a heterogeneous fluid medium from expressions for the conservation of mass, the conservation of momentum, and the equation of state and find a physically meaningful effective material response from first-principles. Coupling between the ensemble-averaged volume strain and momentum fields is shown explicitly. The approach is valid for an infinite periodic lattice of heterogeneities and a one dimensional example is provided. [This work supported by the US Office of Naval Research]

Wed 10:30 Citadelle 2 Chemical and molecular ultrasonics: General

Memory effect and redistribution of cavitation nuclei – (Contributed, 000129)

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A better understanding of the relationship of cavitation cloud and cavitation nuclei will contribute to the application of cavitation in the field of ultrasonic sonochemistry and ultrasonic cleaning. Temporal evolution and spatial distribution of acoustic cavitation structures (evolving complicated patterns with clear boundary) in a very thin liquid layer were investigated experimentally with high-speed photography. The inception and disappearance processes of cavitation bubble cloud are revealed that the metastable cavitaton structures formed in the thin liquid layer cause a long-term "memory effect". The mechanism and effect factors of memory effect are analysed. The redistribution of cavitation nuclei was investigated by changing the temporal decay of the memory effect. The experimental results indicate that the spatial distribution of cavitation nuclei can be well controlled by cavitation cloud. The thin-liquid-layer-cavitation method is useful for the investigation of cavitation nuclei because of the two-dimensional nature of thin liquid layer.

Wed 10:45 Citadelle 2 Chemical and molecular ultrasonics: General

A numerical study of the formation of a conical cavitation bubble structure at low ultrasonic frequency – (Contributed, 000506)

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This paper presents a study of the formation of a conical bubble structure due to cavitation at 20 kHz in water. This analysis is performed by using the numerical code Snow-Bl, which solves the interaction of finite amplitude pressure waves and a population of oscillating bubbles. We present multi-dimensional simulations that show how a variation of bubble density in a thin bubbly layer at the surface of the source induces the strong focusing of the ultrasonic field. Moreover, waves at high amplitudes exhibit nonlinear distortion due to the bubbles and similarities with the acoustic field associated to a self-stabilized conical bubble structure observed experimentally at the surface of a sonotrode working at 20 kHz in water are shown. This work is funded by the research project DPI2012-34613 (Spain).

Wed 11:00 Citadelle 2 Chemical and molecular ultrasonics: General

Transient Cavitation Bubbles in a Molten Aluminium Alloy: In Situ Synchrotron Radiography and Acoustic Characterization – (Contributed, 000130)

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In metallurgy and especially in the melt processing of conventional and advanced metallic materials high-intensity ultrasonic vibrations significantly improve the quality and properties of molten metals during their solidification process. These improvements are primarily due to ultrasonic cavitation, with the creation, growth, pulsation, and collapse of bubbles in the melt. However, the development of practical applications is limited by the lack of fundamental knowledge on the dynamics of cavitation bubbles as it appears very difficult to directly observe ultrasonic cavitation in non-transparent molten metals, especially at high temperatures, using conventional techniques.

In this study in-situ synchrotron radiography experiment was performed to investigate bubble dynamics in an Al-10 wt% Cu alloy under external ultrasound field at 30 kHz. Radiographs with an exposure time of 78 ms were collected continuously during sonication of molten alloys at temperatures around 640 oC. Only the transient cavitation bubbles which were observed for first time ever were considered for analysis. Quantification of bubble parameters such as average size and time of collapse were evaluated from radiographs using advanced image analysis. Additionally, broadband noise associated with the acoustic emissions from shock waves of transient cavitation bubbles and estimation of their real-time acoustic pressures was performed using an advanced high-temperature cavitometer in a larger melt volume and the data was correlated to synchrotron observations.

Wed 11:15 Citadelle 2 Chemical and molecular ultrasonics: General

Effects of operational conditions on preparation of oil in water emulsion using ultrasound – (Contributed, 000095)

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Emulsions are used in many industrial fields such as reaction field of polymerization, cosmetics, ink, and food etc. It is important to control the droplet size to design the property of products. Ultrasonic emulsification is known to be useful in preparation of nano emulsion, because use of surfactant can be reduced. Moreover, nano emulsion whose droplet diameter is around 100 nm is able to prepare by sequentially ultrasonic irradiation from low frequency to high. In this study, oil in water systems of toluene - water emulsion is prepared using ultrasonic emulsification and mechanical emulsification methods. We also investigate sequential emulsification process, and the relationships between the droplet size of crude emulsion and ultrasonic frequency in the second stage are examined. Ultrasound is more suitable for emulsification than homogenizer. In addition, dynamic process operational method is applied to preparation of emulsion. Crude emulsion is prepared by mechanical method in the first stage, and ultrasound is irradiated in the second stage. The droplet size of emulsion is influenced by the relationships between droplet size of crude emulsion and ultrasonic frequency in the second stage. When the initial droplet size was large, ultrasound with low frequency was effective for decreasing droplet size. On the other hand, when the initial droplet size was small, ultrasound with high frequency was effective.

Wed 11:30 Citadelle 2 Chemical and molecular ultrasonics: General

Comparing ultrasound and mechanical steering in a biodiesel production process – (Contributed, 000498)

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The analysis of the kinetics of the transesterification reaction is crucial to compare different routes or routes with different catalysts or reaction accelerators. The use of ultrasound is considered a method for accelerating the biodiesel production. However, little effort has been done and is reported in the literature about how and under what conditions the use of ultrasound really speeds up the process, or the conditions under which its use is unnecessary or even harmful, burdening the process. Two dissimilar energy injections into a typical route were tested: ultrasound (@ 1 MHz and no heating) and mechanical steering (with heating), both applied in an 8:1 ratio of soybean oil and methanol, adding 1% of KOH as catalyzer. As results, during the first 10 minutes of reaction ultrasound showed unbearable effect on the transesterification, whilst mechanical steering and heating achieved almost 70% of conversion ratio. However, during the following 10 minutes, the mechanical steering and heating got nothing more than 80% of conversion, a considerable less efficient process than ultrasound assisted one, which achieved more than 90%. The straightforward explanation is that ultrasound continually inserts energy in a slower rate, what can result in a more stable conversion scenario. On the other hand, mechanical steering and heating provides more energy at a glance, but cannot push the final conversion rate beyond a limit, as the transesterification is a double way chemical process. The instability mechanical steering and heating settles in the reaction medium pulls the components back to their original states more than pushes than to the converted equilibrium state of the matter.

Wed 11:45 Citadelle 2 Chemical and molecular ultrasonics: General

Cyclopentasilane based Liquid Polydihydrosilane Precursor prepared via Sonication – (Contributed, 000373)

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Printable electronics based on liquid silicon hydrides presents a non-vacuum and potentially low-cost technology that has received much attention in recent years. We report on a method for the preparation of a liquid polydihydrosilane (-$(SiH_2)_n$-) precursor via the sonocatalytic ring-opening polymerisation of cyclopentasilane (Si_5H_{10}, CPS). The polymerisation of the CPS monomer is required in order to decrease the volatility of the precursor, thereby making it suitable for the deposition of semiconducting silicon used in optoelectronic devices such as thin-film transistors and solar cells. The sonication of CPS is done in solution using cyclooctane as solvent and a 26 kHz ultrasonic horn. Since CPS is pyrophoric in air, processing is carried out in a N_2-filled glove box. The molecular mass (M_w)of the resulting -$(SiH_2)_n$-, as measured using size exclusion chromatography (SEC), is shown to increase with sonication time and is found to significantly exceed that of identical solutions subjected to purely thermal treatment for the same duration and at the same process temperature. In fact, we show that for a process temperature of ~75°C, only sonication produces precursors with a sufficiently large M_w of 2000-8000 g/mol. The precursor solution is used to produce homogeneous thin films on glass substrates via spin coating which are subsequently converted to hydrogenated amorphous silicon (a-Si:H) by pyrolytic conversion at >400°C on a hot plate. In addition, we use Fourier transform infrared spectroscopy (FTIR) to characterise the Si-H bonding configuration and photothermal deflection spectroscopy (PDS) to study the optical band gap of the thin films.

Wed 12:00 Citadelle 2 Chemical and molecular ultrasonics: General

Acoustic, Thermal and Molecular Interaction Studies of Poly Ethylene Glycol (2000, 3000, 6000) – (Contributed, 000219)

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Polyethylene Glycol (PEG) is a condensation polymer of ethylene oxide and water. PEG finds its application as emulsifying agents, detergents, soaps, plasticizers, ointments, etc. Though the chemical and physical properties of PEG are known, still because of their uses in day to day life, it becomes necessary to study few physical properties like ultrasonic velocity, viscosity and hence adiabatic compressibility, free length, etc. In the present study, an attempt has been made to compute the activation energy and hence to analyse the molecular interactions of aqueous solutions of Polyethylene Glycol of molar mass 2000, 3000 and 6000 at different concentrations (2%, 4%, 6%, 8% and 10%) at different temperatures (303K, 308K, 313K, 318K) by determining relative viscosity, ultrasonic velocity and density. Various parameters like adiabatic compressibility, viscous relaxation time, inter molecular free length, free volume, internal pressure, etc are calculated at 303K and the results are discussed in the light of polymer-solvent interaction. This study helps to understand the behavior of macro-molecules with respect to changing concentration and temperature. Furthermore, viscosity and activation energy results are correlated to understand the increased entanglement of the polymer chains due to the increase in the concentration of a polymer solution that leads to an increase in viscosity and an increase in the activation energy of viscous flow.

Wed 10:30 ESAL 2 Physical acoustics: nonlinear

Generation of impulses from single frequency inputs using non-linear propagation in spherical chains – (Contributed, 000152)

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This paper investigates the use of chains of spheres to produce impulses. An ultrasonic horn is used to generate high amplitude sinusoidal signals. These are then input into chains of spheres, held together using a minimal force. The result is a non-linear, dispersive system, within which solitary waves can exist. The authors have discovered that resonances can be created, caused by the multiple reflection of solitary waves within the chain. The result of Hertzian contact between the spheres is that the multiply-reflecting impulses can have a wide bandwidth, due to the inherent nonlinearity of the contact between spheres.

It is found that the effect only occurs for certain numbers of spheres in the chain for a given input frequency, a result of the creation of a nonlinear normal mode of resonance.The resulting impulses have many applications, potentially creating high amplitude impulses with adjustable properties, depending on both the nature and number of spheres in the chain, and the frequency and amplitude of excitation.

Wed 10:45 ESAL 2 Physical acoustics: nonlinear

WAVE3D : A Parallelised Three-Dimensional Nonlinear Acoustic Wave Propagation Solver – (Contributed, 000178)

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In many applications of focused ultrasound, due to the high acoustic intensities or to the invasive nature of many measurement techniques it is necessary to compute the acoustic field in order to gain knowledge of the in-situ pressures and dose.

This talk presents the applications of a numerical solver, developed as part of the EURAMET funded 'Dosimetry for Ultrasound Therapy' (DUTy) project, as a powerful and flexible tool in ultrasound field characterisation, dosimetry, treatment planning and quality assurance. An aim of the project is to offer access to this model to research groups who may supply input field conditions or transducer specifications.

A forward model is derived by decomposing the Westervelt model into the absorption, dispersion and nonlinearity operators, and applying an operator- splitting approach within a multi-threaded pseudo-spectral spatial-domain or hybrid scheme. Absorption includes the classical absorption model at either quadratic or power-law dependence on frequency, as well as a measure of absorption due to the formation of shock-like waves.

The user may determine the choice of boundary conditions, the methodology for solving each operator and the number of harmonics computed. The computational domain can be a single homogeneous material, a stratified homogeneous material or data from a clinical imaging system.

The input conditions for the simulations can be analytical or numerical. Multiple harmonic components can be included, allowing for nonlinear input fields or tone-burst excitations. This capability provides a balance between the speed of spatial-marching schemes and the utility of time-domain schemes.

The capabilities of the solver are showcased in computing the heat absorption from a shock-like wave, which are validated against one- dimensional analytical results.

Wed 11:00 ESAL 2 Physical acoustics: nonlinear

Propagation of Flexural Waves in Wedges Exhibiting Hysteretic Nonlinearity: Nonlinear Acoustic Black Holes – (Contributed, 000185)

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Asymptotic theory accounting for the influence of hysteretic nonlinearity of micro-inhomogeneous material on the propagation of flexural wave in the plate of continuously varying thickness is developed. For a plate with thickness increasing as a power law of distance from its edge, strong modifications of the wave amplitude dynamics with propagation distance, caused by nonlinear acoustic absorption, are predicted. Particular attention is given to the analysis of the nonlinear effects in wedges exhibiting black hole effect. The considered black hole effect is based on the theoretical prediction of the infinite time needed for the flexural waves to propagate from any point of the plate towards its edge in the wedge with thickness diminishing to zero value at its edge as a square of the distance from the edge or faster [1]. Thus, the wave travelling in the direction of the edge never reaches it, is never scattered by it, and never gives the information in the form of the reflected wave on its existence. At the same time the backscattering of the wave in each point of the plate, which could be potentially expected because of the plate spatial inhomogeneity, could be also negligibly small for the waves of short lengths propagating in the plates of slowly varying thickness, when the conditions of the so-called geometrical acoustic approximation are satisfied [1]. We found that nonlinear absorption progressively disappearing with diminishing wave amplitude leads to complete attenuation of the acoustic waves in the most of the black holes. It is also demonstrated that black holes exist beyond the geometrical acoustic approximation. Applications include nondestructive evaluation of micro-inhomogeneous materials and vibrations damping. [1]. M. A. Mironov, Propagation of a flexural wave in a plate whose thickness decreases smoothly to zero in a finite interval, Soviet Phys. Acoust. 34 (1988) 318.

Wed 11:15 ESAL 2 Physical acoustics: nonlinear

Nature of acoustic radiation force – (Contributed, 000221)

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Motivation:

When a fluid is insonified with ultrasound, a flow consequence of a net stress becomes observable, which has been described as acoustic streaming, quartz wind, acoustic radiation force or acoustic fountain. Following Sir James Lighthill's formulation of the Reynold's streaming, these phenomena have been attributed to a cumulative viscous effect.

Method:

Instead, a multiscale effect, whereby the constitutive elastic nonlinearity scales from the ultrasonic to the macroscopic time, is here proposed and formulated to explain its origin.

Results:

This raises an additional term in the Navier-Stokes equation, which ultimately stems from the anharmonicity of the atomic potential. In our experimental validation, this theory is consistent in water and for a range of ultrasonic configurations, whereas the formerly established viscous theory fails by an order of magnitude. This ultrasonic-fluid interaction, called nonlinear mechanical radiation since it is able to remotely exert a stress field, correctly explains a wide range of industrial and biomedical active ultrasonic uses including jet engines, acoustic tweezers, cyanobacteria propulsion mechanisms, nanofluidics or acoustic radiation force elastography.

References:

G. Rus. Nature of acoustic nonlinear radiation stress, Appl. Phys. Lett. 105, 121904 (2014)

Wed 11:30 ESAL 2 Physical acoustics: nonlinear

Nonlinear Evolution of Acoustic Pulses at Crystal Edges – (Contributed, 000287)

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Acoustic waves guided by the apex of an elastic wedge are non-diffractive, they can be highly tip-localized, and in ideal wedges they are non-dispersive, which favors cumulative nonlinear phenomena. While second-order nonlinear effects on flexural wedge waves are symmetry-forbidden in isotropic media, anisotropic wedge configurations of sufficiently low symmetry can exhibit second-order nonlinearity sufficiently large to give rise to pronounced waveform evolution over propagation distances much smaller than typical attenuation lengths. This has been verified in laser-ultrasound experiments at a rectangular silicon wedge. Acoustic pulses at the tip of the edge were generated by a high-intensity pulsed laser source. Their shapes were detected at two different distances from the source by the probe-beam deflection technique. Spiking of the pulse shapes and wave-front steepening with a clear tendency towards shock formation was observed in agreement with simulations carried out with a nonlinear evolution equation derived within nonlinear elasticity theory. This equation contains an effective second-order nonlinearity with dominating frequency up-conversion when compared with evolution equations for nonlinear bulk and surface acoustic waves. Fourier spectra of the simulated pulse shapes for propagation distances larger than the shock-formation length were examined, and power law behaviors were identified.

Wed 11:45 ESAL 2 Physical acoustics: nonlinear

Second-Harmonic Generation by a Single Layer of Bubbles – (Contributed, 000423)

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Bubbles are well known for being strong nonlinear scatterers in acoustics. This feature is actually used in medical ultrasound [1], and nonlinear phenomena, such as phase conjugation [2] or second-harmonic generation [3], had been reported in bubbly liquids. However, the link between the parameters of the bubbly medium (concentration of gaz, size of the bubbles) and its nonlinear properties has not been clearly identified. We propose to study the nonlinear

response of a single layer of identical bubbles impinged by a plane wave. This simple situation gives an insight on the subtle interplay between the nonlinear response of the bubbles and the multiple scattering of sound waves in the medium. In particular, our model shows that the intensity of the second-harmonic signal generated by the layer is not proportional to the number of scatterers: optimal concentration of bubbles is predicted. Experiments with stable and well-characterized layers of bubbles of different concentrations were performed to check this prediction. [1] J. Powers et al, Medica Mundi 44 (2000) [2] D. V. Vlasov et al, Sov. Phys. Acoust. 29 (1983) [3] J. Wu et al, J. Acoust. Soc. Am. 89 (1991)

Wed 12:00 ESAL 2 Physical acoustics: nonlinear

Propagation of non linear waves passing over submerged step – (Contributed, 000494)

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Water waves can be described in simplified cases by the Helmholtz equation. However, even in these cases, they present an high complexity, among which their dispersive character and their non linearities are the subject of the present study.
We study experimentally the propagation of waves passing over a submerged step. The step delimitates a deep water region where the incident wave propagates and a shallow water region where the wave is partially transmitted. Because of the small water depth after the step, the wave enters in a non linear regime and we focus on these non linear propagation (being nevertheless below the threshold of wave breaking).
First, the region after the step is considered as infinite (in the practice a almost perfect reflexionless beach is used). In this case, it is known that the generation of harmonics is quite involved, due to the dispersive character of the water waves. Indeed, the harmonic associated to 2ω lead to two types of waves: bound waves which are slaves of the fundamental frequency, with $2k(\omega)$ wavenumber, and free waves which propagate according to the usual dispersion relation with $k(2\omega)$ wavenumber. Because of the presence of these two waves associated to the same frequency, beats are produced with characteristic beat length being given within a simple model due to Massel in 1983.Owing to time space resolved measurements of the wave field, we inspect the relative importance of free and bound waves in the shallow water region and revisit the hypothesis used in Massel's model.

Next, the region after the step is imposed of finite size L and ended with a reflecting wall. For certain frequencies and L- values, the spectral component becomes involved, with the appearance of sub harmonics. This regime is analyzed in more details, suggesting a transition to a chaotic wave behavior.

Wed 10:30 Esplanade Standing waves, resonating and actuating ultrasonics I

Contactless Handling of Supercooled Drops and Ice Crystals for Impacts Studies on Solid Surfaces – (Contributed, 000285)

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Understanding the interaction of supercooled drops and ice crystals with solid surfaces in extreme icing conditions is crucial for the design and development of icephobic surfaces, which can prevent or significantly delay ice formation. Effective icephobic surfaces foresee crucial practical applications, ranging from aerospace industry to wind energy. The fundamental study of supercooled drop and ice crystal impact on solid surfaces represents a primary research field, allowing investigation of the physics underpinning the ice formation and accretion on solid surfaces. It is however difficult to experimentally simulate extreme icing conditions, especially for supercooled drops, due to their inherent metastability. Supercooled drop impact experiments are limited by the maximum degree of supercooling that can be reached with the classical pendant-drop system, used for drop generation, due to heterogeneous nucleation of drops at the needle tip. Due to this critical issue, only low degree of supercooling can be typically studied, and experiments with minimum drop temperatures down to -17 °C have been reported. In this work, we designed, realized and optimized a supercooled drop and ice crystal handling system, based on acoustic levitation, where liquid water drops and crystals can be handled at extreme icing conditions. Preliminary results allowed to investigate the complex interaction between non-wetting superhydrophobic surfaces and drops/crystals the range of -16°C to -22°C.

Wed 10:45 Esplanade Standing waves, resonating and actuating ultrasonics I

Design of a Slender Tuned Ultrasonic Needle Insert for Bone Penetration – (Contributed, 000033)

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This paper reports on an ultrasonic bone biopsy needle, particularly focusing on design guidelines applicable for any slender tuned ultrasonic device component. Ultrasonic surgical devices are routinely used to cut a range of biological tissues, including mineralized tissue, such as bone. However the realisation of an ultrasonic bone biopsy needle is particularly challenging. This is due to the requirement to generate sufficient vibrational amplitude capable of penetrating mineralized tissue, while avoiding flexural vibrational responses, which are known to reduce the performance and reliability of slender ultrasonic devices. This investigation uses finite element analysis (FEA) to predict the vibrational behaviour of a resonant needle which has dimensions that match closely to an 8Gx4inch bone marrow biopsy needle. Features of the needle, including changes in material and repeated changes in diameter, have been included and systematically altered to demonstrate that the location of and geometry of these features can significantly affect the resonant frequency of bending and torsional modes of vibration while having a limited effect on the frequency and shape of the tuned longitudinal mode. Experimental modal analysis was used to identify the modal parameters of the selected needle design, validating the FEA model predictions of the longitudinal mode and the close flexural modes. This verifies that modal coupling can be avoided by judicious small geometry modifications. Finally, the tuned needle assembly was driven under typical operational excitation conditions to demonstrate that an ultrasonic biopsy needle can be designed to operate in a purely longitudinal motion.

Wed 11:00 Esplanade Standing waves, resonating and actuating ultrasonics I

A Miniature Surgical Drill using Ultrasonic/Sonic Frequency Vibration – (Contributed, 000034)

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A study is presented of a miniature ultrasonic surgical drill designed for bone biopsy, based on an ultrasonic/sonic drill which converts high frequency to low frequency vibrations through a freely vibrating mass between an ultrasonic transducer-horn and a drill bit. For conventional surgical drilling using a rotary drill or an ultrasonic drill, considerable power is required to penetrate into bone and the efficiency is low. However, for ultrasonic/sonic drilling, sufficient acoustic energy is accumulated and then released through each impact to achieve precise drilling with a lower power requirement. The ultrasonic/sonic drill was originally invented for rock drilling in low gravity environments. In this study it is incorporated in a miniature ultrasonic surgical drill and the effective impulse delivered to the bone is used to evaluate the drilling performance. To develop a miniature surgical device based on maximizing the effective impulse, optimisation of the ultrasonic horn and free-mass is first demonstrated. The shape and dimensions of the ultrasonic horn and free-mass are determined through FEA, which focuses on maximising the post-collision velocity of the free-mass. Then, the entire dynamic stack constituting the surgical drill device is modelled as a mass-spring-damper system to analyse the dynamic behaviour. The numerical model is validated through experiments, using a prototype drill, which record the velocity of the free-mass and the drilling force. The results of the numerical models and experiments indicate this miniature ultrasonic surgical drill can deliver sufficient impulse to penetrate bone and form the basis of an ultrasonically activated bone biopsy device.

Wed 11:15 Esplanade Standing waves, resonating and actuating ultrasonics I

Design and Implementation of the Frequency Control in an Ultrasonic Break Water-in-Oil Emulsion Chamber – (Contributed, 000170)

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In petroleum extraction industry, it is often required the reduction of the water content mixed with oil. Water-in-oil emulsions present high stability and its separation is commonly accelerated by the addition of chemical demulsifiers or with electrostatic techniques. An alternative to reduce the amount of chemical demulsifiers is the use of a standing waves ultrasonic system. Such system operates in the resonance with a frequency around 1 MHz, generating a standing pattern of nodes and antinodes. Acoustic radiation force propels water droplets to the pressure nodes, inducing the coalescence of the water droplets. However, temperature variations can cause a shift in the resonance frequency. In these cases, a tracking system is required to maintain the system in resonance. In this study, a frequency tracking control setup to keep the ultrasonic system in resonance is presented. The control system must follow a resonance with maximum transmission power and correct the changes in the operating frequency due to temperature variation. The thermal characterization of the cell is also presented. The ultrasonic cell must be operated in the resonance of the fluid cavity avoiding other resonant frequencies. A pilot oil processing plant was used for testing. Tests were performed with ultrasound on and off, varying the mass flow, the amount of demulsifier, the initial water content of the water-in-oil emulsions, and controlling the temperature. Ultrasound use improved the water-from-oil separation process by 33%, with cell operating in the range of 330W/L, when compared with a test without using ultrasound.

Wed 11:30 Esplanade — Standing waves, resonating and actuating ultrasonics I

Complete Elastic Constants of a-BBO Resonant Ultrasound Spectroscopy versus Schaefer-Bergmann Diffraction – (Contributed, 000482)

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We use resonant ultrasound spectroscopy (RUS) and Schaeffer-Bergmann diffraction patterns (SBDP) to measure the elastic properties of crystalline samples. In this paper we compare RUS and SBDP for measuring the stiffness coefficients of the trigonal crystal α-barium borate (BBO).

RUS determines the elastic tensor by measuring and adjusting a model for the resonant frequencies of the sample. We measure the resonant frequencies by lightly holding the sample between two piezoelectric transducers. One transducer sweeps through a range of frequencies and excites the resonant modes. The other transducer measures the resonant spectrum of crystal deformations. The elastic tensor is iteratively refined by varying the tensor coefficients until the error between the measured and calculated resonant spectra is minimized.

In the SBDP experiment we create a diffuse spectrally-rich acoustic field containing nearly all plane wave acoustic modes in the transparent sample of interest. A collimated laser beam propagates through the sample and is diffracted by the acoustic waves. A Fourier transform lens maps the resulting SBDP onto a CCD camera, giving a cross-section of the acoustic slowness surface. Analytic solutions for the XY, XZ, and YZ slowness surface cross-sections can then be fit to the measured SBDPs by adjusting the elastic coefficients in order to optimize the overlap.

We have measured the elastic tensor of α-BBO with both RUS and the SBDP method and have found both approaches to agree to less than 3% and to provide substantial improvements over previous measurements.

Wed 11:45 Esplanade — Standing waves, resonating and actuating ultrasonics I

Model-Based Feedback Control of an Ultrasonic Transducer for Ultrasonic Assisted Turning Using a Novel Digital Controller – (Contributed, 000268)

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Ultrasonic turning has time variant parameters due to temperature effects and changing load during the process. This results in a change of the resonance frequency and vibration amplitude. To realize constant vibration amplitudes it is necessary to control the ultrasonic transducer by a suitable feedback controller. One approach to drive such a system is to use the resonance frequency as operating point in connection with an amplitude feedback controller. The advantages of resonant driven low damped systems are low voltages and high values of effective power. This paper presents a digital system used for parameter identification and model-based feedback control of an ultrasonic turning tool. During the turning process the system load depends on several factors like chip formation, material inhomogeneity, warming and tool wear. To achieve a stable process and a uniform surface of the work piece the feedback controller has to guarantee constant vibration amplitude of the ultrasonic tool. The controller used in this paper consists of a digital resonance controller and a current amplitude controller with a frequency of 500 Hz. The current amplitude and phase between the excitation voltage and current are determined by phase sensitive demodulation. To determine the feedback parameters a model-based approach is used.

Wed 10:45 Citadelle 1 Bio-medical: Bones

Fundamental Frequency Estimation Method based on Hilbert Transform for Estimate Trabecular Bone Spacing – (Contributed, 000048)

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Osteoporosis is a disease that affects bone mass and deteriorates bone microstructure. Ultrasound methods have been increasingly used to assess the risk of fracture. Ultrasonic backscatter can reflect the microstructural information of cancellous bone. To estimate the trabecular bone spacing (TbSp), a fundamental frequency estimation method based on Hilbert transform (HFE) is proposed in this study. The HFE was verified with backscatter signals from *in vitro* and *in vivo* experiments. Compared with the TbSp obtained from μ-CT, the HFE-estimated TbSp was accurate (estimation error<3 %) and stable (standard variation $< 4\%$) in higher frequencies (5MHz and 10MHz), and had a high correlation (r^2=0.75~0.99, p<0.01, n=16) with the standard TbSp in different frequencies (0.5~10 MHz) *in vitro*. Moreover, in the *in vivo* applications, the HFE-estimated TbSp was moderately correlated to the hip and lumbar BMD (R=-0.74~-0.66, p<0.05, n=470). It shows that the HFE method is accurate and stable for TbSp estimation. This paper demonstrates the HFE method can be used to characterize the cancellous bone TbSp.

Wed 11:00 Citadelle 1 Bio-medical: Bones

Resonant Ultrasound Spectroscopy to Measure Anisotropic Viscoelastic Properties of Bone and Other Attenuative Materials – (Contributed, 000259)

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Resonant Ultrasound Spectroscopy (RUS) is developed with the aim to become a routine technique for the accurate assessment of anisotropic elastic and viscoelastic properties of mineralized tissues (bone, dentin) and other attenuative materials such as plastic composites. RUS does not suffer from some drawbacks and limitations of the conventional sound velocity approach which is popular to measure bone anisotropic elasticity. In particular a conventional RUS setup can measure small parallelepiped samples of characteristic dimension as small as two millimeters. RUS allows to estimate the real and imaginary parts of the terms of the stiffness tensor from the measurement of the mechanical resonant behavior of a specimen. It is based on a comparison of measured and model-predicted resonant frequencies (optimization problem). While RUS was developed in the 1990's to measure metals, the difficulty raised by the high level of mechanical damping of bone, which causes resonant peaks to overlap, has only been recently overcome (Bernard et al, J Acoust Soc Am 2014). Still, some predicted frequencies cannot be observed and correctly pairing the predicted and measured frequencies in the definition of a cost function is challenging. We propose a Bayesian formulation and the use of Monte Carlo Markov chain (MCMC) methods to overcome this problem and automatize the processing of the RUS experimental data. In this communication, we will first give an overview of the recent improvements of RUS to measure attenuative materials including signal processing and inverse problem issues. Secondly we will present the results of measurements of 59 cortical bone specimens. The high precision of the method allowed to reveal strong correlatations between the different stiffness coefficients in a large density range.

Wed 11:15 Citadelle 1 Bio-medical: Bones

Estimation of bone thickness with topological energy imaging – (Contributed, 000367)

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Osteoporosis is a frequent bone disease that mainly (but not only) affects women after menopause. It is characterized by a decrease in bone mass and a deterioration of the microarchitecture which can lead to an increased risk of fracture. Ultrasound technologies provide an affordable means to implement non invasive solutions to diagnostically assess the characteristics of the bone structure. In this work, we are interested in the evaluation of the thickness of cortical bone using the topological energy method. The topological energy method has been developed during the last 10 years for the ultrasonic target detection in metallic and composite materials [1]. We first start with a plane wave illumination and record the received signals from the imaged sample with a phased-array receiver. In a second step, these temporal signals are time-reversed and back-propagated in the computer, leading to an image of the discrepancies between the unknown medium (the immersed sample of interest) and the reference medium (homogeneous fluid for example). The method has been adapted to the inspection of the femoral neck. Some experiments have been run on various femoral neck phantoms using a 128-elements phased array at a central frequency of 1 MHz. These exprimental measurements are also compared with two-dimensional Finite Difference Time Domain numerical simulations. This method can be extended straightforwardly to other bone sites like the tibia.

We show that it is possible to obtain an image of the external shape of the bone, as well as a local estimate of the cortical thickness, two characteristics which are requested to interpret the measurements of guided waves dispersion curves. To the best of our knowledge, this work represents the first ultrasound application of the topological energy method in the medical field.

[1] Dominguez N., Gibiat V. and Esquerre Y., Time domain topological gradient and time reversal analogy: an inverse method for ultrasonic target detection, Wave Motion, 2005, Vol. 42, n° 1, pp. 31-52.

Wed 11:30 Citadelle 1 Bio-medical: Bones

A robust optimization method for estimating the cortical bone properties from guided wave measurements – (Contributed, 000519)

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Measurements of the guided modes dispersion relations, along with suitable waveguide modeling, have been shown to have the potential for providing estimates of material and structural properties of cortical bone (J Foiret, IEEE TUFFC, 2014). Nonetheless, such a model-based approach usually leads to a multidimensional and non-convex cost functional when pairing the incomplete data with the model. As a consequence, the performance of conventional gradient-based techniques to minimize this cost functional strongly relies on the choice of the initial guess.

To overcome this difficulty, the present work presents a global search approach based on genetic algorithms, which enables us to estimate the model parameters, avoiding any prior knowledge on the model parameters. This approach is evaluated on a cohort of healthy subjects.

The proposed methodology consists of three elements: (1) Measured dispersion curves obtained after processing of the full time-domain response (J.-G. Minonzio, JASA, 2010), (2) theoretical dispersion curves derived from a free transverse isotropic plate model, based on homogenized elastic bone properties (W Parnell, JRSI, 2009), and (3) a model-based inverse problem used to estimate the material and structural properties of cortical bone. These properties are found by a global search algorithm that minimizes the discrepancy between the measured and numerically predicted dispersion spectra, by means of a least-square estimation of the residual error. Genetic algorithms are used as search algorithms due to their capability of finding a global solution where the cost functional has multiple local minima.

Nine healthy subjects were included in this pilot study. The obtained properties were compared to those delivered by the high resolution X-ray peripheral computed tomography.

Results showed a good agreement between the cortical thicknesses obtained with the ultrasound-based technique and those obtained with the X-ray-based technique ($R2=0.86$, $RMSE=0.14$ mm, $p<0.005$). The results indicate that genetic algorithms provide a robust optimization tool for extracting mechanical features from guided wave measurements.

Wed 11:45 Citadelle 1 Bio-medical: Bones

An anisotropic bi-layered model to predict in-vivo measurements from guided waves – (Contributed, 000518)

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Recent studies on the ultrasonic characterization of cortical bone have reported that cortical bone behaves as a waveguide for ultrasound. Measurements of the guided modes dispersion relations, along with suitable waveguide modeling, have the potential for providing estimates of geometrical and elastic properties of cortical bone. Nonetheless, it could be observed that the presence of soft tissue may bias those estimates, especially due to the appearance of additional guided modes and coupling effects at the solid-fluid interface.

To improve our understanding of such influence, the present work presents an anisotropic bi-layered model to extract unbiased estimates from cortical bone measurements. This model is first validated on a series of soft tissue-bone-mimicking phantoms using an ultrasonic probe in an axial transmission configuration. Then, the potential of this modeling is evaluated on in-vivo measurements at the forearm.

The measurements were performed using a 1-MHz bidirectional multi-element probe. The full time response of the waveguide is recorded and a singular value decomposition signal processing technique is applied to extract the guided waves spectrum. The structural and mechanical properties of the specimen can be estimated by comparing the measured guided modes with those predicted by the model using a model-based inverse problem framework.

Six soft-tissue-bone-mimicking phantoms (three bone-mimicking plates of different thicknesses (1-3 mm) coated with two layers of zerdine of different thicknesses (5-10 mm)) were used for validating the model, while healthy subjects were included to evaluate the performance of such approach for in-vivo exploitation.

Additional guided modes and coupling effects were identified in all the phantoms, and our first observations suggest, that even in the presence of the overlying soft tissue-mimicking layer, the modes propagating in the bone-mimicking plate can still be extracted. In addition, we also show that the anisotropic bi-layered model allows explaining experimental data from in-vivo measurements that were considered as outliers when using a free transverse isotropic plate model.

Wed 15:30 Citadelle 1 Bio-medical: Bones

In vivo clinical measurements of ultrasonic guided modes in an elderly population – (Contributed, 000524)

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Assessment of osteoporotic fracture risk is still largely unpredictable. Cortical bone, known for its key role in the mechanical stability, is the subject of extensive research. Ultrasound guided by the long bone cortical layer have shown some diagnostic promises using the first arriving signal (FAS). A specific appealing aspect of ultrasonic guided waves is their ability to account for material or structural properties of the waveguide. The cortical thinning and the increase of porosity observed with aging change the propagation characteristics of the guided modes. Thus, QUS guided waves-based technologies would be expected to provide estimates of bone quality factors which cannot easily be captured by X-ray densitometry techniques (DXA).

Forty eight female patients (age from 50 to 94 year old) were included in this pilot study. QUS measurements were performed at the distal radius in all the patients using a prototype axial transmission device (Azalée, Paris, France) consisting of a multi-transmitter and multi-receiver probe. In addition to the FAS velocity and to the fundamental wave velocity (FWV), the cortical thickness (C.Th) and the apparent porosity (App.Por) were estimated by fitting a homogenized waveguide model to the experimental dispersion curves measured in the 0.5 - 1.5 MHz frequency bandwidth. The bone mineral density T-scores at the femoral neck (FN T-score) and the lumbar spine (LS T-score) were obtained using DXA.

The best discriminating parameters between fractured (N = 18) from non-fractured (N = 30) patients were the apparent porosity (control: 8.9 $\pm$3.2%; fractured: 12.1 $\pm$3.4%; p-value $<$ 0.003; AUC = 0.63) and the femoral neck T-score (control: -1.52 $\pm$0.65; fractured: mean$\pm$SD; -2.30 $\pm$0.65; p-value $<$ 0.001; AUC = 0.65). These preliminary results will be completed in the next future by the inclusion of new patients.

Wed 15:45 Citadelle 1 Bio-medical: Bones

Evaluating the Relation of Trace Fracture Inclination and Sound Pressure Level and Time-of-flight QUS Parameters Using Computational Simulation – (Contributed, 000540)

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Bone healing is a complex process that stars after the occurrence of a fracture to restore bone optimal conditions. The gold standards for bone status evaluation are the dual energy X-ray absorptiometry and the computerized tomography. Ultrasound-based technologies have some advantages as compared to X-ray technologies: nonionizing radiation, portability and lower cost among others. Quantitative ultrasound (QUS) has been proposed in literature as a new tool to follow up the fracture healing process. QUS relates the ultrasound propagation with the bone tissue condition (normal or pathological), so, a change in wave propagation may indicate a variation in tissue properties. The most used QUS parameters are time-of-flight (TOF) and sound pressure level (SPL) of the first arriving signal (FAS). In this work, the FAS is the well known lateral wave. The aim of this work is to evaluate the relation of the TOF and SPL of the FAS and fracture inclination trace in three stages of bone healing using computational simulations. Four fracture geometries were used: normal and oblique with 30, 45 and 60 degrees. The TOF average values were 63.23 μs, 63.14 μs, 63.03 μs 62.94 μs for normal, 30, 45 and 60 degrees respectively and average SPL values were -3.83 dB -4.32 dB, -4.78 dB, -6.19 dB for normal, 30, 45 and 60 degrees respectively. The results show an inverse pattern between the amplitude and time-of-flight. These values seem to be sensible to fracture inclination trace, and in future, can be used to characterize it.

Wed 16:00 Citadelle 1 Bio-medical: Bones

Thickness and Porosity Estimates of Cortical Bone Using the Ultrasound-based Axial Transmission Technique: an ex vivo Study – (Contributed, 000538)

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Numerous efforts have been made over the last decades to improve the mechanical characterization of cortical bone. It has been shown that the long bones such as the radius and the tibia behave as a waveguide (WG) for ultrasonic waves. Bone strength-related factors such as the cortical thickness and porosity can be estimated by comparing the measured dispersion curves with an appropriate waveguide model of the cortical bone.
Twenty-two radii (right and left) were investigated ex vivo. They were obtained from eleven donors (7 males, 4 females), aged from 50 to 91 years old (74$\pm$13). Measurements were first performed using axial transmission technique consisting of a 1-MHz bi-directional multi-element probe, comprising two groups of 5 transmitters placed at each side of a group of 24 receivers. The full time response of the waveguide for all possible pairs of transmitter-receiver is recorded and a singular value decomposition signal processing technique is applied to extract the guided waves spectrum. The thickness and the apparent porosity of the cortical shape were extracted by comparing the experimental data with a 2-D free transverse isotropic plate waveguide model, coupled with an homogenization model (Parnell JRSI 2009). The data processing is fully automated The obtained cortical thickness and apparent porosity range respectively from 1 to 4mm, from 5 to 25%. These values are qualitatively in agreement with previous analysis done on five specimens (Foiret IEEE-TUFFC 2014).

This study suggests the feasibility of a guided wave-based QUS technology to provide automated estimates of both the cortical thickness and porosity on ex vivo human radii. To assess the method reliability and accuracy, the next step will consist of a confrontation between these estimates and the actual values (cortical thickness and porosity) derived from X-ray micro-computed tomography (μ-CT Brukker 1176, 9μm resolution) site-matched to ultrasound measurements (currently under analysis).

Wed 16:15 Citadelle 1 Bio-medical: Bones

Effect of Mechanical and Dimensional degradation on Ultrasonic Guided waves in Bone system – (Contributed, 000173)

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This paper investigates the feasibility of using ultrasonic guided waves for assessing the mechanical properties of human bone towards realizing a safe and economical non-invasive method for the detection of conditions such as osteoporosis. Effects of material (variation in mechanical properties) and dimensional (changes in thickness) degradation in the cortical bone on guided wave characteristics are studied using numerical simulation and analysis.
Guided wave propagation in tubular multi-layered waveguides mimicking the bone system under healthy and degraded conditions is studied using the Semi Analytical Finite Element (SAFE) method. Uniform tri-layered structures consisting of bone-like tubes filled with marrow and surrounded by tissue are considered for the models. The results, validated using analysis and data from literature, show that material and geometric condition strongly impacts the velocity of guided waves supported in the bone system. The impact of underlying assumptions in these models and identification of suitable guided wave modes for practical assessment of bone condition are also discussed.

Wed 16:30 Citadelle 1 Bio-medical: Bones

Quantitative Ultrasonic Imaging of Bones – (Contributed, 000144)

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This study focuses on the ultrasonic imaging of high impedance acoustical contrast targets. The aim is to obtain information about shape, dimensions and sound speed profile of the studied objects. One domain of application is the characterization of long bones. Quantitative information about the acoustic properties of bones tissues are of great interest for diagnosing or treatment monitoring of bone diseases. Inverse scattering problems of this kind are non-linear. Various approximations can be used to linearize the scattering equations. Classical methods based on the first-order Born approximation give good results for weakly scattering targets but fail when it comes to give a quantitative information especially for high impedance contrast targets such as bones. In the inversion algorithm proposed here, Green's theorem is used to obtain a domain integral representation of the scattered field. An iterative non-linear algorithm minimizing the discrepancy between the measured and computed scattered fields is used to reconstruct the sound speed profile in the region of interest. The minimization process is performed using a conjugated-gradient method. An experimental study was performed both with synthetic targets and with animal bones. Images of the sound speed profile obtained by inversion of experimental data are presented.

Wed 10:45 ESAL 1 NDE / NDT: Guided waves

Acoustic Characterization of an Aluminum Plate with Corrugated Interface – (Contributed, 000020)

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In this paper, the propagation of Lamb waves in an aluminum plate with a controlled roughness is studied. The roughness is located in a limited zone of the plate. The density of the spectral power (DSP) of the roughness exhibits three main peaks. Theoretically, a phonon relation can be written, linking the wavenumber of an incident Lamb mode, the wavenumber of a reflected converted Lamb mode and the phonon related to a peak of the DSP. This relation allows to link acoustic behaviors to the topography of the roughness. Experimentally, an incident Lamb mode is excited on the flat area and its interaction with the roughness is studied. Reflected converted waves and the transmission of the incident Lamb mode are observed. Results show the link between the main spatial frequencies included in the roughness and the wavenumber of the converted Lamb modes, as predicted theoretically.

Wed 11:00 ESAL 1 NDE / NDT: Guided waves

Ultrasonic NDT of dissimilar joints – (Contributed, 000381)

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There is a need to reduce the weight of vehicles in order to reduce the carbon dioxide emissions. To achieve this hybrid structures where introduced where dissimilar materials are joined together resulting in high performance lightweight structures. However, for inspection of such structures novel nondestructive testing techniques are required as well. The joints between different metals or metal with fiber reinforced composites is challenging task for any of NDE technique. In the case of ultrasonic techniques the complicating factors are different acoustic impedances and propagation velocities, higher level of the attenuation or scattering in the joined materials, complex geometries and rough surface of the samples. The objective of this work was to develop novel ultrasonic nondestructive testing techniques for inspection of different dissimilar joints (metal/composite and metal/metal). The samples of metal/composite joints with and without defects were investigated using high frequency focused ultrasonic transducers. It was shown that in the case of metal-composite joints biggest problems for inspection are caused by surface unevenness and a special signal processing method for extraction of information of the adhesion area was proposed and tested on experimental data. It is demonstrated, that the proposed method enables positions of the defects in joints to be determined. Dissimilar metal samples were joined using friction stir welding with nanoparticles fillers as reinforcing materials (SiC, TiC and CNTs). It was determined, that for inspection of dissimilar metal joints the high frequency (50-110MHz) ultrasonic focused transducers are required. Investigations show, that scanning acoustic microscopy gives detailed view of inner structure of the welds and defects in it.

Wed 11:15 ESAL 1 NDE / NDT: Guided waves

Time-Frequency and Time-Scale Analysis of Lamb Waves in a Cracked Metal Plate – (Contributed, 000261)

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From recent years, the Lamb waves have experienced a growing interest in the field of non-destructive ultrasonic testing. These waves offer a great potential to increase the inspection quality and reduce the inspection time. However, these waves have the particularity of being dispersive. Several Lamb modes can coexist in the controlled waveguide, which complicates the results' interpretation. To overcome these difficulties, different signal processing methods have been developed. In the present paper, we propose to study experimentally the behaviour of S0 Lamb mode propagating in a steel plate. This waveguide contains a groove located at 4 cm from the free end of the plate. The experimental setup is based on the use of a contact transducer placed on a Plexiglas wedge for excitation and of a laser velocimeter for reception. This latter offers a punctual measurement of the normal displacement on the plane surface of the plate. The main aim of this work is to identify the different Lamb waves propagating in the inspected plate and to detect the groove. To achieve our goal, we have used two signal-processing methods to analyse the experimental results: a time-frequency analysis by Smoothed Pseudo Wigner-Ville Distribution and a time-scale analysis by Complex Morlet Wavelet. The study has brought to the fore that the two proposed signal-processing methods are very effective for both fault detection and for identifying the multiple Lamb modes resulting from the interaction of the incident wave with the groove. The well-expected mode conversion phenomenon of the S0 mode to the A0 mode has been pointed out by using 2D-images of the Smoothed Pseudo Wigner-Ville Distribution together with the dispersion curves giving the arrival time as a function of frequency.

Wed 11:30 ESAL 1 NDE / NDT: Guided waves

Estimation of Distance Between Impact and Sensor on Thin Plates Using a Single Passive Sensor – (Contributed, 000158)

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The sound waves generated by an impact force on a thin plate can be recorded using one or several passive piezoelectric sensors placed at different locations on the plate surface. In principle, using three sensors, the location of an impact force can be estimated by means of triangulation, provided that the time-delay-of-arrival (TDOA) to the different sensors can be accurately estimated. In practice, however, the dispersive nature of the wave modes propagating in the plate makes this difficult. If the dispersion curves of the plate waves are known there are several approaches available to *undo* the dispersion effects and then find the TDOA.
Another approach is to develop a model of the wave modes which, given a small set of parameters, including the propagation distance, describe the entire waveform. For the bending wave mode, given that the excitation (i.e. the impact force) is unknown and the sensor has an unknown transfer function, the received signal $u(t;r,D)$ can be modeled as $u(t;r,D) = h_{er}(t) * h_{SIR}(t;r,D) + e(t)$, where $h_{er}(t)$ is the combined impulse response of the excitation and the sensor, $h_{SIR}(t;r,D)$ is the spatial impulse response of the plate, parameterized by the unknown plate stiffness D, and the unknown distance r between impact and sensor. The term $e(t)$ denotes zero mean additive white Gaussian noise with variance σ^2, and $*$ denotes convolution.

In previous work we showed that, given some constraints that $h_{er}(t)$ is bandlimited and has linear phase, the plate stiffness D can be estimated from a simple calibration experiment. In this paper we show that the model can then be used to estimate the distance between the impact location and the sensor based solely on the waveform. Adding two more sensors, the location of the impact can then be determined.

Wed 11:45 ESAL 1 NDE / NDT: Guided waves

Study for Evaluating of Surface Microcrack on the Steel Wire Rods using Electromagnetic Acoustic Resonance Method – (Contributed, 000561)

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In a manufacturing process of a steel wire rod, lots of micro scale axial cracks usually occur on surface. Cracks over 30 micrometer of its depth may bring about severe problems, so it is very necessary to evaluate the depth of surface microcracks. Traditional NDT Methods had a some difficulties to detect a micro crack because of its accuracy, so this work concerns a nondestructive method to defect micro surface cracks in a steel wire rod using an electromagnetic acoustic resonance (EMAR) technique, which generates SH waves circumferentially in a cylinderical rod and measure the in-lane resonance of its cross section. EMAR is the method for measurement of resonant features using electromagnetic acoustic transducer (EMAT) and sensitive to small variation of the structures. Because of the feature of noncontact measurement, EMAR method is applied easily to the industrial field. The resonance frequency and attenuation coefficient were analyzed about healthy and damaged specimens. The results clearly showed the present method can detect surface cracks of a few tens of micrometers.

Wed 15:30 ESAL 1 NDE / NDT: Guided waves

Discrimination of Epoxy Curing by High Lamb Modes Order – (Contributed, 000021)

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This work is a contribution to the non destructive testing of structural adhesive bonding by ultrasonic methods. In this paper, only the cure of the adhesive is on the focus. Epoxy bulk samples are manufactured with different curing cycles that lead to epoxy networks either partially or totally crosslinked. The aim is to link acoustic behaviors of these samples with their level of cure, quantified by the epoxy conversion. On the one hand, the experimental determination of the longitudinal and shear celerities is performed. Results show that even if the velocities are increasing with the conversion, there variations are not significant enough to discriminate the samples. On the other hand, the theoretical dispersion curves of Lamb waves are obtained using the measured celerities. They predict a high sensitivity of some high Lamb waves order to the cure level by the variation of the wave number, for a given mode and for the same frequency range. In parallel, an experimental study is conducted using a contact transducer as an emitter and a laser vibrometer as a receiver. The double FFT performed on the space-time data allows the determination of the experimental dispersion curves for the different samples. The experimental results and the

predicted ones are in a good agreement. The next step is to extend this study to an aluminum substrate coated with epoxy films having different level of cure.

Wed 15:45 ESAL 1 NDE / NDT: Guided waves

Visualization of Leaky Ultrasonic Lamb Wave Experiments in Multilayer Structures – (Contributed, 000041)

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Leaky ultrasonic Lamb waves propagating in liquid-filled steel pipes are widely used by the oilfield service industry in wellbores to measure the acoustic properties of the material located outside the pipe. Typically, the annular region between the steel pipe and the geological formation is cemented to provide mechanical integrity and to ensure hydraulic isolation between different depths in the well. We present results from an experimental study along spatial and temporal dimensions to visualize the propagating waveforms of such measurements for liquid or solid annular layers behind the steel pipe. Our measurements focus on the lowest-order flexural waves. These radiate energy into neighboring layers if the flexural phase speed is supersonic with respect to the bulk compressional or shear wave phase speeds of the adjacent media. However, if the compressional phase speed is higher than the flexural phase speed, then the flexural mode attenuation is strongly reduced. Several annular materials with compressional velocities higher and lower than the flexural phase speed were investigated to demonstrate this effect. Finally, the propagation of compact flexural wave packets along the steel pipe was recorded and the results were compared with computed modal dispersion and attenuation curves.

Wed 16:00 ESAL 1 NDE / NDT: Guided waves

Separation of leaky Lamb modes for ultrasonic evaluation of multilayer structures – (Contributed, 000022)

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Ultrasonic guided Lamb waves are a major tool for nondestructive evaluation of cylindrically layered, fluid-loaded, elastic structures. When used in fluid-immersed pipes with a frequency-thickness product in the range of 1 to 3 MHz·mm, fundamental Lamb modes - the antisymmetric flexural and symmetric extensional modes - can be selectively excited by a suitable combination of broadband pulse and oblique incidence angle. Both modes exhibit dispersion, but the specific advantage of the flexural mode is that its group velocity is only weakly frequency dependent for the frequency-thickness product range of interest and can therefore be detected after propagation over relatively long distances. The determination of flexural attenuation in pitch-catch configuration of one transmitter and two receivers is particularly adapted to the "inside-out" evaluation of elastic properties of an inaccessible medium outside of a pipe. However, the highly dispersive, coexcited extensional mode interferes with the flexural mode and complicates the determination of the flexural attenuation. We examine two techniques designed to separate the flexural mode from mixed leaky modes. Both techniques are built on an asymptotic forward model describing the interaction of Gaussian ultrasonic transducer beams with loaded, cylindrically layered, elastic structures. The first technique is a mode decomposition algorithm, based on estimates of the complex mode dispersion relations. The second technique benefits from the differences in the frequency dependence of the Lamb waves to build mode dictionaries and to recover the flexural wave by a pursuit algorithm. Both techniques are tested on synthetic and experimental data.

Wed 16:15 ESAL 1 NDE / NDT: Guided waves

Application of the Probabilistic Algorithm for Ultrasonic Guided Wave Tomography of Carbon Composites – (Contributed, 000580)

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The Reconstruction Algorithm for Probabilistic Inspection of Damage (RAPID) was first proposed for the inspection of aluminum aircraft wing panels. It is a tomographic reconstruction method which uses a permanent array of ultrasonic transducers that covers the region of interest, and estimates the presence of damage in a structure by comparing signals measured in the damaged state to baseline signals from an intact state. RAPID has already proven its capability to detect different types of damage in aluminum plate structures, e.g. for crack or corrosion damage inspection. In the present study, we apply RAPID to inspect carbon-fiber reinforced polymer (CFRP) structural components for the presence of barely visible impact damage and tight delaminations. The study is motivated by the fact that the usage of CFRP has significantly grown in importance as a construction material for the aerospace and automotive industries. As a result, the call for an easy and reliable nondestructive inspection and structural health monitoring methods is getting more urgent. RAPID might be a promising option, because it is capable of covering large areas and it's more robust with respect to the quality of the input signals compared to conventional tomographic algorithms. In this contribution, we will demonstrate the applicability of the conventional RAPID approach to CFRP structural parts with different shapes and defects. In addition, we will present numerical and experimental results of a baseline-free approach for the detection of nonlinear defects by means of a modified RAPID algorithm. This modified RAPID relies on the techniques such as pulse inversion and lack of scalability that are well known from the field of nonlinear ultrasound.

Wed 16:30 ESAL 1 NDE / NDT: Guided waves

Application of ZGV Lamb modes in non-destructive testing of composite materials – (Contributed, 000338)

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Laser ultrasonics is a more and more widespread non-destructive testing method as it shows specific advantages compared to conventional ultrasonic methods based on transducers or EMATS. Particularly, it has a high spatial resolution, a large bandwidth, and it is non-contact. Thanks to these features, laser ultrasonic techniques allow characterizing the mechanical properties and/or evaluating the structural health of materials, even where the tested samples present complex geometry and/or are subjected to extreme conditions, such as high temperatures. Up to now, applications of the laser ultrasonic method to non-destructive testing of composite materials have already proved its ability to detect delaminations, fiber-breakage, matrix cracking, or porosity.
In this work, elastic waves are generated in a composite plate by a pulsed Nd:YAG laser and detected using a two-wave mixing interferometer. By varying the focusing of the pump laser radiation, it is possible to favor the generation of one or another type of the acoustic waves in the plate. Especially, in some cases, non-propagating zero group velocity (ZGV) Lamb modes are efficiently excited [1]. These ZGV Lamb modes are first studied in a flawless sample in order to determine their relevant characteristics. In particular, the composite plate anisotropy is shown to influence the resonance spectrum of the sample close to the frequency of ZGV Lamb modes. Then, a damaged composite is considered and the influence of the damage on the ZGV Lamb modes is analyzed.

This presentation is part of the LUCITA project managed by IRT Jules Verne (French Institute in Research and Technology in Advanced Manufacturing Technologies for Composite, Metallic and Hybrid Structures). The authors wish to associate the industrial and academic partners of this project; Airbus Group and Aerolia, EMN-Subatech and LAUM respectively.

[1] PRADA, C., BALOGUN, O., MURRAY, T. W. , Appl. Phys. Lett. 87, 194109 (2005)

Wed 16:45 ESAL 1 NDE / NDT: Guided waves

Robust Ultrasonic Waveguide based Distributed Temperature Sensing – (Contributed, 000369)

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This is the novel technique for the distributed temperature measurements, using single robust ultrasonic wire or strip-like waveguides, special embodiment's in the form of Helical or Spiral configurations, that can cover large area/volume in enclosed regions. Such distributed temperature sensing has low cost applications in the long term monitoring critical enclosures such as containment vessels, flue gas stacks, furnaces, underground storage tanks, buildings for fire, etc. The range of temperatures that can be measured from very low to elevated temperatures. The transduction is performed using Piezo-electric crystals that are bonded to one end of the waveguide which both transmitter as well as receivers. The wires will have periodic reflector embodiment's (bends, gratings, etc.) that allow reflections of an input ultrasonic wave, in a pulse echo mode, back to the crystal. Using the time of flight (TOF) variations at the multiple predefined reflector locations, then the measured temperatures are mapped with multiple thermocouples. Using either the L(0,1) or the T(0,1) modes, or simultaneously, measurements other than temperature may also be included. This paper will describe the demonstration of this technology using a 0.5MHz longitudinal piezo-crystal for transmitting and receiving the L (0, 1) mode through the special form of waveguide at various temperatures zones.

Wed 17:00 ESAL 1 NDE / NDT: Guided waves

Sparse Inversion SVD for Multichannel Ultrasonic Guided Waves Analysis – (Contributed, 000525)

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Recently, ultrasonic guided waves have been used to characterize long bones. A variety of processing techniques have been described to transform the data from the time-distance (t, x) space to the frequency-wavenumber (f, k) space, leading to the velocity dispersion curves of guided waves. In order to enhance the extraction of the dispersion curves of low amplitude guided modes, our group has proposed to add a SVD- based de-noising step to the 2-D spatio-temporal Fourier transform (2-D FT) (Minonzio, JASA, 127(5), 2913-19, 2010). However, whereas the relatively long duration of the recorded time signals ensures a high frequency resolution, the limited number of positions where these signals are recorded (a few tenths of points at best) results in a much lower resolution on the k-axis. In this study, we explore a new processing technique, the sparse inverse SVD (SI-SVD), to overcome this limitation and to improve the resolution of the guided dispersion curves in the (f, k) space. We assume that the SVD decomposition enables to obtain the stable singular vectors and eigenvalue matrix which are not highly correlated to the errors. With the sparse penalty of the wavenumber, the (f, k) spectrum is inversely determined using the least-squares method. Different sparse penalty terms, e.g. the L2-norm and the revised-Cauchy-norm, are compared by processing the synthetic signals corrupted by the additive Gaussian noises simulating the propagation of wideband dispersive guided waves. Finally, the SI-SVD method is testified by processing the experimental data obtained from a 3-mm-thick bone-mimicking plate. We compare the contrast between the dispersion energy and the background obtained from the SI-SVD and SVD-based 2D-FT methods. The preliminary analysis of the synthetic and experimental signals shows that the SI-SVD method using the revised-Cauchy-norm enables to significantly enhance the energy contrast for the accurate dispersion curves extraction.

Wed 17:15 ESAL 1 NDE / NDT: Guided waves

The new signal processing method for the time frequency domain analysis of the dispersive wave signals – (Contributed, 000382)

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Ultrasonic guided waves are one of advanced techniques for structure health monitoring enabling to determine changes in structure caused by damage or variation of elastic properties. However, analysis of the signals is very complicated, due to multi-modal dispersive character of guided waves. Usually only the signal corresponding to the fastest mode is analysed as other modes cannot be identified in the signal. On the other hand the signals of different guided waves modes are distorted by propagation in different unique ways due to different character of the dispersion. This feature can be exploited by signal analysis for identification of the signal segments corresponding to different guided wave modes, however it requires a high resolution both in the time and the frequency domains. The current time-frequency analysis methods are mainly oriented for processing of narrow band signals. The objective of the work presented was to develop time -frequency analysis technique of the guided wave signals enabling identification of different guided wave modes in structure health monitoring applications. For solution of this task the technique is based on the reconstruction of the distributions of different frequency components in the time domain of the signals using optimisation was proposed. The technique was investigated using modelled and experimentally measured signals of different Lamb waves modes in the aluminium and the carbon fibber composite plates. The

investigations demonstrated that the proposed technique determines the distribution of different frequency components in the time domain of wide band signals and using them different signal segments to the corresponding guided wave modes. Additionally, the proposed technique enables also to estimate propagation distance. The determined mode related to the propagation distance simplifies estimation of the propagation path in such a way creating possibility to indicate the position of the damage.

Wed 15:30 ESAL 2 Physical acoustics: physics

Characterization of acoustic streaming beyond 100 MHz – (Contributed, 000204)

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The aim of this study is to investigate acoustic streaming in water at very high ultrasonic frequencies which are difficult to reach technologically. In contrast to previous work that used mainly surface acoustic waves as sources, we employ piston-type transducers at frequencies beyond 100 MHz. The acoustic streaming effects are characterized by particle image velocimetry and electrochemical methods. As the dissipation length of acoustic waves in water shrinks considerably when such frequencies are reached, the acoustic streaming can transform from the well-known "Eckart type" into a "Lighthill type": While Eckart streaming is driven by a small momentum transfer along the path of a weakly damped travelling sound wave, Lighthill streaming is generated by local and complete momentum transfer of a strongly damped and therefore rapidly decaying wave. Then the induced flow field is much larger than the acoustic wave penetration into the liquid, and the flow phenomena are reminiscent of a submerged jet flow. The results indeed show very narrow high-speed jet flows that extend orders of magnitudes farther into the liquid than the acoustic field. The findings are compared to numerical simulations.

Wed 15:45 ESAL 2 Physical acoustics: physics

Temperature Increase Dependence on Ultrasound Attenuation Coefficient in Innovative Tissue-Mimicking Materials – (Contributed, 000278)

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High intensity focused ultrasound beams (HIFU) have found rapid agreement in clinical environment as a tool for non invasive surgical ablation and controlled destruction of cancer cells. However, some aspects related to the interaction of ultrasonic waves with tissues, such as the conversion of acoustic energy into heat, are not thoroughly understood. In this work, the relation between the acoustic absorbed energy and the temperature increase during HIFU exposure is investigated by means of innovative tissue mimicking materials (TMMs), which simulate soft biological tissues. These free of scattering agents TMMs, based on agarose, gellan gum and zinc acetate, achieve attenuation coefficient values up to 1 dB/(cm·MHz). The absence of scattering agents and, in the same time, acoustic properties suitable to simulate soft tissues make these TMMs ideal samples to be used for the investigation of absorption phenomena of acoustic energy in tissues. The temperature increase in the transducer focus region is evaluated as a function of samples ultrasound attenuation coefficient by means of a fiber optic hydrophone, which is inserted into the investigated material. The HIFU transducer has a resonance frequency of 1.1 MHz, while the ultrasound attenuation coefficient is determined up to 10 MHz. An empirical relation between TMMs attenuation coefficient and temperature increase, achieved in the focus region of an HIFU transducer, is deduced establishing useful basis for further processes of validations of numerical models to be adopted for customizing therapeutic treatments.

Wed 16:00 ESAL 2 Physical acoustics: physics

Adaptation of a high frequency ultrasonic transducer to the measurement of water temperature in a nuclear reactor – (Contributed, 000294)

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Most high flux reactors for research purposes, have fuel elements composed of plates where their relative distance is a crucial parameter, particularly concerning the irradiation history. For the High Flux Reactor of the Institut Laue-Langevin, the measurement of this distance with a microscopic resolution becomes extremely challenging for spent elements.
To address this issue, a specific ultrasonic transducer, presented in a first paper, has been designed and manufactured to be inserted into the 1.8 mm width channel between curved fuel plates. It was set on a blade yielding a total device thickness of 1 mm. To achieve the expected resolution, the system is excited with frequencies up to 150 MHz and integrated into a set of high frequency acquisition instruments. Thanks to a specific signal processing, this device allows the distance measurement through the evaluation of the ultrasonic wave time of flight.

One of the crucial point is then the evaluation of the local water temperature inside the water channel. To obtain a precise estimation of this parameter, a ultrasonic sensor is used as a thermometer thanks to the analysis of the spectral components of the acoustic signal propagating in the sensor multilayered structure.

The feasibility of distance measurement was proved during the December 2013 experiment in the RHF (Réacteur à Haut Flux) fuel element of the Institut Laue- Langevin. Some of the results will be presented as well as some experimental constraints identified to improve the accuracy of the measurement in future works.

Wed 16:15 ESAL 2 Physical acoustics: physics

Multiple SH wave roundtrip type liquid sensor of pipe structure with c-axis parallel oriented ZnO film – (Contributed, 000342)

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Because shear waves with in-plane displacement can propagate without the energy leakage into liquid, it is suitable for the liquid sensor to measure viscosity. (11- 20) oriented ZnO piezoelectric films whose c-axis is oriented parallel to the substrate plane can excite the in-plane shear wave. We have demonstrated the growth of these ZnO films on glass substrates and the excitation of SH-SAW[1]. In this study, we fabricated IDT/c-axis parallel oriented ZnO film/silica glass pipe structure. A high-sensitive sensor is expected if the long propagation path can be achieved such as multiple wave roundtrip system in the Ball SAW[2]. We consider that the roundtrip also occurs on a pipe with wide aperture IDT (6.6 mm, wavelength 23 μm).
(11-20) oriented ZnO film was deposited on a part of a silica glass pipe (diameter 20 mm, thickness 1.5 mm) or a cylinder (diameter 20 mm) using a magnetron sputtering system. Then, IDTs was fabricated on the film so that the electrode fingers were parallel to the pipe axis. The time responses and frequency characteristics of acoustic wave were obtained by a network analyzer.
In the pipe sensor, the fourth roundtrip was observed. The insertion loss of the first lap showed two frequency components at 131 MHz and 160-350 MHz, with the insertion loss of -50 dB, whereas the insertion loss of the cylinder sensor was less than -70 dB. This indicates that the plate wave (not SAW) propagated in the pipe. Then, we load pure water inside of the pipe. Because the increase of the insertion loss was less than 1 dB, we confirmed that the wave was SH-type plate wave. The sensor is expected for the viscosity measurements in the next step.
[1] A. Tanaka, et al., IEEE TUFFC, 55, 2709 (2008). [2] K. Yamanaka, et al., APL, 76, 2797 (2010).

Wed 16:30 ESAL 2 Physical acoustics: physics

Surface Acoustic Waves in ZrCu Metallic Glass Films: A Comparative Study by Brillouin Light Scattering and Picosecond Ultrasonics – (Contributed, 000552)

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We investigated the structure, the acoustic and the elastic properties of ZrCu metallic glass films deposited by rf magnetron sputtering from a $Zr_{50}Cu_{50}$ target in Ar plasma discharge. Process parameters such as rf power, Ar flows and time of deposition were varied and the conditions for glass forming ability identified. Their influence on the thickness, the films microstructures, the chemical composition and the mechanical properties were explored. The structural properties of the metallic glass compounds were characterized by X-ray Diffraction, X-ray reflectivity, and chemical composition by wavelength-dispersive spectroscopy. The picosecond ultrasonics and the Brillouin light scattering techniques were employed to measure their acoustic and elastic isotropic properties through surface waves measurements as a function of the thickness.

Wed 16:45 ESAL 2 Physical acoustics: physics

Peculiarities of acoustooptic transformation of Bessel light beams in gyrotropic crystals – (Contributed, 000025)

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The peculiarities have been studied of acoustooptic (AO) diffraction of quasi- nondiffracting vector Bessel light beams on the ultrasound waves in optical gyrotropic cubic crystals. The system of coupled equations describing the process of acoustooptic interaction is solved, diffraction efficiency has been calculated. The mathematical description of AO interaction, which differs from the similar description for the plane optical waves means of two types of synchronism, is conducted. It is seen that besides the usual longitudinal synchronism realized at the equality of phase velocities transmitted and diffracted waves, for Bessel beams it is also necessary to perform the so-called transversal synchronism. It is related with the fact, that Bessel beams with differing cone angles have different spatial structure and, consequently, various values of overlapping integral with the transmitted beam. The possibility has been investigated of transformation of the order of phase dislocation of Bessel beams wave front due to AO diffraction. It is proposed to use the process of acoustooptic diffraction as a method of splitting of TE an TH-polarized Bessel beams in gyrotropic crystals and also for dynamic manipulation of beam polarization at the crystal output.

Wed 15:30 Esplanade Standing waves, resonating and actuating ultrasonics II

An acoustothermal heater for paper microfluidics towards point-of-care glucose detection – (Contributed, 000197)

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We report the first observation of acoustothermal heating of paper under high frequency (∼MHz) vibrations. The heating mechanism utilizes acoustic absorption of cellulose fiber networks which peaks at certain 'hit' frequencies. In order to generate acoustic waves and couple them with paper, a conventional surface acoustic wave (SAW) microfluidic system was adopted. The SAWs propagating on the piezoelectric substrate readily refract into a piece of wet paper placed on the substrate, deliver ultrasonic energy into the paper, and in turn heat it by molecular oscillations. Based on this finding, we developed a heating system incorporated in paper microfluidics to promote and accelerate chemical reactions for point-of-care (POC) diabetes diagnosis, having expensive enzymes needless. The most common method for the diabetes screening test is a reagent strip test for urinalysis as it is simple and easy yet provides semi-quantitative glucose measurements. However, the test is too expensive to be widely employed in developing countries. On the other hand, the traditional Benedict's test is the cheapest and provides the most unambiguous results but has not been widely used because the chemical reaction requires heating. Our heating system can address the limitation as it provides rapid (exceeding 500 K/s), volumetric heating of the paper strip that contains both Benedict's reagent and urine. Moreover, the heater provides a disposable platform as no bonding is required to couple the heater and the paper strip. Furthermore, the heating system can be built to be portable when operated by a CR123 battery-powered palm-size electronic driver circuit unit.

Wed 15:45 Esplanade Standing waves, resonating and actuating ultrasonics II

An Acoustothermal Microheater with Omni-temperature Controllability – (Contributed, 000027)

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Heating phenomena caused by high frequency (∼MHz) vibration damping have been little studied, let alone taken advantage of, as they have been considered rarely significant or important. Here we report the first observation of rapid (exceeding 2,000 K/s) volumetric heating of viscoelastic materials under cyclic loadings at certain 'hit' frequencies. Based on the finding, we developed a microheater which utilizes the vibration damping of polydimethylsiloxane (PDMS), the most commonly used material in microfluidics, induced by sound waves generated and precisely controlled by a surface acoustic wave (SAW) microfluidic system. The SAWs couple with the PDMS microchip and deliver ultrasonic energy deep enough (∼1.2mm) to cover most sizes of microchannels. The penetration depths (δ) were measured to follow the power law, $\delta \sim [\text{SAW frequency}]^{-\gamma}$, where γ was fitted to be 0.7 from experimental data, which supports that the heating is induced by acoustic absorption rather than electromagnetic. Our microheater offers conductive, noninvasive, and fast heating of fluid samples with locally independent control of temperature. All of these functionalities could not have been achieved at once by metal patterned Joule-heating, infrared-mediated heating, or microwave dielectric heating techniques. The omni-temperature controllability of the microheater enabled us to perform two-step continuous flow polymerase chain reaction for a billion-fold amplification of 134 bp DNA amplicon in less than 45 sec. In addition, the heating mechanism was found to work effectively for across a variety of viscoelastic materials such as thermoplastic, elastomer, food, paper, as well as biological tissue, implying its broad applicability in research and industry.

Wed 16:00 Esplanade Standing waves, resonating and actuating ultrasonics II

Acoustical Tweezers : trapping elastic particles with a forward propagating beam of sound – (Contributed, 000447)

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The ability to manipulate matter precisely is critical for the study and the development of a large variety of systems in biology, chemistry and physics where small particles play an important role. Using the radiation pressure of light, optical tweezers are excellent tools to handle particles ranging in size from a few micrometers to hundreds of nanometers but become inefficient and severely damaging on larger objects. Although ultrasonic manipulation techniques are becoming very popular, various drawbacks in the state of the art of acoustic manipulation, relying on the radiation pressure of either standing wave patterns or high frequency focused beams, have prohibited the accurate manipulation of single particles in three dimensions. For the first reported time, we demonstrate the trapping of elastic particles by the large radiation force of a single acoustical beam in three dimensions. Obtaining a stiff and stable potential well with a forward propagating helicoidal beam is the crux of the *acoustical tweezers* presented here. At equal power, acoustical forces overtake by 5 orders of magnitude those of optical ones on macroscopic objects. Their ability to push, pull and accurately control both the position of a unique particle and the forces exerted under damage-free conditions opens prospects to new applications of non-contact manipulation techniques.

Wed 16:15 Esplanade Standing waves, resonating and actuating ultrasonics II

Proposal of Pump Using Ultrasonic Transducer and Opposing Surface – (Contributed, 000305)

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Currently, pumps are used in various fields to supply air and liquid. These pumps include sliding parts and there is a limit of life time due to friction and wear. To solve this problem, a number of pumps using ultrasonic vibration have been proposed. A common feature of such ultrasonic pumps is having no sliding parts. Therefore, the life time of these pumps seems longer than that of the conventional pumps because there is neither wear nor damage in use. Since some medical devices like MRI use high magnetic field, the ultrasonic pumps have advantages for such medical cases as they can avoid use of magnetic material in their structure. In the present study, we found an occurrence of pump effect when applying tapered surface for the block opposing the surface that is ultrasonically vibrating. The ultrasonic transducer has a hole to provide the path for fluid flow and the opposing surface was tapered on the end of an aluminum cylinder. According to the measurement results of gauge pressure, when circumference of the opposing block is tapered, fluid was discharged from the gap of two surfaces. On the other hand, when center of the block is tapered, fluid was sucked in the gap. In addition, the gauge pressure of the pump was changed due to changes in the taper angle and area of the block.

Wed 16:30 Esplanade Standing waves, resonating and actuating ultrasonics II

Torque Improvement in Grease-lubricated Ultrasonic Motors – (Contributed, 000229)

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Motivation: Ultrasonic motors possess the feature of high torque at low speed due to their friction-drive mechanism. The torque of ultrasonic motors is typically determined by the static preload (friction limit) and the dynamic preload (the modulation of the friction force). However, high static preload is usually avoided, because it causes severe wear of the friction materials, and hence the high-torque feature of ultrasonic motors cannot be fully realized. In our previous study, we have proven that the motor efficiency can be drastically improved using lubricant, without losing the output torque. This phenomenon is attributed to that the lubricant can effectively modulate the friction force according to the Stribeck curve and enables ultrasonic motors to withstand much higher preload. In this report, the torque improvement of ultrasonic motors using lubricant is extensively studied.
Methods: Hybrid transducer-type ultrasonic motors with 25 mm in diameter were employed. The grease with a base oil viscosity grade of 460 was selected as the lubricant. Sufficiently high voltages were applied to the torsional vibrator in order to ensure that the torque generated by the torsional vibrator was beyond the friction limit, and the voltage applied to the longitudinal vibrator was fixed to 77 Vrms.

Results: Preload as high as 267 N was applied and maximum torque as large as 1.01 Nm was obtained using the grease, which were 3.5 and 2.6 times higher than those without lubricant. The speed ratio between the rotational speed of the rotor and the amplitude of torsional vibration velocity, the coefficient of friction, and the worn surfaces with and without lubricant were also compared, which prove that lubrication can significantly improve the motor performance if high static preload is applied. The findings in this work will expand the high-torque applications of ultrasonic motors to a great extent.

Wed 16:45 Esplanade Standing waves, resonating and actuating ultrasonics II

Ultrasonic Friction Reduction in Elastomere/Metal Contacts and Application to Pneumatic Actuators – (Contributed, 000242)

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Ultrasonic friction reduction is well known for metal-metal contacts. Due to the vibration, the stick phase in the contact phase vanished and only sliding occur. As long the macroscopic relative velocity of the contact partners is much lower than vibration velocity, the necessary force to move the parts tend to (nearly) zero. If the effect also exist in material combinations with a significant difference in stiffness or damping characteristic has not got much attention in the past. This contribution shows the effect for various material pairs, which are typical for the sealing contact in pneumatic actuators. Further a novel integrated transducer design for a pneumatic actuator is presented. In this design the transducer also act as moving part within the pneumatic actuator. The design challenges are the two contact areas on the moving part, where the friction reduction is needed and consequently high vibration amplitudes. One of those is fixed on the transducer geometry the other is moving over the piston. This novel design has been implemented in the laboratory; the detailed experimental results are presented in this contribution.

Wed 9:30 Main Hall Bio-medical (poster)

Detection of Microcalcifications in Breast Tissue with Use of Acoustic Radiation Force – (Contributed, 000175)

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Microcalcifications (mineral deposits in the form of microcrystals) are a diagnostic feature of malignant tumor growth in the mammary gland. At present, mammography is the "gold standard" for detecting microcalcifications. Microcalcifications in a mammogram look like white points with dimensions on the order of a millimeter, distributed over an area of 1-2 cm. This work theoretically and experimentally substantiates a new method for revealing microcalcifications in the mammary gland; it measures the motion character of a medium with solid microparticles under the action of a sufficiently long (on the order of hundreds of microseconds) acoustic pulse on the medium. Such a pulse creates a radiation force, the peak value of which is maximal in the particle region. Motion of the medium in this case has a sufficiently complex character and is determined by displacement of both individual particles and the medium itself. Measurements were conducted with an open-architecture Verasonics ultrasound diagnostic system. Via software, the system made it possible to form radiated pulses and ensure access to the high-frequency signals obtained. The pulses generate radiation pressure in the indicated region, after which the motion of the medium in this region is recorded. In particular, the amplitudes of displacements and their dependence on time are measured. The obtained relaxation dependences of displacements and their amplitudes are compared. Detection of the amplitudes of displacements exceed by several times the values obtained in healthy tissue, and the presence of local maxima in the relaxation curve give grounds for diagnosing microcalcifications in the selected region.

Wed 9:30 Main Hall Bio-medical (poster)

Assessing Temperature Rise at Different Tissue Types Using Mathematical Morphology Segmentation Procedure and Average Gray-Level from B-Mode Ultrasonic Images – (Contributed, 000212)

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To estimate and understand ultrasound bio-effects, it is mandatory estimating temperature rise in region of cells or tissues of interest even when a thermal mechanism is not being tested. It is desirable that temperature assessment should be performed by minimally invasive or optimally by non-invasive methods. Magnetic resonance imaging is recognized as the technology able to reach appropriate results. However, ultrasound-based methods based on raw signals have been studied as a feasible low-cost alternative. Moreover, image-processing methods applied directly to the grey-level content of B-mode images have also demonstrated their potential in estimating temperature rise. A previous work demonstrated the possibility of tracking temperature changes on different tissue types assessing the average grey-level (AVGL) of B-mode images. However, it was also observed that different tissues could present different AVGL-temperature relations, which can be a limitation to assess temperature at different regions directly on the same image. This paper presents a solution to that limitation by including an image segmentation procedure to the AVGL temperature rise analysis. A porcine sample containing fat and muscle tissues was subjected to heating cycles (36°C and 46°C), and temperature was monitored at each 5 seconds using Type-T thermocouples. Images were generated by an ultrasound imaging system (7.5 MHz linear array transducer). Videos were recorded using a USB video-acquisition device (30 frames/s). Images were averaged in 5-second epochs to reduce noise and synchronize with temperature samples. Finally, an image segmentation procedure based on Mathematical Morphology was applied to separate fat and muscle regions, and the AVGL for the two studied regions was computed. Results point out that it is possible to track temperature rise on different tissues by segmenting the B-mode images and calculating the respective AVGL values, and suggest that the proposed procedure could be applicable in more complex scenarios, as in vivo applications.

Wed 9:30 Main Hall Bio-medical (poster)

The Biological Sensor for Detection of Bacterial Cells in Liquid Phase Based on Plate Acoustic Wave – (Contributed, 000252)

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The interactions "bacterial cells - bacteriophages" and "bacterial cells - antibodies" were experimentally investigated directly in liquid phase by acoustic sensor. It represented piezoelectric plate of thickness of 0.5 mm with two interdigital transducers for radiation and reception of plate acoustic waves with shear - horizontal polarization. The liquid container was glued on plate surface between transducers. The frequency dependencies of phase and insertion loss of output signal of sensor without suspension were measured in range 2 - 4 MHz by the meter of S - parameters. It was found that insertion loss did not exceed 24 dB and the frequency dependence of phase was linear. Then meter was switched in time regime on fixed frequency 3.3 MHz (minimum of loss) and container was filled by suspension of cells with the certain concentration. After the time interval which was enough for stabilization of the phase and amplitude of output signal the certain amount of specific bacteriophages was added in suspension. The phase and amplitude were changed and after some time achieved the stable values. The changes of phase and insertion loss were measured. Then suspension was removed and the experiment was repeated with the same cells concentration and different amount of bacteriphages. As a result the dependencies of changes of the phase and insertion loss of output signal on the amount of bacteriophages were obtained. In control experiments with nonspecific bacteriophages the phase and amplitude of the signal did not change. Analogous experiments with specific and nonspecific antibodies revealed the same regularities. So the investigations showed the possibility of development of sensors for detection of bacterial cells directly in liquid phase by registration of the specific interaction "cells - bacteriophages" or "cells - antibodies." The work was supported by grant of President MK-5551.2014.9 and grant of RFBR 14-02-31352.

Wed 9:30 Main Hall Bio-medical (poster)

Multi-Element Compact Transducer Module System For Therapeutic Ultrasound – (Contributed, 000309)

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1. Introduction We developed compact and high power multi-element amplifier module and phase delay signal generator for therapeutic ultrasound transducer. We adopted a direct drive amplifier system for the multi-element transducer. This system has an advantage of reduce the energy loss at the connecting cable between the transducer element and the amplifier. So, we could assemble the very compact multi-element transducer system combined with multi-element amplifier. Our motivation of the study is to develop the handheld mobile phased array HIFU system.
2. Method In this study, we evaluated the specification and system design of the first prototype module transducer with numerical simulation and output power measurement of the amplifier module. In the numerical simulation, we use four parameters, Element pitch, Element size, focal distance from the transducer surface and focus sift value. This module connected to array amplifier modules directly. One amplifier module has 16ch driving circuit. This amplifier module size was 70mm height, 20mm width and 5mm thickness.
3. Result The module amplifier capacity is 0.1 Watt per element during the ON time. We measured the performance of the amplifier module. One of the amplifier on the module can drive 4 x 4 mmˆ 2 single transducer element. The electrical power consumption of this module was very low. This module system could control multi-element phase delay easily and focused the ultrasound beam by the phase delay signal generator.
4. Conclusion In this study, we developed first prototype of the compact and high power multi-element module transducer system for therapeutic ultrasound. Various types of therapeutic ultrasound array transducer design can be realized easily by this module system.

Wed 9:30 Main Hall Bio-medical (poster)

Design of a simple pulse generator using an Arduino platform for ultrasonic applications – (Contributed, 000113)

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The pulse generator is one of the critical components in an ultrasonic system. Because it is the device that produces the electrical pulses that are applied to the emitter transducer. The most important parameters associated with the pulse generator are frequency, amplitude and power of these electrical pulses, which determine the energy delivered to the ultrasonic transducer. Ultrasonic non-destructive testing applications are often based on pulsed electrical excitation of the piezoelectric transducers (e.g.: PZTs) by means of a single-phase pulse (shock excited) or by means of two-phase waves (burst excited); using to produce these pulses, generators (pulsers) producing voltages in the order of hundreds of volts, these pulsers usually include as circuit breaker SCRs or MOSFETs. Arduino is an electronic open platform for the creation of prototypes based on free and easy-to-use hardware and software. The micro controller within the Arduino tablet is programmed using the Arduino (based on Wiring) programming language and the Arduino (based on Processing) development environment. There are several models of Arduino platforms, most of them contain digital ports that can be configured as inputs or outputs. These ports can supply 5 volts and 40 mA at each terminal. A PVDF film can generate voltage pulses from 100mV to 100V depending on the strength and the impedance of the circuit. The bandwidth range can be from 0.001 Hz to 108 Hz. PVDF arrays are desirable in the tests of non-destructive testing due to its flexibility. Unlike PZT transducers, PVDF transducers can be excited using voltages ranging from 1 to 30 V, Therefore output voltages from the Arduino platform are large enough to make the piezoelectric element vibrate. In the market there is a need of low-cost pulsers to excite transducer arrays. So in an attempt to provide a solution to this problem, this paper proposes to use the Arduino platform as a pulse generator of to excite a PVDF transducer array which require very little power.

Wed 9:30 Main Hall Bio-medical (poster)

Generating shear waves in the human brain for ultrasound elastography: a new approach – (Contributed, 000600)

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Motivation

Brain elastography has been recognized as a being a promising diagnostic tool. Neurodegenerative diseases evolution as well as normal aging could be precisely evaluated using quantitative elastography. For ultrasound elastography, one of the challenges to overcome is the generation of the shear wave in the brain. Several methods have been developed for magnetic resonance elastography which we found to be unsatisfactory.

Methods

We chose to use transient excitation to allow us to separate more easily the shear and compression wave. Two generating techniques are used and compared. First, an acoustical generator made of a dynamic loudspeaker affixed with a tuned flexible hose with the other end placed in the subject's mouth. The upper respiratory tract then acts as a resonator, making the whole cranium vibrates. By adjusting the length of the hose and the signal sent to the loudspeaker we can adjust the frequency, length and amplitude of the shear wave generated in the brain. The excitation signal is also used to trigger an ultrafast ultrasound recorder (SSI Aixplorer), using a linear 2.8 MHz, 128 elements probe placed on the temporal window. Particle velocity is derived from the IQ data using a Doppler algorithm. A custom strain rate estimator is then used to isolate the shear wave from the compression wave.

The second method used is an impact hammer, equipped with a force sensor. By changing the tip material of the hammer, we can adjust the length (or bandwidth) of the excitation. The force signal is used to trigger the ultrasound recorder, the recording and data treatment being the same as before.

Both methods were also tested on tissue phantom.

Results

In both phantom and in vivo conditions, the two methods allow us to measure shear wave speed in accordance with literature values and our own ex vivo measurements.

Wed 9:30 Main Hall Chemical and molecular ultrasonics (poster)

Investigation of the surface condition of an electrode after electropolishing under the influence of Surface Acoustic Waves – (Contributed, 000055)

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Previously it could be shown that it is possible to enhance the anodic current at an electropolishing experiment by surface acoustic waves [1]. In general the diffusion boundary limits the transport rate of ions. The Vortices which will be built up by acoustic streaming disturbed the diffusion boundary layer and the transport of ions is no longer limited. The observation of acoustic enhancement promises to be useful in acceleration of industrial electrochemical process. However, besides the process time the surface condition after the electropolishing is of importance as well.

This investigation is focused on surface condition of the electropolished surface after acoustic wave treatment. For the experiments copper electrodes will be used. At the anode the surface acoustic wave, especially Scholte waves, will be generated. The wave will propagate to the electrolyte and cause Schlichting streaming at the boundary layer. After the electropolishing process the surface of the anode is analyzed by a laserscanning microscope. For different frequencies and different intensities of the surface acoustic wave the surface roughness (Rz and Ra values) are measured and compared. First results indicate that the surface acoustic waves increases the roughness of the surface. This can be caused by cavitation effects. The investigation of different intensities and frequencies of the surface acoustic waves will allow to find the best parameters for polishing and avoid cavitation damage.

[1] S. Tietze, J. Schlemmer, and Gerhard Lindner, Influence of surface acoustic waves induced acoustic streaming on the kinetics of electrochemical reactions, Proceedings of SPIE 8923, 89231B (2013)

Wed 9:30 Main Hall Chemical and molecular ultrasonics (poster)

The effect of ultrasonic treatment in a novel synthesis route of layered double hydroxides – (Contributed, 000089)

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Our experimental work led to the development of a novel and simple method for the preparation of CaAl- and ZnAl-layered double hydroxides (abbreviated as LDHs): it is the combination of hydrotreatment and milling. To enhance it further, ultrasonic mixing was used instead of the mechanical, and its effects were studied at different operational parameters.
All pristine LDHs were prepared in the same way: the starting materials were mechanically activated in a mixer mill; then, Na_2CO_3 solution was added and stirred by ultrasound in a thermostated glass vessel. The ultrasound waves were generated by a Hielscher Ultrasonic Homogenizer (UP200Ht) of adjustable power and pulse capability. The effects of the alterations of these parameters and the temperature of the system were investigated. The obtained materials were characterised by X-ray diffractometry (XRD), which was the major tool, but scanning electron microscopy (SEM), energy dispersive X-ray fluorescence (EDX) and infrared (IR) spectroscopy were also used.
In all cases, X-ray diffractograms attested the formation of LDHs. SEM, EDX, and IR measurements added additional proofs for the success; however, the amounts of the secondary products and the remaining precursors altered in a wide range. Nevertheless, we were able to find the three parameters, providing with high-quality ZnAl-, or CaAl-LDHs.
To sum up, a novel technique, was further improved by ultrasound stirring, and its effects were studied on the synthesis of CaAl- and ZnAl-LDHs.

Wed 9:30 Main Hall Chemical and molecular ultrasonics (poster)

Monitoring of Lactic Fermentation Process by Ultrasonic Technique – (Contributed, 000253)

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The non-destructive control by using ultrasound has become of great importance in food industry. This innovative technique allows optimizing the production process, improving the product quality and ensuring consumer safety. Yogurt is one of the large consumed food products. Its manufacturing requires quality control during its fermentation steps. Actually, the PH-meter is the experimental tool used to determine the progress of the fermentation of milk by measuring acidity versus time. However, its use requires the introduction of the probe into the sample and, subsequently, regular cleaning. On the contrary, ultrasonic techniques provide high advantageous compared to other control techniques, as it is a non-invasive, a real-time and a contactless technique. The evolution of the ultrasonic parameters, such as the attenuation coefficient and the ultrasound propagation velocity, can provide information on the state of the milk. That is why we have adopted this technique in the context of this work. Good correlation has been found between the measured PH and the determined ultrasonic parameters.

Wed 9:30 Main Hall Chemical and molecular ultrasonics (poster)

Ultrasound Absorption in Imidazolium-Based Room Temperature Ionic Liquids – (Contributed, 000355)

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Thermophysical properties of different families of ionic liquids have gained increasing interest over a dozen last years. However, very little effort was spent in the study of ultrasound absorption in this promising class of compounds which are at present not only laboratory curiosities but are already in use for a wide range of applications. In this study we present results of ultrasound absorption measurements for over a dozen 1-alkyl-3-methylimidazolium (alkyl groups from ethyl to octyl) based Room Temperature Ionic Liquids (RTILs) having three different anions, namely bis-trifimide, ethylsulfate, and tetrathiocyanatocobaltate). The ultrasound absorption in the frequency range (10 to 300) MHz and at temperatures from (293.15 to 323.15) K was measured by means of a standard pulse technique (first traveling pulse in the variable path length). The results reveal that all samples are middle or highly absorbing, i.e., the frequency normalized absorptions (10 MHz, 298.15 K) lie between (483 and 2370)$\cdot 10^{-15} s^2 \cdot m^{-1}$. In all cases, the ultrasound absorption spectra indicate relaxation frequencies in the investigated range. Moreover, always the negative temperature coefficients of absorption in the non-dispersion region are observed. The comparison of obtained results shows some systematization with respect to the structure of RTILs (a change of anion or carbon chain length in cation). To the best of our knowledge, this is the first attempt of systematization of ultrasound absorption in RTILs. The results show also that in many cases shear viscosity relaxation can be supposed in the megahertz range.

Wed 9:30 Main Hall Chemical and molecular ultrasonics (poster)

Characterization of olive oil by ultrasonic and physico- chemical methods – (Contributed, 000256)

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Olive oil excels by its nutritional and medicinal benefits. It can be consumed without any treatment. However, its quality can be altered by inadequate storage conditions or if it is mixed with other kinds of oils. The objective of this work is to demonstrate the ability of the ultrasonic methods to characterize and control the olive oil quality. By using of a transducer of 2.25 MHz nominal frequency in pulse echo mode, ultrasonic parameters such as propagation velocity and attenuation and mechanical properties such as density and viscosity were measured for pure olive oil and for its mixtures with sunflower oil at different proportions. The results of ultrasonic measurements are consistent with those obtained by physico-chemical methods such as rancidity degree, acid index, specific extinction coefficient and viscosity. They show that the ultrasonic method allow to distinguish between mixtures at different proportions. The study allows concluding that ultrasound techniques can be considered as a useful complement to existing physico-chemical analysis techniques. <latex>

Wed 9:30 Main Hall Chemical and molecular ultrasonics (poster)

Investigation of Sonodynamic Effects of Chloraluminium Phthalocyanine on Ehrlich Ascites Tumor Cells – (Contributed, 000394)

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Purpose: The purpose of this study was to evaluate sonodynamically induced cytotoxic effect of chloroaluminum phthalocyanine (AICIPc) on Ehrlich Ascites Tumor (EAT) cells, and the possible apoptotic response was also investigated.

Methods: EAT cells suspended in PBS were exposed to ultrasound at 1 MHz for 60 s in the presence and absence of AICIPC. Cell death rates were evaluated by trypan blue staining after sonodynamic therapy (SDT) administration with different density of ultrasound (1, 1.5, 2 W/cm^2) and increasing concentration (5, 10, 15, 20, 25 μM) of AICIPc. Apoptosis was observed with flourescence microscope using Hoechst 33258 staining. Western blotting was performed to analyze the activity of caspase-3.

Results: A significant cytotoxic effect was observed by AICIPc mediated SDT. The ultrasonically induced cell

damage increased as the ultrasound intensity and AICIPc concentration increased. Flurescence microscopic analysis showed a significant increase in the early apoptotic cell populations by AICIPc mediated SDT of EAT cells. EAT cells also showed obvious caspase-3 activation two hours after SDT treatment.

Conclusions: Our findings demonstrated that AICIPc mediated SDT significantly decreased cell viability and induced apoptosis of EAT cells. These findings indicate a caspase-depended apoptosis could be an important mechanisms of cell death induced by SDT. Thus, AICIPc mediated SDT might be a potential therapeutic application for combating tumor cells.

Wed 9:30 Main Hall NDE / NDT (poster)

Thin wall pipe ultrasonic inspection through paint coating – (Contributed, 000011)

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Classical ultrasonic inspection of welds is currently done for plates thicker than 8 mm. The inspection of but welds in thin walled pipes has considerable implementation difficulties, due to guided waves dominating ultrasonic pulses propagation. Generation of purely symmetric modes, either torsional or longitudinal, requires a circumferential uniform distribution of transducers and dedicated inspection equipment, which are increasing the inspection costs. Moreover, if the surface is paint coated, the received signals are close to the detection level. The present work implies a single transducer, coupled to the painted surface. The proper choice of the guided mode and frequency range, allows the detection of a standard, small diameter through thickness hole. In this way, the inspection of pipe welds can use the same equipment as for thick materials, with only wedge adaptation.

Wed 9:30 Main Hall NDE / NDT (poster)

Split-Spectrum Signal Processing for Reduction of the Effects of Dispersive Wave Modes in Long-Range Ultrasonic Testing – (Contributed, 000145)

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Abstract-This paper presents a Split-Spectrum Signal Processing (SSP) with applications to Long-Range Ultrasonic Testing (LRUT). The problem of coherent noise due to Dispersive Wave Modes (DWM) in the context of ultrasonic scattering is addressed and a novel solution by utilizing the signal processing technique is proposed for reduction of the effects of DWM in received signals. The proposed SSP algorithm investigate the sensitivity of SSP performance to the filter bank parameter values such as processing bandwidth, filter bandwidth, filter overlap and number of filters. Therefore, as a result the optimum values are introduced which significantly improves the signal to noise ratio (SNR). The proposed technique is compared with conventional approaches for both synthesized and experimental signals in a pipe by applying the different recombination SSP techniques. The Polarity Thresholding (PT) and Polarity Thresholding with Minimization (PTM) methods were found to give the best result and substantially improve the SNR performance by an average of 10 dB.
Index Terms- Split Spectrum Processing; SNR; Ultrasonic guided waves; Signal Processing;

Wed 9:30 Main Hall NDE / NDT (poster)

Time-Frequency Analysis of Lamb Waves Propagation in a Viscoelastic Plate – (Contributed, 000265)

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Guided waves, known as Lamb waves, are characterized by complex multimodal and frequency dispersive propagation, which distort signals and made their analysis difficult. Estimating these multimodal and dispersive characteristics from experimental data becomes a difficult inverse problem. As a result of all of these effects, accurate characterization and analysis of guided waves is very challenging. In this purpose, this paper presents a signal-processing method referred as Smoothed Pseudo Wigner-Ville Distribution based on time- frequency analysis to

accurately and robustly recover these multimodal and dispersive properties of Lamb waves and to successfully detect or locate the eventual existing damages in the controlled medium. The case studies in this paper are conducted on a Plexiglas viscoelastic plate, on which a piezoelectric transducer is used to generate Lamb waves and the detection of which is achieved thanks to a laser interferometer. The superposition of the 2D-images obtained by the Smoothed Pseudo Wigner-Ville Distribution and the dispersion curves of the theoretical Lamb waves shows that this time-frequency method is very effective for identifying multiple Lamb modes propagating in the tested plate. The results highlight also the ability of this time-frequency analysis to accurately calculate the group velocity.

Wed 9:30 Main Hall NDE / NDT (poster)

New quick and flexible method for ultrasonic imaging of large metal or composite structures by generation of Guided Wave with matrix phased Array Technologies – `(Contributed, 000619)`

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An innovative new control method using guided ultrasonic waves generated and detected by array probes was developed as part of a collaborative project between I2M and CETIM. This method allows to excite and receive various types of guided waves (with a pilot of modal and directional selectivity) to test large structures, and more particularly difficult access areas. It consists in associating guided ultrasonic waves to a system of detection / generation of phased matrix array type, which, so far, has been used to produce wave volume and to control areas in the immediate vicinity of the probes. Compared to existing methods exploiting the guided waves, this new method has an advantage in terms of speed, simplicity and flexibility in the implementation, providing opportunities for the control of metallic and composite structures.

Wed 9:30 Main Hall NDE / NDT (poster)

Mechanical Strain Monitoring in Plates Using Wavelet Coherence Based Filter of Wideband Ultrasonic Guided Waves – `(Contributed, 000148)`

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The time-of-flight of ultrasonic guided waves modes can be related to the strain in strips and plates. In order to be effective, this technique requires the use of high sampling rates to detect time shifts of nanoseconds for strains of 1 μm/m. An alternative is to relate the amplitude level, or energy concentration, of focusing techniques such as time-reversal, or numerical cross-correlation, of wideband guided waves. In this case variation is of the order of percent for strains of 1 μm/m, being technologically easier to detect. In addition to the straightforward time-reversal approach, signal processing techniques can be applied in order to enhance the amplitude sensitivity.
In this work, wavelet coherence filter is used for processing wideband guided waves signals aiming to detect the most sensitive coefficients to longitudinal strain. Then a continuous wavelet transform based filter was designed in order to filter out the stationary modes, synthesizing a highly sensitive reference signal. Experiments were performed in a 3mm thick aluminum plate subjected to longitudinal strains up to 150 μm/m. A pair of wideband piezocomposite transducers is bonded at each end of the plate working in through-transmission mode. Three different transducers' pairs were used with center frequency ranging from 500 to 2000kHz. Instead of using the raw signal, a synthesized signal obtained by using a wavelet transform based filter is used as a reference for cross-correlations of the received signals at different strain levels.
Results reveal that this filter led to a tenfold increase in the sensitivity to longitudinal strain, depending on the filtering threshold and the transducers bandwidth. Parameter sweeping was performed revealing that the trade-off between sensitivity and focusing quality must be considered. This technique can also be applied in the strain monitoring complex structures submitted to strain.

Wed 9:30 Main Hall NDE / NDT (poster)

Relation between the Ultrasonic Attenuation and the Porosity of a RTM Composite Plate – (Contributed, 000406)

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We propose a comparative study of two methods, X-ray tomography and ultrasound reflection, for determining the porosity of a RTM (Resin Transfert Moulding) composite plate that we have realized in the laboratory with an industrial process.
The reference 4D and 2D representations of the porosity in and on the plate have been obtained from X-ray tomography by another laboratory.
We measure first the attenuation of ultrasound propagating in the thickness of the plate by use of non-focusing 5 MHz and 10 MHz. Comparing these results to the 2D porosity map helps establish a linear relation between attenuation and porosity.
We then realize a C-scan of the plate with a focusing 10MHz transducer. The picture given by the ultrasonic echoes reflected by the upper surface is comparable to a photography of that surface. The picture given by those coming from the rear surface provides a global information on the attenuation. Time windowing the reflected signals allows the exploration slice by slice of the whole thickness of the plate. It shows the presence of bubbles that are much more reflective than the interfaces between resin and fibers. If we group together all the pictures of the different slices, we obtain a 4D representation that is in good agreement with the tomographic image.

Wed 9:30 Main Hall Physical acoustics (poster)

Study of Ultrasonic Machining by Longitudinal-Torsional Vibration for Processing Brittle Materials -Observation of Machining Mark- – (Contributed, 000096)

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The machining processing methods for the brittle materials are the ultrasonic machining method as an example. The brittle materials are fragile, and are ceramic and glass materials as representative. The ultrasonic machining method is a processing method using the ultrasonic vibration of the tool horn and abrasive slurry. Conventional ultrasonic machining methods use only longitudinal vibration. Conventional method has to overcome a number of problems. The problems of conventional method are slow machining speed and low machining accuracy. Accordingly, we have developed a new ultrasonic machining method using ultrasonic complex vibration caused by the longitudinal and torsional vibration in order to improve the machining speed and the machining accuracy compared with longitudinal vibration machining. In previous studies, we found that the machining speed and the hole roundness error as a machining accuracy when using a complex vibration is improve as compared with that using conventional method. However, the mechanism of ultrasonic machining method using ultrasonic longitudinal-torsional vibration has not been clarified. In this presentation, we study that observation of machining marks of soda-lime glass caused by ultrasonic machining using longitudinal or complex vibration as a basic study of understanding mechanism of ultrasonic machining method using ultrasonic complex vibration.

Wed 9:30 Main Hall Physical acoustics (poster)

Non-Contact Atomization of Droplets by Powerful Aerial Ultrasonic Source – (Contributed, 000097)

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Powerful ultrasound has been applied in a wide range of fields. The qualitative analysis of the liquid used in the field of analytical chemistry, there are various methods such as mass spectrometry. These methods have a number necessary step for fine particles of a certain size of the sample liquid. There are several ways of atomization such as evaporating droplet with heat, letting droplet contact with ultrasonic vibration surface and so on. However, property change of liquid by heating and impurities contamination of liquid or deterioration of device by liquid caused from the contact with vibration surface has been the object of concern. Although the authors think that noncontact atomizer by ultrasonic is the most suitable way to solve these problems, existing noncontact atomizing de-

vice is oversized. Therefore, we developed 28 kHz ultrasonic source using small rectangular transverse vibrating plates as miniaturized device and the noncontact atomizer of droplet caused by aerial ultrasonic. Sound pressure distribution is revealed by study of the standing wave sound field. So far, it is found that the atomization is capable. In this paper, to know the particle size distribution of the fine particles when water is atomized, we examined by measuring the size of each particles.

Wed 9:30 Main Hall Physical acoustics (poster)

Single-transmitter on nonlinear mixing to measure acoustic nonlinearity – (Contributed, 000216)

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Motivation
The nonlinear manifestations usually observed in classical materials are ultrasonically quantified by nonlinear acoustic parameter of first order β. The aim of this study is to extract β parameter with a new experimental setup based on nonlinear mixing. The novelty of this configuration resides on the use of just one transducer as transmitter. It permits to avoid the need to amplify the signal beyond 10V while canceling out system nonlinearities.
Methods
We performed our two sine waves mixing measurements that was chosen between $\omega_a = [4, 4, 3.6, 5.4, 3.6]$ [MHz] and $\omega_b = [5.7, 6.3, 5.54.3, 6.3, 6.3]$ as frequencies, respectively. The voltage was varied in [5, 7.5, 10] V for low frequency and was fixed in 7.5 V for high frequency. This experimental setup provides a clear resolution of the signal processed.

Results and Conclusions

As result, perturbation solutions of beta parameter in water are analytically calculated and validated with experimental measurements, for each $2\omega_a$, $2\omega_b$, $\omega_a + \omega_b$. A a β value of 3.5 approximately was obtained, it is consistent with the literature references. (See Barriere et al. 2001). However, it must be noted that in the case of $\omega_a - \omega_b$, β value is not related to the harmonic of the difference.

Wed 9:30 Main Hall Physical acoustics (poster)

Ultrasound wave phase conjugation in stationary and moving dispersive media – (Contributed, 000281)

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Ultrasound wave phase conjugation is an effective tool for monitoring of dispersive acoustic media. Previously application of phase conjugation for testing of micro-bubble density in a liquid was demonstrated experimentally. In the first part of this presentation the generalized theory of propagation of phase conjugate waves (PCW) in moving dispersive media is developed and applied for interpretation of the experimental results on simultaneous measurements of velocity and scatterer density in a bubbly flow. In the second part of the presentation we report the results of comparative studies of phase conjugation and coherent backscattering phenomena in the system of solid microspheres of 300 μm diameter imbedded in the agar gel matrix. Phase conjugation of the scattered acoustic waves at frequency 10 MHz was implemented by the parametric technique. In contrast with the stochastic behaviour of the signal of backscattered wave (BSW), the amplitude of PCW is found to be almost regular and insensitive to the statistical features of the scattering ensemble. The mean values of amplitude and the signal to noise ratios for PCW are found one order of value higher than for BSW. A variation of the number of scatterers in the aperture of the incident acoustic beam revealed the proportionality of the mean values of PCW amplitude and BSW signal intensity. The results are in quantitative agreement with the developed theory. In the last part of the presentation the experimental results on nonlinear mixing of phase conjugate ultrasound waves on scattering objects are reported. The advantages of the wave phase conjugation technique in comparison with the traditional methods for testing of randomly scattering media are discussed. The work was supported by the ANR Smart US (ANR-10-BLAN-311) and Russian Foundation of Basic Researches (project No. 13-02-93108).

Wed 9:30 Main Hall Physical acoustics (poster)

A Comparative Analysis of Ultrasound Velocity in Binary Liquid Systems of PPG by Mathematical and Experimental Methods – (Contributed, 000454)

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The estimation of the speed of ultrasound is the fundamental requirement for investigating the transport properties of liquid and solid systems. Ultrasonic velocities of liquid mixtures containing polar and non-polar groups are of considerable importance in understanding inter-molecular interaction between component molecules and they find applications in several industrial and technological processes. There are many standard mathematical methods available to measure the ultrasonic velocity. In the present study, interferometric technique is planned for experimental measurement of ultrasound velocity. In this paper, the speed of ultrasound waves in Polypropylene Glycol (PPG 400, PPG 4000) in toluene has been estimated for different concentrations (2%, 4%, 6%, 8% & 10%) at 303K and these experimental values compared with theoretical values obtained by using various mathematical methods like Nomotto's Relation, Vandeal and Vangeal Relation, Impedance Relation, and Rao's specific sound velocity. The most reliable method that matches with experimental method is identified using Average Percentage Error (APE) and analysed in the light of molecular interactions occurring in the binary liquid systems. Comparison of evaluated theoretical velocities with experimental values will reveal the nature of interaction between component molecules in the mixtures. Such theoretical study is useful in defining a comprehensive theoretical model for a specific liquid mixture. Also, various molecular interaction parameters like free volume, internal pressure, viscous relaxation time, inter atomic free length, etc are calculated and discussed in terms of polymer-solvent interactions.

Wed 9:30 Main Hall Physical acoustics (poster)

Dynamics of Microsphere Suspensions Observed by Frequency-Domain Dynamic Ultrasound Scattering Techniques – (Contributed, 000142)

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Motivation Dynamic ultraSound Scattering (DSS) techniques are promising tools to investigate the dynamics and structures of microparticle suspensions. However, the detectable size was limited in micron range because of the wavelength of ultrasound. Here, we show the technique can be applied to submicron particles by 30MHz composite transducers with an optimized system. When the size becomes submicron, the dynamics involves Brownian motion in addition to sedimentation. We show such a coupling of the dynamics can be evaluated by the technique.
Methods A spike pulse emitted from a pulser was transferred to a 30 MHz-longitudinal plane wave transducer immersed in a water bath to generate ultrasound pulses. The signals were amplified by the receiver, followed by successive recording with a high-speed digitizer. Polydivinylbenzene(PDVB) and silica particles with the radii a = 100 nm - 1 μm were examined.
Results The lag time, τ dependence of the correlation function indicated sedimentation (proportional to $\tau\hat{}\ 2$, mode 2) for the smaller scattering-vector, q range, while the dynamics was diffusive for the larger q range (mode 1). Different types of particle motion was simaltaneously observed for the microparticles in range a=100 nm - 10 μm. The decay rate should be proportional to q$\hat{}$ 2 if the particle dynamics is dominated by Brownian motion. The hypothesis was proved by the frequency-domain DSS method. Furthermore, the deviation from the diffusive mode was also observed at the smaller q-range. DSS might be useful to investigate dynamical hierarchy from a single q-dependent measurement.

Wed 9:30 Main Hall Standing waves, resonating and actuating ultrasonics (poster)

Acoustic levitation transportation of small objects using a vibrator of the ring type – (Contributed, 000267)

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Acoustic levitation transportation of small solid object in a linear trajectory is discussed here. Ultrasonic flexural vibrations are generated along the ring shaped vibrator using two Langevin transducers and a reflector is placed at 18 mm of a face of the vibrator in order to trap small particle at the nodal points of the resulting acoustic standing wave. The particles are then moved by generating a traveling wave along the vibrator, which can be done by modulating the vibration amplitude of the transducers. The working principle of the traveling wave along the vibrator has been modeled by the superposition of two orthogonal standing waves, and the position of the particles can be predicted using finite element analysis of the vibrator and the resulting acoustic field. A prototype consisting of a 3mm thick, 220mm long and 52mm radius aluminum ring type vibrator and a reflector of the same length was built and small polystyrene spheres are transported along the vibrator without contact.

Wed 9:30 Main Hall Standing waves, resonating and actuating ultrasonics (poster)

Design of a mechanical amplifier for the Langevin transducer – (Contributed, 000310)

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In high-power ultrasound applications, it is usual to adapt an amplifier on the Langevin transducer since amplification level of the transducers was not to enough to induce ultrasound effects. Stepped, exponential or catenoidal amplifier or horns are widely used in high-power ultrasound. However, in practice, it is not to easy to make a nodal plane for holding the transducer and also to design an amplifier for avoidance modes interference. In this works, a barrel type amplifier using FEM code was designed and its characteristics were analyzed. Vibration measurements using interferometer shows that the amplifier has kinds of vibrations including longitudinal mode depend on its geometries. It was possible to optimize vibration mode of the amplifier in accordance with results.

Wed 9:30 Main Hall Standing waves, resonating and actuating ultrasonics (poster)

Control of the Spectrum of magneto-acoustic Resonator – (Contributed, 000421)

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Acoustic resonators based on antiferromagnetic crystals of "easy plane" type, like α-Fe2O3 or FeBO3, are of interest for applications in magneto-acoustic sensors of electrical and mechanical values because of high sensitivity of their resonance frequency to variations of external magnetic field or mechanical stress /1,2/. The range of control of the resonance frequency exceeds 40% due to strong coupling between elastic and magnetic subsystems. Use of all range of frequency control often finds difficulties caused by the discontinuities of the acoustic spectrum arising near the mode intersections /3/. In this presentation we report the results of numerical simulation of the acoustic spectrum of the α-Fe2O3 disk resonator in the vicinity of the fundamental contour-shear mode. Magnetic contributions to the elastic moduli of the crystal are calculated on the basis of the theory of magnetoelastic interaction in antiferromagnets /1/. The simulation was carried out using the software "COMSOL Multiphysics". The results of simulation are compared with the experimental dependence of the resonance frequency on magnetic field. Both simulation and experiment show the spectrum discontinuity in the interval of magnetic field 180-250 Oe for the resonator of diameter 4.95 mm and thickness 0.39 mm. The discontinuity is caused by intersection of the spectra of the contour-shear and flexural modes. On the other hand the simulations show that decrease of the thickness up to 29 mm provides continuous dependence of the contour-shear mode spectrum in all the range of control from 20 to 1000 Oe that corresponds to the resonance frequency variations from 350 to 600 kHz. The elaborated numerical model allows for optimization of characteristics of magnetoelastic resonators.

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Wed 14:30 Main Hall Bio-medical (poster)

Orthogonal Decoding for High-bit Golay Excitation in Dual-Frequency Harmonic Imaging – (Contributed, 000126)

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Dual-frequency (DF) harmonic imaging has the advantage of transmitting signal at both f_0 and $2f_0$ frequency and thus utilize the entire bandwidth of the transducer for harmonic compounding. Theoretically, complementary Golay sequence can be use to improve signal-to-noise ratio (SNR) of DF harmonic imaging with no range side lobes. However, due to the spectral crosstalk from neighboring harmonic components at DC and $3f_0$ frequency, significant range side lobes may be generated with Golay-coded excitation and degrade the DF image quality. In this study, a high-bit orthogonal technique has been developed for range side lobe elimination in DF harmonic imaging. The high-bit orthogonal Golay sequences are encoded at f_0 and $2f_0$ frequency. In the decoding process, the axial resolution in f_0 and $2f_0$ images can be correctly recovered while the range side lobe artifacts from the DC and $3f_0$ harmonic components are completely cancelled. Experimental results in hydrophone measurements show that the high-bit orthogonal Golay pair suppresses the range side lobe level (RSLL) by 20 dB in f_0 signal and by 35 dB in $2f_0$ signal. Moreover, B-mode harmonic imaging also indicates the side lobe magnitude (SLM) reduces by 7 dB in f_0 imaging and by 13 dB in $2f_0$ imaging.

Wed 14:30 Main Hall Bio-medical (poster)

Ipsi- and contralateral motor response using ultrasound- induced neurostimulation in deeply anesthetized mice – (Contributed, 000493)

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Ultrasound neurostimulation has been proven capable of eliciting motor responses. However, the studies in sedated rodents presented problems with target specificity due to the use of low ultrasound frequencies (<700 kHz). Additionally, the light anesthesia administered limited the working time and was prone to cause spontaneous movements during sonications. Here, we show that focused ultrasound (FUS) in mega-Hz range was able to evoke motor responses in mice under deep anesthesia. The level of anesthesia induced by intraperitoneal injection of sodium pentobarbital (65 mg/kg) in mice (n=6) was assessed by the pedal reflex, heart rate (HR) and respiratory rate (RR). The mice were placed in a stereotaxic frame with the limbs and tail free to move. The FUS transducer was driven at 1.94 MHz and 4.7 MPa (in water). The transducer attached to a 3D positioning system was centered at -2 mm to the Lambda suture on the midline and moved in a randomized pattern within a 6x6 mm grid (1 mm spacing). The sonication started when the HR and RR were less than 250 bpm (beats per minute) and 60 brpm (breaths per minute), respectively. The evoked limb movements were recorded with video cameras. Each animal remained unresponsive to pedal pinches throughout both the sonication and the sham studies. No spontaneous movements were observed when HR and RR were less than 350 bpm and 90 brpm, respectively. The sodium pentobarbital allowed us to perform the ultrasound neurostimulation for a period of 45 to 80 minutes, longer than ketamine/xylazine anesthesia (reportedly ∼30 min). Contralateral movements of the hind limbs were observed when sonications were carried out at +2 mm of Lambda and ± 2 mm lateral of midline in three mice. Moreover, stimulating other regions of the somatosensory and cerebellum induced trunk and ipsilateral limb movements in all six mice.

Wed 14:30 Main Hall Bio-medical (poster)

Investigation of Microbubble Composition on Ultrasonic Dispersion Properties for Biosensing Applications – (Contributed, 000572)

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Lipid shelled microbubbles are gaining attention as possible biosensors for monitoring the microbubble's in-vivo environment. These novel applications require the microbubble shell and gas components to be readily responsive to environmental changes. Since the ultrasonic properties of the microbubbles, for instance the resonance frequency or attenuation, are inherently related to the material properties of the monolayer shell such as viscoelasticity and thickness as well as on the physical properties of the encapsulated gas, it is important to investigate the influence of the shell composition and gas content on the ultrasonic behavior as well as the change in response after modifications of the microbubble environment. In this study, homemade microbubbles with different shell compositions and gas content are characterized using ultrasonic through-transmission and backscatter measurements in the range of 500 kHz to 20 MHz, thereby providing the dispersion relations of phase velocity, attenuation and nonlinear coefficient as well as the backscatter coefficient. Using this approach, the evolution of the dispersion properties of such bubbly media in time has been followed up in order to detect changes in microbubble stability. In addition, several microbubble populations have been subjected to thermal changes to investigate their temperature dependence. The experimental observations have been compared to results from a nonlinear least squares fitting procedure with a theoretical model accounting for linear as well as nonlinear bubble behaviour. As such, the model allows to give a qualitative interpretation of the dynamic behaviour and evolution of a microbubble population in the medium.

The research leading to these results has gratefully received funding from the Research Coordination Office KU Leuven (IOF leverage project HB/13/025), the Agency for Innovation by Science and Technology (IWT), and the Research Foundation - Flanders (FWO).

Wed 14:30 Main Hall Bio-medical (poster)

Ultrasound Characterization of Microbubble Populations in Complex Vascular Flow Phantoms – (Contributed, 000583)

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Predicting in-vivo microbubble behavior based on results from ultrasonic characterization measurements on homogenous microbubble media in large volumes is not a straightforward task. In-vivo measurements on live animals suffer from a lack of information on the organ vasculature, blood volume and flow, microbubble concentration and distribution, etc. and make the determination of the acoustic microbubble properties difficult. On the other hand, in vitro measurements in homogenous media do not take into account the interaction with blood vessel walls and other bubbles in confined areas, wash-in behavior, in-vivo stability, etc. Prior studies have been conducted on simple flow phantoms usually constructed with straight tubes of varying thickness representing fairly large blood vessels within agar gel and on extracted organs under more controllable conditions. However, neither of these techniques manages to completely close the gap. With the emergence of 3D printing techniques vascular flow phantoms containing micro-vessels and more elaborate geometries is becoming a reality.

In this study the potential of these new vascular flow phantoms for understanding microbubble behavior in-vivo is investigated. Ultrasonic CT, through-transmission and backscatter measurements are conducted to get the dispersion properties of phase velocity, attenuation and backscatter coefficient of large volumetric areas as well as localized information on individual channels. In addition, the wash-in behavior through these phantoms is monitored in time. Besides, the system can be subjected to changes in temperature and other external fields to study the effect of environmental changes on the microbubble behavior.

The research leading to these results has gratefully received funding from the Research Coordination Office KU Leuven (IOF leverage project HB/13/025) and the Institute of Science and technology - Flanders (IWT).

Wed 14:30 Main Hall Bio-medical (poster)

Identifying cemento-enamel junction using high frequency ultrasound – (Contributed, 000601)

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Introduction: The cemento-enamel junction (CEJ) is the intersection between the enamel, which covers the crown of a tooth, and the cementum, which covers the root. The CEJ is an important marker to diagnose root resorption, alveolar bone loss, and clinical attachment level in periodontal disease. In practice, cone beam computed tomography has difficulty to image and identify the CEJ and involves ionizing radiation which is harmful to patients.

Motivation: The objective of this work is to demonstrate the feasibility of using ultrasound (US) technique to identify the CEJ and compare the findings with micro-CT.
Methods: Small notches were made on the enamel of two lower central incisors of a fresh porcine mandible. The pulse-echo data were acquired along the tooth's axis starting before the notch to the mucogingival junction with a 0.4-mm spacing (2.5 records/mm) using a 20-MHz and 0.125-in diameter transducer. The US scanning was repeated three times for each tooth. The time-distance (t-x) data were bandpass-filtered to enhance signal-to-noise ratio and record density was increased 4-folded to 10 records/mm by frequency-distance (f-x) interpolation scheme. The CEJs were identified. The distances from the notches to the CEJs were measured and then compared with micro-CT data.
Results: The CEJs were unambiguously identified in the t-x records. The measured notch-CEJ distances from two incisors were 4.69 ± 0.09 mm and 3.86 ± 0.23 mm respectively. Comparing with micro-CT data, the ultrasonic measurements were accurate up to an average of 93%.
Conclusion: The results have shown that high frequency ultrasound is a reliable, accurate, and non-ionizing technique to locate the cemento-enamel junction.

Wed 14:30 Main Hall Bio-medical (poster)

A 16-channel Reconfigurable Digital Transmit Beamformer using PWM Modulation for medical ultrasound imaging and HIFU beamforming applications – (Contributed, 000046)

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A critical component of every medical ultrasound system is the high voltage pulse generator used to excite the piezoelectric elements of an array transducer. The digital transmit beamformer typically generates the necessary signals to transmit a focused acoustic energy into the body to achieve high image quality and provide highly accurate blood flow information. In this paper we present the initial results of a compact and reconfigurable 16-channel FPGA-based arbitrary pulse generator using a pulse-width modulation (PWM) method for focusing beamforming research. A low cost EP3C120 FPGA (Altera Inc.) was used to provide a suitable scheme to control simultaneously sixteen MD2131 (Supertex Inc.) high-speed ultrasound beamforming source drivers. Matlab (Mathworks Inc.) scripts were written to synthesize complex waveforms with Gaussian profile. Transmission parameters including output frequency, phase adjustment, time delay, bandwidth, pulse repetition frequency and windowing function (Rectangular, Gaussian and Tukey) can be selected via a graphical user interface and then sent to the system through a USB 2.0 connection. The digital PWM control scheme was implemented at 250 MHz (4ns resolution) and the synthesized transmission sequences with arbitrary waveforms were stored in concatenated look-up tables (LUTs) in the FPGA memory. Initial results using RC loads (1 kΩ and 220 pF) show that the proposed PWM strategy is able to generate independent high-voltage arbitrary waveforms with programmed sequences suitable to support the development and evaluation of novel dynamic focusing beamforming techniques, including medical and NDT (Nondestructive Testing) applications.

Wed 14:30 Main Hall Bio-medical (poster)

Assessment of flatness of assumed planar surfaces for ultrasound investigation of elastic surfaces – (Contributed, 000549)

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Investigation of the behavior of the electrical received signal from a transducer that insonifies a planar interface with given characteristics is challenging since the geometry has to be controlled precisely. This study investigate the planarity of an assumed planar surface made of an elasomer fixed on its perimeter by a square acrylic frame. The central part of this surface is insonified with two different linear array transducers (types 8811 and 8670, BK Medical) with center frequencies 8 and 9 MHz , respectively, yielding 11 images forming two 3D data sets. The change in flatness of the surface was determined by cross-correlation of the matrix of received signals. The cross-correlation was calculated between signals from the same image and as well between signals that belonged to differ-

ent images. The maximal change over the entire surface investigated is found to be in the order of a wavelength at about 12 MHz ($\lambda = 120\mu$m). Specifically, the surface showed weak concave bending for the two different transducers. The data was validated using the cross-correlation coefficient function. This yielded values of 0.99+/0.01 (mean+/std) when the algorithm was applied to scan-lines in the same image plane and 0.93+/0.05 when it was applied to scan-lines in different image planes. Implications for this minute deviation from planarity has the following potential consequences within the frame of assessing angle-dependence in clinical ultrasound. 1) As long as the diameter of the ultrasound beam at the interface is smaller than a few millimeters, the surface appears (locally) planar. 2) A change of 150μm over a distance of 5cm yield a change in angle of the normal to the surface of 0.17 degrees. 3) When processing data from many scan-lines distributed over the entire surface, it could be important to take the bending into account when considering very distant scan lines or when very accurate measurements are needed.

Wed 14:30 Main Hall Bio-medical (poster)

Parametric Images of Microbubbles and Tissue Mimicking Phantoms Based on Nakagami Parameters Map – (Contributed, 000378)

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The ultrasonic B-mode image is an important clinical tool used to examine the internal structures of biological tissues and contrast microbubbles, Due to the fact that conventional B-scans cannot fully reflect the nature of the tissue, Nakagami statistical model was chosen, because it is more general and simpler to apply than other statistical models (Rayleigh and K models), to generate a parametric images based on Nakagami parameters which is compared to the B-mode image. Experiments were performed using a 2.5 MHz linear array connected to an open research platform. A commercially phantom was used to mimic tissue and microbubbles backscatters. For several regions of interest and for different microbubbles dilutions, the RF signals have been generated with 3 and 5 transmit cycles. The Nakagami image can be combined with a B-mode image simultaneously to visualize the tissue and the contrast microbubbles structures for a better medical diagnosis.

Wed 14:30 Main Hall Guided wave NDT/E: modelling and simulation (poster)

Influences of electrical boundary conditions on second-harmonic generation of ultrasonic guided wave propagation in a piezoelectric plate – (Contributed, 000094)

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The influences of electrical boundary conditions on second-harmonic generation (SHG) of ultrasonic guided wave propagation in a piezoelectric plate are analyzed. The nonlinearity in ultrasonic guided wave propagation is treated as a second-order perturbation to the linear wave motion response. Based on the modal expansion analysis for waveguide excitation, an accurate description for the SHG effect of primary ultrasonic guided wave propagation in a piezoelectric plate has been presented within a second-order perturbation approximation. The formal solution of the double frequency guided waves (DFGWs), constituting the field of second harmonic, has been developed. The analytical results clearly reveal that the SHG effect of primary guided wave propagation is closely related to the electric boundary conditions of the piezoelectric plate. It is found that under different electrical boundary conditions there is an evident difference in the SHG effect of ultrasonic guided waves, and that the SHG effect is highly sensitive to the electrical boundary conditions. The results obtained may provide a means for regulating the SHG efficiency of ultrasonic guided waves by changing the electrical boundary conditions of piezoelectric plates.

Wed 14:30 Main Hall Guided wave NDT/E: modelling and simulation (poster)

The high-frequency scattering of the S0 Lamb mode by a circular blind hole in a plate – (Contributed, 000238)

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The scattering problem of an incident high- frequency S0 Lamb wave in a plate with a circular blind hole is investigated. A 3D approach is used where the wave fields are expanded in all possible Lamb modes, including propagating and evanescent modes. Due to the non-symmetric blind hole defect, the scattered fields will contain higher order converted modes in addition to the fundamental transmitted S0 and converted A0 modes. The scattering directivity patterns of various modes are inspected. The amplitudes of the scattered waves in some directions for each mode are plotted as a function of the ratio between hole diameter and wavelength. Relatively small damage can be detected by selecting the appropriate higher order converted Lamb mode. These results are helpful for the improvement of damage detectability (detection of small defects) in the field of structural health monitoring.

Wed 14:30 Main Hall Guided wave NDT/E: modelling and simulation (poster)

The transmission of Lamb waves across adhesively bonded lap-joints to evaluate interfacial adhesive properties – (Contributed, 000390)

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Because of their numerous advantages, adhesively bonded assemblies are increasingly used in the industry of transports, such as automotive or aeronautics. For safety reasons, the inspection of such joints, and more specifically the evaluation of the adhesion at interfaces between the adhesive and the adherents is critical. The aim of the present work is to infer mechanical interfacial properties for lap joint like structures, using Lamb wave modes. A pair of air-coupled, ultrasonic transducers is used to generate and detect a desired Lamb mode. This is launched from one plate and propagates towards the other plate, via the joint. Signals are picked up by the receiving transducer, before and past the joint, and post-processed to obtain the experimental transmission coefficient versus frequency. In addition, a two-dimensional Finite Element -based model is developed and used to compare with the experimental results. The model includes the finite size of the transducers, the viscoelastic properties of the adhesive layer, and also distributions of longitudinal (KL) and shear (KT) springs at both interfaces between the adhesive and the substrates. Temporal responses of the receiving transducer are predicted before and past the joints, as well as the transmission coefficient versus frequency. Preliminary results shown in this paper concern aluminium substrates. Values for both KL and KT are optimized so that good agreement between experimental and theoretical data are obtained. This demonstrates the potential of Lamb waves to infer mechanical properties at interfaces in adhesively bonded joints. The applicability to adhesively bonded composite plates is finally discussed.

Wed 14:30 Main Hall NDE / NDT (poster)

Ultrasonic Imaging Through Thin Reverberating Materials – (Contributed, 000123)

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Techniques for ultrasonic imaging and flaw detection in bulk materials made from homogeneous isotropic materials can be considered quite mature, and efficient and affordable equipment for inspection is readily available. Imaging though anisotropic or strongly heterogeneous materials, such as fiber reinforced polymers or coarse-grained metals is still challenging and there is a clear need for further development. The reason is that traditional imaging modalities, i.e. based on the delay-and-sum principle, do not handle the coherent backscatter from these materials very well.

A special case, where coherent backscatter is a problem, is in the case of materials that are either thin or materials which are composed of several thin layers. In this case, however, the received signals are affected by multiple reflections from within the layered structure, rather than from randomly located scatterers (e.g. grains, fibers, etc). Often, the structure of a healthy material is reasonably well-known, meaning that the reverberation in a healthy

sample can be modeled. If not suppressed the reverberations will, however, effectively mask any flaws present in the material.
In this paper we first investigate the sensitivity of some traditional imaging modalities to the multiple reflections from thin materials. We then evaluate two different approaches for reverberation suppression, one based on a physical model of the reflections and transmissions in the material, the other based on calibrations on a healthy sample.

The methods are then evaluated with numerical simulations and with practical experiments using a 64 element 5 MHz linear array.

Wed 14:30 Main Hall NDE / NDT (poster)

Ultrasound aided leather tanning, experimental investigation and acoustic characterizations – (Contributed, 000132)

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Several research on applications of ultrasound in the field of tanning technology have been conducted, presenting sometimes conflicting results, with the purpose of achieving improvements for the different working phases of the skins (tanning, dyeing, etc.). The observed phenomena would lead to the conclusion that the ultrasound actions in the conditions tested, are more effective against the solid phase- liquid phase system, maintaining the structure of the skin always accessible to the penetration of smaller particles. Even in tanning for fur was considered the use of ultrasound, but are not specific data, and the characterization of the acoustic properties of these leathers is only at low frequencies. With the perspective of possible specific industrial applications has realized the acoustic characterization and has tested the interaction between ultrasound and fur skins.

Wed 14:30 Main Hall NDE / NDT (poster)

Enhancement of phased array ultrasonic signal in composite materials using TMST algorithm – (Contributed, 000326)

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In this paper, we apply a new technique for the ultrasonic phased array signal enhancement. It is based on the threshold modified S-transform (TMST). The signal processing algorithms generally give very satisfactory results on synthetic signals verifying the implicit or explicit hypotheses on which they are constructed. The obtained performances on the real signals can be however different radically. Time-frequency analysis methods are mainly used to improve the defects detection resolution. Significant performance enhancement is confirmed when the proposed approach is tested with the simulation of the B-scan signals contain a closer delamination to the front face. The experimental results show that the TMST Algorithm can enhance the quality of image provided by composite materials contained delamination defect.

Wed 14:30 Main Hall NDE / NDT (poster)

Modular air-coupled ultrasonic multichannel system for inline NDT – (Contributed, 000372)

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In many production processes it is important to detect in a very early stage basic errors in the fabricated material. If the errors are not visible from the exterior, ultrasonic inspection is a convenient technique, at least if the nature of the error influences the characteristics of sound passing through the material. Examples are: local density variations in non-wovens, delaminations in composites, bad bondings in laminates, inclusions, cracks or other artefacts in plastic or metal plates, etc. There are two major, difficult requirements imposed by industry to

the used detection technique: the sensors shouldn't make physical contact with the material and the speed of testing must be sufficiently high to enable testing in-line. The former requirement can be met by employing an air-coupled ultrasonic approach, the latter by using a multichannel system.
We propose a modular air-coupled ultrasonic multichannel system. Each multichannel module contains 12 air-coupled transducers and exists in a transmitter and a receiver version. The desired scan-width is obtained by connecting several modules to each other. During the scanning all transducers are spatially fixed while the material is moving forward. This way, speeds up to 1m/s are possible, irrespective of the width of the material. To that purpose a FPGA based platform with parallel processing of large numbers of data streams is implemented in the modules. This allows the implementation of all kind of procedures, going from point measurements to more sophisticated techniques.

In spite of all measurements being performed in ambient air, the ultrasonic frequency is rather high (1MHz), but lower frequencies are possible. The most obvious set-up of the modules is a through-transmission configuration. However the system can also be used in a pitch-catch configuration which is very suitable for one-sided testing of thick materials. Examples established in the laboratory are shown to illustrate the performance.

Wed 14:30 Main Hall NDE / NDT (poster)

Material characterization of layered structures with ultrasound – (Contributed, 000058)

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Ultrasound techniques can be used for nondestructive evaluation of material properties. With density and sound velocity of longitudinal and transverse wave, Young's and Shear modulus can be determined. In order to achieve this, one-layered specimens with known dimensions are investigated by straight beam and angle beam probes, or, in scanning acoustic microscopy, by highly focused probes. By evaluating time of flight, the sound velocities can be determined. If the specimen dimensions are not known and if the specimen is additionally covered by another layer, conventional techniques fail.
In this contribution a new method for material characterization of two- layered specimens is presented. By the use of annular arrays, thickness, density and velocities of longitudinal and transverse wave are determined for each layer.
In a first step, the velocities of the longitudinal waves and the thicknesses of both layers are determined simultaneously. To accomplish this, the focus position is used as an additional measure beside the time of flight between two interface echoes. Afterwards, the sound velocity of the transverse wave, appearing due to refraction of the longitudinal waves emitted by the ring-elements, can be easily determined by time of flight, layer thickness and probe dimensions. Finally, multiple reflections are used to evaluate the density.

This method will be demonstrated for the material characterization of different specimens composed of layers of steel, aluminium and brass plates. The accuracy lies in the per mille range for the first and in the percent range for the second layer.

Wed 14:30 Main Hall NDE / NDT (poster)

F-SAFT imaging in the improvement of lateral resolution of defects detection using ultrasound phased arrays – (Contributed, 000389)

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The aim of this work is to study the focusing methods, the imaging method SAFT (Synthetic Aperture Focusing Technique), and its reconstruction in the Fourier domain such as F-SAFT. These methods improve lateral resolution in B-scan and S-scan image obtained in a phased array ultrasonic testing. F-SAFT is performed using the back propagation of wave fronts in the Fourier domain. The experiment was performed on a steel block containing several close defects, and the imaging of defect is improved by using the F-SAFT method with respect to the original S-scan. Results demonstrate the benefits of the proposed method in the enhancement of image quality.

Wed 14:30 Main Hall NDE / NDT (poster)

Semi-automatic characterisation of a large planar crack – (Contributed, 000437)

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A model-based version of Total Focusing Method has been developed and implemented in C for semi-automated characterisation of large isolated planar cracks in stainless steel. A feasibility study has shown that simulating configurations which produce diffraction from defect edges usually leads to acceptable automatic defect sizing, even though further work is being carried out on reducing probability of false indications. The capability of application was demonstrated using a steel block with realistically undulated surfaces and containing four embedded and four surface-breaking relatively large planar notches, some tilted and some non-tilted. It is possible to extend the procedure to other types of defects and geometrical configurations, developing a comprehensive library of generic models for eventual deployment in a portable probe capable of acting as a real-time assistant to an ultrasonic inspector and interpreter. If proved reliable semi-automatic characterisation of safety critical defects, would allow practitioners to produce automatic clear and unambiguous reports, saving time, which is an important consideration in maintenance of the existing fleet of nuclear reactors as well as in planning the new build. It could be later spun-out into other industries, such as rail or oil and gas.

Wed 14:30 Main Hall NDE / NDT (poster)

Some recent advances of ultrasonic diagnostic methods applied to materials and structures (including biological ones) – (Contributed, 000629)

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This paper gives an overview of some recent advances of ultrasonic methods applied to materials and structures (including biological ones), exploring the broad applications of these emerging inspection technologies to civil engineering and medicine. . In confirmation of this trend, some results of an experimental research carried out involving both destructive and non-destructive testing methods for the evaluation of structural performance of existing reinforced concrete (RC) structures are discussed in terms of reliability. As a result, Ultrasonic testing can usefully supplement coring thus permitting less expensive and more representative evaluation of the concrete strength throughout the whole structure under examination.

Main References

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Wed 14:30 Main Hall NDE / NDT (poster)

High frequency acoustic reflectometry for solid/liquid interface characterization: application to droplet evaporation – (Contributed, 000244)

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Wetting and drying evaluation on micro/nanostructures is a critical problem in the field of micro/nanopatterning for which cleaning and etching efficiency using chemical solutions is directly linked to wetting efficiency [1]. Drying kinetics are also required to control the technological processes at these scales. It can also provide important information for the development of superhydrophobic surfaces for which wetting, in that case, has to be avoided. A very sensitive method using high frequency ultrasounds (1 GHz) has been developed [2] to follow wetting transition in micro and nanostructures [3,4]. In that case, the main interest of ultrasounds is due to the high contrast of mechanical impedances between air trapped at the interfaces and liquids. Moreover it does not require optical transparence. This method is based on the use of thin film piezoelectric transducers (from 100 to 500 μm diam-

eter) fabricated on the backside of the substrate on which the solid/liquid interface is characterized. These transducers are used as emitters and receivers and connected to a Vector Network Analyzer used to achieve electrical characterization of Sij scattering parameters. The very sensitive (2.10-4) evaluation of the reflection coefficients at the interface makes it possible to determine the properties of the reflected acoustic echoes in time domain using inverse Fourier Transform. This sensitivity has also made it possible to follow, in a first step, evaporation kinetics of drops of some water/alcohol mixtures at the solid/liquid interface from the tracking of the concentration evolution. Therefore, this method also presents potentialities to track drying kinetics.

Wed 14:30 Main Hall Physical acoustics (poster)

Ultrasonic Loading Effects on Silicon-based Schottky Diodes – (Contributed, 000122)

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Motivation
Ultrasound is established to affect various properties of semiconductors. The ultrasonic wave - defect interaction is a main reason of acoustically induced effects in non-piezoelectric semiconductors. Unfortunately, the experimental data that focus on acousto-defect interaction in silicon are insufficient. This study is devoted to an experimental investigation of the modification of silicon Schottky structure properties by the ultrasonic loading at the varied conditions.
Methods
Mo/n-n$^+$-Si structures have been used in our experiments. The current-voltage characteristics were measured for the samples under ultrasonic loading conditions. The longitudinal waves excited in the samples were 4.1, 8.4, 13.6, 27.8 MHz in frequency and had the intensity of $W_{US} < 0.3$ W/cm^2. The ultrasonic loading temperature was varied from 150 to 330 K.

Results

The acoustically induced reversible both decrease of the Schottky barrier height and increase of the ideality factor have been observed. It was found, that (i) the US influence efficiency increased with the ultrasound intensity increasing and the dependence was close to a linear; (ii) the increase in ultrasound frequency led to the intensification of the acoustically induced parameter variation; (iii) the maximum ultrasound effect was observed at $\sim$210 K.

The obtained results has been analyzed on account of the inhomogeneous Schottky barrier model. The ultrasonic loading has been shown to increase the effective density of patches, and to broaden the patch parameter distribution.

Wed 14:30 Main Hall Physical acoustics (poster)

A nondestructive imaging method for detecting defect in mortal sample by high-intensity aerial ultrasonic wave – (Contributed, 000230)

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Recently, developments have improved methods employing aerial ultrasonic waves for contactless inspection of internal defects in solid materials such as metals, pipe walls, and fiber-reinforced plastics. Specially, this method is noncontact way differ from conventional ultrasonic inspection that is necessary to contact probe to object. Therefore, the object which cannot contact can also be inspected. We proposed an imaging method in non-destructive and non-contact way by high-intensity aerial ultrasonic wave. This method detects to image the defect area from vibration velocity distribution on the surface of object which is excited continuously in noncontact way by irradiated an aerial ultrasonic wave. In previous study, we exam to detect for imaging the defect in acryl plate by this method. In this report, we attempted to detect defect in mortal sample by this method.

Wed 14:30 Main Hall Physical acoustics (poster)

Focalization of Acoustic Vortices Using Phased Array Systems – (Contributed, 000275)

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Acoustic vortices (AV) are helical wavefronts that exhibit a screw-type dislocation and a phase singularity along its principal axis of propagation, at which the pressure of the field is zero. AV can be generated using various methods among which stands out the use of phased array systems because they allow us to electronically control the acoustic beam by means of the application of a given delay law to the array elements. Little research has been reported regarding the focalization of AV to obtain a higher pressure distribution. In view of this, this work presents the study of different delay laws for generating and focusing AV. The analysis of the resultant geometry and pressure distribution of the focused beams is included. We demonstrate that it is possible to increase the pressure amplitude up to 3 times with respect to a non-focalized, at the focal distance. Experimental tests were carried out using a hexagonal multitransducer of 30 elements at 40 kHz. A good agreement between simulations and experimental results was obtained.

Wed 14:30 Main Hall Physical acoustics (poster)

Theoretical and numerical study of the reflection of an ultrasonic pulse radiated by a linear phased array transducer at a fluid-fluid interface – (Contributed, 000292)

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This study is devoted to the calculation, in transient mode, of the acoustic field emitted by a linear array and reflected from a fluid-fluid interface. The calculation is based on the theoretical model of a spherical wave pulse emitted by a point source reflected from a plane interface separating two fluid media, and detected by a receiver assumed punctual. This model uses a Fourier transform in the time space followed by a Hankel transform on space variables. The resulting field is written as the sum of three integrals using simple integration nuclei. The superposition principle is then applied to calculate the pressure wave resulting at any point of the field. This calculation method can follow in time all the waves contributing to the reflected field. The model developed shows the various waves emerging at the interface: direct and edge waves, specular reflection and the appearance of radiating surface waves at critical angle. The various waves are identified by calculating their arrival times by using the ray method. The results are validated thanks to a finite element package widely used in computer simulations for solving partial differential equations describing such physical phenomena.

Wed 14:30 Main Hall Physical acoustics (poster)

Ultrasonics in an Atomic Force Microscope – (Contributed, 000448)

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We have investigated applications of ultrasound for materials characterisation in conjunction with atomic force microscopy (AFM), in which a nanoscale tip on the end of a cantilever is rastered over a sample surface and the deflection of the cantilever is used to obtain a high resolution (nm) map of the surface. This has been done in two ways; firstly by using ultrasonic excitation as an extension to normal AFM techniques giving ultrasonic force microscopy, where high frequency (8 MHz) ultrasound is used to oscillate a sample, inducing an additional deflection in the cantilever that varies with changing material properties, such as the Young's modulus, near to the sample surface. The ultrasonic excitation used in UFM is also known to provide a superlubricity phenomenon, and this was used to image delicate samples such as carbon nanotubes. Secondly, an AFM has been used to pick up lower frequency (below 1 MHz) ultrasound generated using electromagnetic acoustic transducers (EMATs), with potential applications in high resolution (sub μm) nondestructive testing (NDT). It has also been shown that this method of pickup is sensitive to very small (sub nm) oscillations, allowing for low power operation or improved signal to noise.

Wed 14:30 Main Hall Physical acoustics (poster)

Optimization of Surface Acoustic Wave Streaming in PDMS microfluidic channels, effect of frequency – (Contributed, 000632)

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Acoustic streaming is of rapidly growing significance to microfluidics due to the large range applications such as fluid pumping, low Reynolds number mixing and particle trapping etc (Refs). Very little attention has been paid to the effect of the frequency of the SAW wave on the streaming that is produced. This study is motivated to better understand the effect of frequency for producing fast and efficient streaming. A micro PIV system was used to measure the instantaneous vector field at different focal depths in a PDMS chamber when actuated with different frequencies of SAW. Immediately afterwards a Laser Doppler Vibrometer was used to measure the SAW magnitudes that were in the chamber. In this way it is possible to compare the streaming produced by different SAW waves. A novel ëcave' design was used to control the shape of the SAW beam in the microfluidic chamber, this exploits the damping induced by the PDMS to spatially filter the SAW beam. Over the range of frequencies used in this study (40-500 Mhz) the streaming speeds varied over 3 orders of magnitude with the highest frequencies corresponding to the fastest streaming.

Wed 14:30 Main Hall Sonic and phononic crystals (poster)

Quaternion Formalism for the Intrinsic Transfer Matrix – (Contributed, 000059)

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A quaternion formulation is applied to the intrinsic transfer matrix for longitudinal elastic wave propagation through a multilayer medium in order to find the spectral response of a sonic crystal. Resonance conditions and the band structure of the crystal are obtained. The presence of a defect is also analysed. The analysis is carried out theoretically and through simulations. A coupled oscillators model is used to validate the obtained results from a phenomenological point of view. Experimental measurements are carried out for some periodic multilayer arrangements and they are correlated with theory. The obtained spectral response and band structure are essential in characterising the sonic crystal and also in optimising its structure in order to obtain specific passbands and stopbands. The adaptedness of the quaternion formulation to periodic structures and to the inclusion of defects is considered. References [1]M. Badreddine Assouar, J. H. Sun, F. S. Lin, J. C. Hsu, Hybrid phononic crystal plates for lowering and widening acoustic band, Ultrasonics (2014), http://dx.doi.org/10.1016/ultrs.2014.06.008 [2].Nicolae Cretu and Gelu Nita. Pulse propagation in finite elastic inhomogeneous media. Comp. Mat. Sci. 31(3-4), pp. 329-336, 2004. [3] N. Cretu, G. Nita, A simplified modal analysis based on the properties of the transfer matrix, Mechanics of Materials 60 (2013) 121-128.

Wed 14:30 Main Hall Sonic and phononic crystals (poster)

Phononic Crystal of Surface Acoustic Wave based on Gold Pillar Array on LiNbO3 Substrate – (Contributed, 000233)

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Motivation: The surface acoustic wave device received much attention. They can be used to many application such as filter, MEMs and sensors. We aim to develop a phononic crystal for surface acoustic wave. Because of the facility of LiNbO3 in the application of surface acoustic wave, we chose the LiNbO3 substrate as our research subject. Methods: Simulation results Results: In this study, we demonstrate a phononic crystal of surface acoustic wave. The phononic crystal consists of gold pillar array on the surface of LiNbO3 substrate. The gold pillars are arranged in square lattice. The lattice constant is set to be 400nm. The height of each gold pillar is 80nm. The radii of gold pillars extend from 130nm to 150nm. The LiNbO3 substrate is considered to be semi-finite, i.e., one surface is free. We adopt finite-element-Method (FEM) to calculate the band structure of surface acoustic wave of our structure. The results show that the band gap of surface acoustic wave are opened at around 3GHz. The band gap extends from 2.76GHz to 3.58GHz for the pillar with radius equals to 130nm. The band gap extends from 2.73GHz to 3.52GHz for the pillar with radius equals to 140nm. The band gap extends from 2.75GHz to 3.47GHz for the pillar with radius equals to 150nm. The bandwidth of band gap decreases with the increasing of radius. On the other hand, we also calculate the transmission spectrum of our phononic crystal. The forbidden transmitted band agrees well with the band structure calculation.

Wed 14:30 Main Hall Sonic and phononic crystals (poster)

Near-Field Coupling of Resonators in Locally-Resonant Sonic Crystals – (Contributed, 000258)

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Motivation - Local resonance is one of the major physical mechanisms that can open complete band gaps in sonic and phononic crystals. In contrast to Bragg interference, the band gap is mostly dictated by the resonant frequency of the isolated resonator and is not strongly influenced by the lattice constant. It is consequently often used to induce deep sub-wavelength band gaps. When the resonators are brought at a close distance, however, near-field coupling between resonators may occur. We show that this coupling can influence very strongly the transmission of a finite crystal.
Methods - We consider a simple sonic crystal as a one-dimensional sequence of air tubes grafted along a waveguide. The dimensions are chosen to operate in the audible frequency range and the waveguide supports only one propagating mode. The sequence of resonators is composed of two tube lengths, either short or long, with non-overlapping resonant ranges. Transmission experiments are performed with PVC tubes. Comparison with a matrix model involving both propagating and evanescent waveguide modes is used to analyze the experimental results.
Results - It is found that both the composition and the order of the sequence of short and long resonators have a very strong influence on the transmission spectrum. We explore all the 25 possible combinations of a sequence of 5 resonators and exhibit sequences with almost no attenuation and sequences with a strong attenuation over a wide bandwidth. Comparing with the one-dimensional matrix model, we show that near- field coupling of the resonators is probably responsible for the observations.

Wed 14:30 Main Hall Sonic and phononic crystals (poster)

Analysis of a phononic crystal constituted of piezoelectric layers using electrical impedance measurement – (Contributed, 000556)

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Piezoelectric materials are often used for ultrasonic devices (actuators, sensors, resonators, ...). Wave generation and propagation in such devices results from the coupling between electrical and mechanical variables, i.e. electromechanical properties of each constitutive layer. The characterization of such physical parameters can be deduced from geometric properties and electrical impedance measurements. An electrical impedance measurement at a given position makes it possible to deduce the thickness properties of the piezoelectric and surrounding layers around the thickness resonance. This study deals with the electrical impedance measurement of a piezoelectric layer, as a function of the properties of the surrounding media. The propagation along the thickness mode is assumed. A theoretical model is proposed to calculate the electrical impedance of an active layer located inside a finite one-dimensional periodic structure constituted of piezoelectric and passive layers. The position of the considered active layer inside the finite periodic structure is a significant parameter. Depending on the connected impedance load (capacitance, inductance), various effects on the position and the amplitude of the electrical resonance are observed. Experimental and theoretical are in very good accordance. Finally, this local electrical characterization of one piezoelectric layer is used to analyse the acoustic transmission through the stack.

Thu 8:30 Grande Salle Plenary lecture V

The Possibility of Using Metamaterials in the Design of Optical Quantum Gyroscope – (000541)

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The concept "negative refraction" made a fresh look at the phenomena and devices, which are described by formulas containing the value of the refractive index n . If the value n is negative, corresponding formula or conditions may drastically change their meaning or properties. This statement is completely fair in describing the properties of a device such as an optical quantum gyroscope. Its output frequency $\Delta\omega$ is zero if the device is placed in

the inertial frame and stationary, but if the unit begins to rotate with the frequency Ω , the value $\Delta\omega$ is different from zero and equal

$$\Delta\omega = 4S\Omega \div n\lambda L$$

where - S is the area covered by the perimeter of the loop of the gyroscope, L is the length of the perimeter and λ is the wavelength in vacuo. Previous formula assumes that both beams of gyroscope are propagated in a transparent material having a refractive index n . However, by using this expression, a question arises about its possible transformation in the case that the optical path in the gyroscope is filled with a dielectric only on part l of the overall length L of such optical path , and the remaining length L-l is filled with vacuum still. In accordance with previouse expression $\Delta\omega$ takes the form

$$\Delta\omega = 4S\Omega \div [ln + (L - l)]\lambda$$

Very interesting consequence of this expression is the sharp increase in the value $\Delta\omega$ if the value n became negative. Thus, the gyro sensitivity increases with the absolute value of negative coefficient of refraction. This means that the use of metamaterial with negative refraction could increase the sensitivity of the gyroscope.

Thu 9:00 Grande Salle Plenary lecture V

Phase and Group Velocities of Bulk Optic and Acoustic Waves in Crystals and Artificial Periodically Structured Media – (000245)

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The report reviews laws and general trends of propagation and reflection of bulk optic and acoustic waves in media possessing strong anisotropy of optical and acoustical properties. We discuss unusual cases of wave phenomena taking place in crystals demonstrating large birefringence and exhibiting extremely strong elastic anisotropy. As known, the anisotropy manifests itself in the wide walkoff angles separating the Poynting vector and the wave vector. In particular, the optic waves propagating in birefringent media at walkoff angles wider than 20 degrees are considered in the presentation. Results of the research are generalized over media with artificially induced optical anisotropy such as photonic crystals and structured materials. We also predict behavior of the waves propagating in the new artificial media such as metamaterials. The propagation of the waves is also examined for the case of elastic waves. A few unusual effects of the acoustic wave reflection are analyzed in the report. We prove that the new effects originate from the strong physical anisotropy of the media. One of the peculiar effects is the acoustic reflection form a free boundary separating a crystal and the vacuum. As found, the examined reflection becomes possible due to the acoustic walkoff angles as wide as 70 degrees. During the reflection, energy of the elastic wave is incident on the boundary at the angles up to 160 degrees, i.e., amazingly exceeding 90 degrees. Finally, in the presentation, we also discuss a few applications of the examined phenomena in modern acousto-optic and acousto-electronic instruments.

Thu 10:30 Grande Salle Acoustic Emission

Acoustic Emission of Composite Structures: Story, success, and challenges – (Invited, 000523)

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Thanks to their attractive advantages (Good anti-corrosion performance, long service life, light convenient installation and transportation, low thermal conductivity, small thermal stress, good electrical insulating property, high specific strength, reasonable mechanical property...), composite structures are in increasing use in various fields. However, they are not immune to different defects, which can occur either during manufacturing or in service-life, such as delaminations, abrasions, disbondings, fiber fractures, voids, cracks. Many nondestructive techniques can be used to contribute in preventive and curative maintenances of this kind of structures. Acoustic emission, which is a phenomenon whereby transient elastic waves are generated by defect or discontinuities (crack initiation and propagation, fiber breakage, fiber-matrix debonding...), occupies a strong position among these techniques. The success of this technique is linked to advanced signal processing and statistics techniques, experimental feedback and procedures, high-tech instrumentation, and modeling.

This conference will be devoted to this technique and will be focused on the state-of-the-art of its application (from the sixteenth till nowadays). Major realizations via this technique will be carried out. Examples underlying the maturity of acoustic emission will be debated. To continuously improve the reliability of this method, many world-wide researchers are hard working. Some perspectives will be discussed.

Thu 11:00 Grande Salle Acoustic Emission

AT on Buried LPG Tanks Over 13 m3: An Innovative and Practical Solution – (Contributed, 000623)

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In Italy, since 2005, techniques based on Acoustic Emission have been introduced for testing of underground LPG tanks up to 13 m3, according to the European standard EN 12818:2004.
The testing procedure for these tanks, plans to install one or more pairs of sensors inside the "dome" suited for the access to the valves and fittings of the tank , directly on the accessible metal shell.
This methodology is not applicable for the underground LPG buried tanks, where it is necessary to install a larger number of AE sensors, in order to cover at 100% the whole tank shell, even at very deep positions.
Already in 2004 , the European standard EN 12820 (Appendix C - Informative)give the possibilty to use Acoustic Emission testing of LPG underground or buried tanks with a capacity exceeding 13 m3 , but no technique was specified for the application.
In 2008, Blu Solutions srl - Italian company of TÜV AUSTRIA Group - has developed a technique to get access at tank shell, where tank capacity is greater than 13 m3 and its' diameter greater than 3,5 m.
This methodology was fully in comply with the provisions of the European Standard EN 12819:2010, becoming an innovative solution widely appreciated and is used in Italy since this time.
Currently , large companies and petrochemical plants , at the occurrence of the tank's requalification, have engaged Blu Solutions to install such permanent predispositions , which allow access to the tank shell - test object - with diameters from 4 to 8 m. Through this access, you can install the AE sensors needed to cover at 100% the tank surface and then to perform AE test.
In an economic crisis period, this technique is proving a valid and practically applicable answer, in order to reduce inspection costs and downtime by offering a technically advanced solution (AT), increasing the safety of the involved operators, protecting natural resources and the environment.

Thu 11:15 Grande Salle Acoustic Emission

Acoustic Emission technique: italian experience on the requalification of underground LPG vessels – (Contributed, 000624)

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In Italy, according to the existing legislation, the structural integrity and stability of small underground LPG vessel shall be assessed every ten years (hereafter "requalification"). A technique for requalification, based on the Acoustic Emission (AE) method, has been developed in Italy in the last decade to prevent the use of "conventional" NDT techniques requiring complete accessibility of the external surface of the vessel. This technique allows requalification tests to be performed during service, avoiding digging out.
The technique has been codified into a comprehensive requalification procedure, which is consistent with the requirements set by the European standard EN 12817:2010. The test is based on a interpretative model of measured AE data, which links the vessel structural stability to compliance with a specified threshold.
The procedure was officially released as part of the Italian national legislation in January 2005, and requalification tests were first carried out in late 2005. At the end of January 2015, after ten years of extensive activity, the number of tests successfully completed exceeds 130.000. This paper provides a summary of the technique developed for testing small underground LPG vessels and the on-line signal processing of data recorded during tests. Finally, a synthesis of results obtained for all tested vessels is shown.

Thu 11:30 Grande Salle Acoustic Emission

EA monitoring with WSN to verify the stability and the leakage of pressure vessel – (Contributed, 000625)

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For monitoring and diagnostics of pressure equipment, new techniques based on Acoustic Emission (AE) appear more useful than the control traditionally performed at a certain time of life of the equipment. In fact monitoring, with a Wireless Sensor Network (WSN) that can transmit data in real time, can provide useful information on the "health" of the equipment, component or element monitored and, in case of incipient problems, immediately alert the staff responsible for the supervision and / or maintenance.

This type of approach, in addition allowing remote management system, is evidently implementable and integrated with other diagnostic methods.

The systematic analysis of the collected data and operating parameters of the equipment monitored contribute to the optimal management of the aspects related to the safety of the same equipment.

The present paper describes the preliminary results of a research activity performed by the Laboratory Diagnostical Techniques, Research Center INAIL of Monte Porzio Catone (RM) aimed at monitoring tanks for the storage of hazardous fluids.

The purpose of monitoring is evidently to diagnose, through interpretive analysis based on validated models, incipient structural instability of the pressure vessels or leak detection product, determining causes of possible catastrophic events.

Thu 11:45 Grande Salle — Acoustic Emission

Some factors affecting time reversal signal reconstruction – (Contributed, 000508)

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Time reversal (TR) ultrasonic signal processing is now broadly used in a variety of applications, and also in NDE/NDT field. TR processing is used e.g. for S/N ratio enhancement, reciprocal transducer calibration, location, identification, and reconstruction of unknown sources, etc. TR procedure in conjunction with nonlinear elastic wave spectroscopy NEWS is also useful for sensitive detection of defects (nonlinearity presence). To enlarge possibilities of acoustic emission (AE) method, we proposed the use of TR signal reconstruction ability for detected AE signals transfer from a structure with AE source onto a similar remote model of the structure (real or numerical), which allows easier source analysis under laboratory conditions. Though the TR signal reconstruction is robust regarding the system variations, some small differences and changes influence space-time TR focus and reconstruction quality. Experiments were performed on metallic parts of both simple and complicated geometry to examine effects of small changes of temperature or configuration (body shape, dimensions, transducers placement, etc.) on TR reconstruction quality. Results of experiments are discussed in this paper. Considering mathematical similarity between TR and Coda Wave Interferometry (CWI), prediction of signal reconstruction quality was possible using only the direct propagation. The results show how some factors like temperature or stress changes may deteriorate the TR reconstruction quality. It is also shown that sometimes the reconstruction quality is not enhanced using longer TR signal (S/N ratio may decrease).

Thu 10:30 Claude Lefebvre — Acoustic Metamaterials: fundamentals, applications and emerging topics II

Control of Perfect Absorption in 1D Scattering: An Acoustic Example – (Contributed, 000505)

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We theoretically and experimentally study the acoustic scattering in a two-ports one-dimensional waveguide, side loaded by isolated resonators of moderate quality factor Q. The lossless theory predicts high quality transparent modes induced by Fano interferences. Here we show that these transparent modes comes from the interaction of poles in the transmission coefficient visible in the complex plane. In the presence of the intrinsic losses, these modes can be critically coupled leading to the coherent perfect absorption of acoustic waves. For asymmetric structures, an unidirectional reflectionless propagation is possible at singular points, called exceptional points, as well as to an almost perfect absorption. The control of perfect absorption by the proper tuning of few resonators and the engineering of the losses will open new possibilities in important applications in various wave-control devices.

Thu 10:45 Claude Lefebvre Acoustic Metamaterials: fundamentals, applications and emerging topics II

Broadband attenuation of Lamb waves through a metamaterial interface made of thin rectangular junctions – (Contributed, 000588)

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A class of materials appears where the size of the inclusions is much smaller than the driving wavelength. These acoustic metamaterials are used to reach unusual physical properties, such as acoustic induced transparency or enhanced acoustic transmission as well as sound shielding. In this work, we present the study of analogous phenomena for a Lamb waves propagating in a thin silicon plate drilled with one or two lines of rectangular air holes, constituting a metamaterial interface made of thin junctions. The full Lamb waves, i.e., symmetric and antisymmetric, have been treated with an emphasis of the symmetric ones in our discussions and results. The resonances and antiresonances of periodically arranged rectangular junctions separated by holes are investigated as a function of the geometrical parameters of the junctions. We then consider the case of two rows of holes and especially investigate the possibility of broadband shielding by an appropriate choice of the distance between the two rows. The choice of the distance between the two rows of holes allows the realization of a broadband low frequency acoustic shielding with attenuation over 99% for symmetric waves in a wide low frequency range and over 90% for antisymmetric ones. Two perspectives are currently performed on the metamaterial interface. The first one is to study the influence of the angle of incidence of the incoming Lamb wave on the metamaterial properties. In the second one, we study the geometrical inclination of the junctions and expect some new features from this supplementary degree of freedom.

Thu 11:00 Claude Lefebvre Acoustic Metamaterials: fundamentals, applications and emerging topics II

Acoustic transmission loss by air bubble lattice network in water – (Contributed, 000504)

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Acoustic wave propagation in a bubbly medium (Bubble clouds, clusters, foams and rafts) draws lots of attention due to its potential application in medical and noise shielding fields. The resonance frequency for a single bubble under acoustic harmonic excitation could be determined using Houghton's model. Under small pressure amplitude, the bubble resonance frequency is inversely proportional to its radius. During the oscillations of the bubble its radius varies about its equilibrium position with a linear approximation. However under large pressure amplitude, nonlinear oscillations are introduced. When a gas bubble is in close proximity to other bubbles, the characteristics of the resonance described above are drastically affected because of multiple scattering. Interactions with adjacent bubbles result in shifts of the resonance frequency as well as in variations of the peak amplitude at resonance. The aim of this work is to study the influence of these interactions between bubbles on the acoustic transmission loss.
A finite element method based model using Comsol Multiphysics was developed to study both the dispersion based on the Bloch-Floquet theorem and the acoustic transmission loss from a spherical air bubble network in an unbounded, homogeneous, host water medium. The number of the bubble layers was varied in order to study its influence on the peak amplitude.
Bubbles forming a rectangular network have a remarkable coupling influence starting from a filling factor of 33% up to a foam shaped bubble raft. The filling factor is defined as the ratio between the bubble volume and the englobing medium. On one hand, the calculated transmission loss (larger than 75 dB) shows a shift in frequency of the dissipation peak. On the other hand, the peak amplitude was a directly proportional to the number bubble layers.

Thu 11:15 Claude Lefebvre Acoustic Metamaterials: fundamentals, applications and emerging topics II

Effective birefringence to analyze sound transmission through a layer with sub wavelength slits – (Contributed, 000486)

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We analyze the enhancement and extinction of the sound transmission through a sound hard film or layer with subwavelength slits. For wavelength comparable or larger than the slit spacing, the transmission enhancements and the extinctions are revisited in terms of the transmission through an equivalent, homogeneous and birefringent, layer whose extraordinary and ordinary indices are determined using homogenization theory. It is shown that the Fano type resonances can be understood by means of the dispersion relations of evanescent waves below their cut off frequency. Using homogenization allows to derive close forms of the dispersion relations for these modes guided in the birefringent layer and similar to the spoof plasmons for gratings, well behind the usual low frequency regime. Perpectives to extend the homogenization process to a two coupled wave analysis will be presented.

Thu 11:30 Claude Lefebvre Acoustic Metamaterials: fundamentals, applications and emerging topics II

Sufficiency of the Brillouin zone's borders for the band gap analysis in acoustic metamaterials – (Contributed, 000334)

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To investigate band structures of phononic crystals and acoustic metamaterials with a spatial periodicity, it is sufficient to examine wave vectors within the first Brillouin zone of the reciprocal lattice space. Regardless of the crystal/metamaterial type and the method chosen for the band structure calculation, the computational effort is usually rather high, as the problem is solved numerous times at each value of the wave vector. In cases, when the analysis is limited to finding of frequency band gaps bounded by the pass bands' extrema, the amount of calculations may be significantly reduced due to the symmetry properties of metamaterials by inspecting the wave vectors at the borders of the irreducible Brillouin zone (IBZ). It appears to be possible since the extrema of pass bands occur most probably at the boundary of the IBZ. This is a commonly used assumption, which, to the authors' knowledge, has not been proved yet. Some researches have admitted that this hypothesis is invalid for phononic crystals with asymmetries or with energy dissipation. In this talk, the sufficiency of the IBZ for acoustic metamaterials with a local resonance effect is studied. The Bloch method combined with finite element technique is used to calculate the band structures for locally resonant acoustic metamaterials with energy losses and asymmetric properties. The performed analysis provides the information about the location of pass bands' extrema and answers the question whether the standard way of band structure representation along the high symmetry lines is correct.

Thu 11:45 Claude Lefebvre Acoustic Metamaterials: fundamentals, applications and emerging topics II

Non-specular reflection of acoustic waves from a two-dimensional phononic crystal – (Contributed, 000083)

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Most previous studies have focused on the transmission of acoustics waves through phononic crystals to identify the band gaps. In the present study, we experimentally and theoretically investigated non-specular (anomalous) reflection of acoustics waves from a two-dimensional phononic crystal in water. The two-dimensional phononic crystal consists of periodic square arrangements of 1 mm diameter stainless steel cylinders with the lattice constant of 2 mm. The pressure fields at oblique incidence to the crystal were calculated as a function of the frequency using a finite element method. The reflected waves strongly depend on the frequency and exhibit non-specular reflection at some frequencies. The calculated anomalous reflection from the phononic crystal were validated with measurements obtained in water.

Thu 12:00 Claude Lefebvre Acoustic Metamaterials: fundamentals, applications and emerging topics II

Mechanical parameters for dissipative media with either positive or negative acoustic refractive index – (Contributed, 000422)

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The control of acoustic wave propagation with well-designed structures can be investigated by suggesting unusual values for their constitutive parameters. In this context, artificial media with infinitely large or negative values of bulk modulus κ and mass density ρ have already been proposed. Media with negative refractive index return us to the phenomenon of the backward wave propagation, where the energy flow of a time-harmonic plane wave is opposite to its phase propagation direction. Questions still remain regarding the means to deduce the index sign, or in other words to identify a priori the presence of backward waves, from the complex-valued parameters κ and ρ only. The present work deals with the constitutive parameters of dissipative and isotropic homogeneous media with positive or negative refractive index. The criteria satisfied by these parameters are viewed as a consequence of the plane wave motion exhibition. From the modeling of the plane wave propagation, the negative sign of the refractive index is directly related to the phase angle of the complex-valued wavenumber. Then, the 2D space of dynamic material parameters (κ, ρ) is found to be split into regions characterized by their abilities both to induce wave attenuation and to exhibit opposite directions between the energy flow and the direction of the plane wave propagation [1]. Finally, the relevance of such representation is illustrated by superimposing experimentally-retrieved constitutive parameters of media supporting both forward and backward wave motions.

[1] J. Dubois et al., J. Appl. Phys. 15 (2), 024902 (2014)

Thu 13:30 Claude Lefebvre — Acoustic Metamaterials: fundamentals, applications and emerging topics II

Soft 3D acoustic metamaterials with negative indices – (Contributed, 000106)

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One of the current challenges in the field of metamaterials is to extend beyond electromagnetism by making 3D materials with negative indices in other areas such as acoustics [1]. Soft matter techniques coupled with microfluidics provide a unique tool to take up this challenge [2]. In this paper, we report the achievement of a new class of metafluids made of "ultra-slow" macro-porous micro-beads, acting like Mie-type resonators in the ultrasonic domain. The propagation of Gaussian pulses within these strongly scattering random media is investigated through in situ acoustical experiments. From angular-phase measurements on propagating Gaussian pulses, the acoustic refractive index is shown to be negative over broad frequency bandwidths, depending on the volume fraction of the micro-beads, as predicted by multiple-scattering calculations [3].

[1] M. Wegener, "Metamaterials beyond optics", Science 342, 939-940 (2013).
[2] T. Brunet et al, "Soft acoustic metamaterials", Science 342, 323-324 (2013).
[3] T. Brunet et al., "Soft 3D acoustic metamaterial with negative index", published online in Nature Materials on December 15, 2014 (DOI: 10.1038/NMAT4164).

Thu 13:45 Claude Lefebvre — Acoustic Metamaterials: fundamentals, applications and emerging topics II

Limits of the Kelvin Voigt model for modeling wave propagation in linear viscoelastic discrete periodic structures – (Contributed, 000208)

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In this study waves propagating in discrete linear viscoelastic periodic systems are investigated with the aim of understanding the operative range of some commonly adopted rheological models. First, dispersion laws of a generic linear viscoelastic periodic system under prescribed harmonic motion, i.e. real angular frequency and complex wavenumber (wavenumber and attenuation), are derived. It is shown that such relations can be easily obtained from the linear elastic counterpart in force of the correspondence principle. Then, a formula based on the vibrating modes of the unit cell is introduced to compute the energy velocity. Next, complex band structures and energy velocities for one-dimensional and two-dimensional monoatomic and diatomic periodic structures are computed considering both the Kelvin Voigt and the Standard Linear Solid models. It is proven that unusual dispersive behaviors already observed by other researchers when using the Kelvin Voigt model, such as wavenumber-gaps and strong band-gap shifting, are only caused by its nonphysical rigid behavior at high frequencies, since they disappear once the Standard Linear Solid model is adopted. The comparison between the energy velocity of the Kelvin Voigt and Standard Linear Solid discrete systems provides a further confirmation of these findings.

Thu 14:00 Claude Lefebvre Acoustic Metamaterials: fundamentals, applications and emerging topics II

Exploiting Symmetry and Material Nonlinearity in Mechanical Meta-materials – (Contributed, 000262)

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The manipulation and control of phonons is important in understanding nonlinear propagation, caustic formation and shock interactions, as well as in applications ranging from sound insulation to ultrasonic imaging and shock dissipation. Unique to this challenge lies in the materialës inherently nonlinear response, such as phonon-phonon scattering as well as amplitude dependent shock propagation which stems from the intriguing structure of the different materials across multiple length scales, from the atomic to the meso-scale. Phononic metamaterials (PMM) enables one to access exotic propagation behavior, such as super-tunneling, negative refraction and super-absorption, through deliberate structuring at a particular length scale. Furthermore, dynamic behavior in PMM may be exploited through affine deformation or elastic instabilities which alter the structural symmetry and hence the dispersion behavior. However, we propose that, by harnessing the intrinsic nonlinear responses in materials, (occurring at a particular length scale) together with the structural symmetry at targeted length scales, we can arrive at novel methods of controlling wave propagation behavior. One explicit example of this is in spider silk fibers, which possess macroscopically uniaxial symmetry. We theoretically and experimentally observed an indirect hypersonic polarization band gap (30%) and importantly, negative index behavior; we further demonstrated that these properties can be dynamically and reversibly tuned with large amplitude strains (up to ±40%). The origin of this band gap is distinct from common mechanism attributed to scattering or hybridization while the negative index behavior arises from the elastic nonlinearity, pointing the way forward to new methods of generating negative index behavior through nonlinearities; this reveals the major role of multilevel structural organization on elastic energy flow and the influence of nonlinearity in the mechanical behavior. Exploiting both these properties cooperatively provide avenues for novel systems with tailored and importantly, functionally optimized properties.

Thu 14:15 Claude Lefebvre Acoustic Metamaterials: fundamentals, applications and emerging topics II

Effective acoustic properties of a random suspension of dense spherical particles in an elastic matrix : experiment and theory – (Contributed, 000501)

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We study both experimentally and theoretically the propagation of longitudinal acoustic waves through a random suspension of dense, spherical particles in an elastic matrix in a broad frequency range including the particle dipolar resonance frequency. We experimentally determine the effective celerity and attenuation of suspensions with volume fraction ϕ ranging from 2% to 10% from the measurements of the transmission of longitudinal acoustic pulses at normal incidence by slabs. The effective acoustic properties of the suspension are modelled using the expression given by the multiple scattering theory with approximation at the second order in concentration and which takes into account the coupling between longitudinal and shear scattered waves. We observe excellent agreement between measurements and theory up to $\phi = 5\%$, which is further improved when longitudinal-transverse conversions are taken into account. A simplified analytical model is presented that reproduces the main features of the acoustic properties of the suspension around the dipolar resonance. The behavior of the effective density of the metamaterial is also discussed, based on both measurements and theoretical predictions.

Thu 14:30 Claude Lefebvre Acoustic Metamaterials: fundamentals, applications and emerging topics II

Optimizing Broadband Super Absorbance of Acoustic Waves with Bubble Meta-Screens – (Contributed, 000299)

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We show that a super-absorbing metamaterial for waterborne acoustic waves can be constructed by optimizing the structure of a bubble meta-screen in contact with a rigid reflector [1]. The optimization is guided by a simple analytical model, which not only facilitates the optimization but also gives insight into the underlying physics. The model allows meta-screens to be designed with fully tunable and optimized absorption properties over wide frequency ranges. In this presentation we explain how the absorbance can be maximized by optimizing the viscosity of the medium for the bubble size and separation. Both experiments and fnite element simulations support the predictions of the model. When the meta-screen is placed on a rigid interface, super-absorption is achieved, with less than 1% of the incident energy being reflected. The optimization of a bubble meta-screen as a coherent perfect absorber will also be discussed.

[1] V. Leroy, A. Strybulevych, M. Lanoy, F. Lemoult, A. Tourin, and J.H. Page, ."Super-Absorption of Acoustic Waves with Bubble Meta-Screens", Phys. Rev. B Rapid Communications, in press (2015).

Thu 14:45 Claude Lefebvre Acoustic Metamaterials: fundamentals, applications and emerging topics II

Porous soft silicone rubbers as ultra-slow resonators for acoustic metamaterials – (Contributed, 000430)

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The field of metamaterials is more alive than ever judging by the exponential growth of the publications devoted to this subject. In that context, the first 3D negative-acoustic-index metamaterial has been recently demonstrating by taking benefit from strong Mie resonances of "ultra-slow" porous soft silicone rubber beads [1]. Although, it has been well known for a long time that the sound speed could be very low in porous media [2], the latter can be much lower in porous elastomeric media even if the porosity is rather low (about a few percents). By contrast, porous silica aerogels require much higher porosity (more than 95%) to exhibit similar values of the sound speed [3]. In this paper, we will discuss about the strong dependence of the sound speed on the porosity in porous soft silicone rubbers. It will be shown that the low value of the shear modulus of the elastomeric matrix plays a crucial role as supported by multiple scattering calculations performed in the long-wavelength limit [4].

[1] T. Brunet et al., "Soft 3D acoustic metamaterial with negative index". Nat. Mater. (2015).

[2] J.-F. Allard, "Propagation of sound in porous media", Springer, Netherland (1993).

[3] J. Gross et al., "Sound propagation in SiO2 Aerogels", J. Acoust. Soc. Am. 91, 2004 (1992).

[4] K. Zimny et al., "Soft porous silicone rubbers as key elements for the realization of acoustic metamaterials", submitted to Langmuir.

Thu 10:30 Esplanade Micro/nano technology-based transducers, acoustic microsystems, and applications

Development of microsystems based on PZT thick film technology for high frequency ultrasonic transducers – (Invited, 000618)

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In recent years there has been a drive towards developing smaller, lower cost electronics. This drive is obviously present in the piezo industry and it calls for novel manufacturing techniques such as thin and thick film technology. This talk willtouch on the development of thick film technology over the last 10-20 years and showcase applications from academia and industry with focus on the business. Over the years, several applications has been proposed and realised such as miniaturised accelerometers, flow cells, ultrasonic transducers, energy harvesting devices etc. and some have been successfully commercialised. The most successful business case within Meggitt is the high frequency ultrasonic transducer for medical imaging, currently used in a cosmetic application. The thick film technology offers ultrasonic devices with competitive and in some cases superior properties compared to devices made in the conventional way and the manufacturing lends itself to high volume and low cost. The development and the functionality of the imaging transducer, associated with the unique manufacturing technology will be presented along with technical characteristics and imaging properties.

Thu 11:00 Esplanade Micro/nano technology-based transducers, acoustic microsystems, and applications

Gas flow sputtered thick layers of columnar lead zirconate titanate on silicon wafers for high frequency ultrasound transducers – (Contributed, 000341)

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The piezoelectric ceramic material PZT, lead zirconate titanate, is the most spread material to generate ultrasound in medical and technical applications. The frequency range between 50 MHz and 100 MHz requires ceramic material with thicknesses between 40 μm and 20 μm. A gas flow sputtering process will be presented, which uses the hollow cathode effect to deposit PZT layers in this thickness range. The process has a high sputtering rate of about 100 nm/min and a substrate temperature lower than 600°C. These process temperatures permit the uncomplicated use of prepared silicon substrates without the diffusion of lead. The PZT layers show a typical columnar structure with a piezoelectric coefficient d33,f of about 250 pm/V. The gas flow sputtering is compatible to other technologies common in the MEMS world. Examples for the production ultrasound transducers and arrays with the sputtering process and micro lithographic structuring are given.

Thu 11:15 Esplanade Micro/nano technology-based transducers, acoustic microsystems, and applications

MEMS digital loudspeaker based on thin-film PZT actuators – (Contributed, 000529)

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This paper reports on the development of a MEMS Digital Loudspeaker (DL) based on PZT thin-film actuated membranes called speaklets. The matrix operates in a binary manner by emitting short pulses of sound pressure. Using the addition of pressures principle in the air, it is possible to reconstruct audible sounds. Typical speaklets resonant frequencies can range from few KHz up to 100 KHz. DL structure is therefore similar to a Piezoelectric Micromachined Ultrasonic Transducer. Through Finite-Element-Method and analytical analysis, high performances speaklets have been designed to increase as possible the acoustic pressure. A generic PZT technology developed at LETI on 200mm standard silicon wafers has been used to build demonstrators. First, silicon- oxide (1.9μm) and poly-silicon (4μm) layers were deposited followed by the deposition and patterning of the actuator composed of a 2μm thick PZT layer in-between Pt bottom and Ru top electrodes. Membranes are then released by backside etching of the substrate. Using a dedicated electronic board, electromechanical and acoustics characterizations were performed to evaluate DL performances. Acoustic characterizations consist in analyzing a 5.5 kHz sinus played by the DL. It exhibits a satisfactory limited number of harmonic parasitic peaks. The acoustic pressure generated by the 256 MEMS-DL was also investigated using an actuation voltage of only 8V and compared with the acoustic pressure of a 64-membranes MEMS-DLA previously reported. It shows an acoustic pressure improvement of about 20dB, coming from membrane number increase and actuator optimization. Sound quality measured via Total-Harmonic- Distortion evaluation was improved by a factor 3.

Thu 11:30 Esplanade Micro/nano technology-based transducers, acoustic microsystems, and applications

The effect of acoustic-structure interaction in confined spaces on the performance of PMUTs – (Contributed, 000315)

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Piezoelectric Micromachined Ultrasonic Transducers (PMUTs) are being explored for a wide range of applications including doppler velocimetry, intravascular ultrasound imaging, and photoacoustic imaging, where they are deployed in a confined space with non-radiating boundary conditions.
Since PMUTs are thin plate type structures operating in the flexural mode of vibration, their vibrational behaviour

is acoustics dominated. We have observed, for the first time, that the vibrational response of a PMUT can change significantly when it is operated in a confined space due to changes in the acoustic impedance of the radiator caused by scattering and reflections from the fluid and the boundaries.
We have fabricated PMUTs with radii of 500μm with first resonance at 75kHz when operated in air. While the in-air operation of our PMUT is dominated by acoustic damping, the in-water operation is dominated by both acoustic damping and acoustic mass. For in-air operation with confinement conditions varying from a reflecting cover placed 5mm away from the surface, to an absorbing boundary at approximately 50cm, the deflection sensitivity of these sensors varies from 600nm/V to 1.4μm/V at the center. The same sensors when operated underwater show the first resonance at 17.5kHz with deflection sensitivity varying from 40nm/V to 200nm/V for different water heights. We have compared these observations against FEM simulations and approximate analytical solutions.
This study is an attempt to quantify the changes in vibrational behaviour of PMUTs due to changes in the acoustic impedance caused by non-radiating boundary conditions. Since PMUTs are likely to find many applications in confined spaces due to their size, our findings will be relevant to their design customization. Further, our current study points to a possibility of exploiting an array of PMUTs to detect and map small changes in confined environments through changes in the vibrational response of the PMUTs.

Thu 11:45 Esplanade Micro/nano technology-based transducers, acoustic microsystems, and applications

Analytical Model for Electrical Impedance of CMUT including Dynamic Changing Capacity – (Contributed, 000203)

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A novel analytical model to describe the electrical impedance of a CMUT is presented here. The developed model offers a physical implementation of the working principle of a CMUT, which also includes the dynamically changing capacity.

$\underline{I}(t) = \underline{U}(t) \cdot \frac{\mathrm{d}\underline{C}(t)}{\mathrm{d}(t)} + \underline{C}(t) \cdot \frac{\mathrm{d}\underline{U}(t)}{\mathrm{d}t}$

It allows to simulate CMUT devices and provides direct access to electrical and mechanical characteristics, enabling better designs for driving and readout circuits for CMUT technology.

The model covers the description of a static and a dynamic capacity linked to the displacement of a mass spring damper system. Recent lumped electrical circuit models (e.g. Mason's model) or equivalent circuits such as the Butterworth Van Dyke (BVD) model do not cover this dynamic capacity change. For simulating the resonant behaviour of CMUTs, the model requires a set of parameters comparable to the ones of the Mason's model (material and dimension information). On the other hand, it is also possible to extract physically meaningful parameter information (e.g. displacement current, plate stiffness, damping) out of impedance measurement results. This can be done using a best fit algorithm, which solves four degrees of freedom. The expense for the parameter estimation is as little as fitting the BVD equivalent circuit, but provides more information.
The model has been verified on several CMUT designs fabricated at Fraunhofer IPMS and the model results match the measurements. The agreement for impedance curves between experiment and model increased compared to the BDV circuit.

Thu 13:30 Esplanade Micro/nano technology-based transducers, acoustic microsystems, and applications

Reverberation Reduction in Capacitive Micromachined Ultrasonic Transducers by Front-Face Reflectivity Minimization – (Contributed, 000271)

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Front-face acoustic reflectivity of ultrasonic imaging transducers, due to acoustic impedance mismatch with the propagation medium, may cause reverberation phenomena during wideband pulse-echo operation. Front-face reflectivity may be reduced by promoting the transmission of the echoes, received from the medium, to the transducer backing, and by maximizing the mechanical-to-electrical energy conversion and dissipation by tuning the electrical load impedance connected to the transducer. In piezoelectric transducers, the energy transfer from the medium to the backing is favored by the presence of typically employed matching layers. On the other hand, in Capacitive Micromachined Ultrasonic Transducers (CMUTs), the same energy transfer is very low due to the large impedance mismatch between the medium and the transducer substrate, typically made of silicon. Reverse Fabrication Process (RFP) makes it possible to provide CMUTs with custom substrate materials thus eliminating the original silicon microfabrication support. In this paper, we analyze two methods for the front-face reflectivity reduction in RFP-CMUTs: the first one is based on the use of low-impedance, highly attenuating substrate materials, and the second one is based on the use of a conveniently chosen resistive electrical load. We perform finite element simulations in order to study the effect of different substrate materials and electrical loads on the CMUT front-face reflection coefficient. We then minimize the CMUT front-face reflection coefficient by combining the two proposed methods. We experimentally validate the results by fabricating and characterizing single-element RFP-CMUTs provided with different substrates and electrical loads. We obtain a reduction of the reflection coefficient of about 10 dB, thus achieving performance comparable with piezoelectric transducers of similar characteristics. Finally, we discuss the application of the proposed methods on the reduction of reverberation artifacts in ultrasound imaging.

Thu 13:45 Esplanade Micro/nano technology-based transducers, acoustic microsystems, and applications

Design Optimization for 1-D High Frequency CMUT Arrays – (Contributed, 000415)

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High frequency (30-60MHz) ultrasound arrays are gaining importance for applications such as small animal imaging, photoacoustic imaging and intravascular imaging. While it is difficult to fabricate piezoelectric transducers with thin layers and small pitch (~20-40μm) required for phased array operation, CMUTs can be batch fabricated with these dimensions and can be integrated with electronics for optimized overall performance. In this study, we use a system level CMUT array model to optimize high frequency 1-D CMUT arrays considering transmit pulse design and thermal mechanical noise within given voltage requirements.
The model proposed by Satir et.al. was utilized for design optimization of a 40 MHz 1-D CMUT array. The model can incorporate the non-linear behavior of the CMUTs and current output due to received echoes for different impedance terminations can be calculated. The thermo-mechanical noise is estimated from the electrical impedance of the CMUT. The CMUT array for guidewire IVUS application was composed of 12 elements each comprising 10 20μm square Si_3N_4 membranes with 75% electrode coverage and 25μm pitch. The vacuum gap of each membrane was 40nm with 100nm HfO_2 isolation layer.

An ideal short circuit termination case was used to determine the signal current and thermo-mechanical noise at 90% of collapse voltage of 47V. The SNR for a perfect planar reflector 1 cm away from the CMUT array immersed in water was calculated for a unipolar pulse amplitude of 43V. For a single element, a maximum SNR of 31dB was obtained with 47% fractional bandwidth around 35MHz with 12ns wide pulse.

Thu 14:00 Esplanade Micro/nano technology-based transducers, acoustic microsystems, and applications

Electro-Mechanical Characterization of Ultrathin DLC Suspended Membranes for CMUT Applications – (Contributed, 000441)

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Because of their advantages (high resolution and sensitivity, excellent stability, etc.), capacitive micromachined ultrasonic transducers (CMUTs) are used for various applications such as non-destructive testing or medical diagnostic imaging. A further reduction of their size could improve their lateral resolution.

We report the fabrication and characterization of ultrathin diamond like carbon (DLC) suspended membranes that can act as the mobile electrode of CMUTs. First, a DLC layer is deposited by Electron Cyclotron Resonance (ECR). To improve the electrical conductivity of the membrane, a metal layer is subsequently added using the same process. Depending on the process conditions, 5 to 20 nm thick metal/DLC stacks can be obtained. The metal/DLC stack is then transferred on test devices to form suspended membranes over 1 to 2 μm wide trenches.

The device characterization includes MEB imaging and AFM force measurements. In particular, the mechanical properties of the suspended sheets are extracted using a mapping of the spring constant, which allows the determination of the bending rigidity (1 x 10-14 to 10 x10-14 N.m). This parameter is required for device modelling as it integrates the properties of the final membrane (material, thickness, surface alteration, etc.). Using these values, we have modelled the membrane mechanical behavior and estimated the mechanical resonance frequency (10Mhz to 300Mhz, depending on trench width). Further characterizations will be done and: the static membrane deflection, the resonant frequency and the quality factor will be measured using our AFM probe on electrically connected devices.

Thu 14:15 Esplanade Micro/nano technology-based transducers, acoustic microsystems, and applications

Modeling and Characterization of CMUT-based Device Applied to Galvanic Isolation – (Contributed, 000530)

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Galvanic isolation is a key function of power electronic. Recently, we have fabricated the first prototype of an ultrasound based isolator using cMUT technology [1]. The operating principle consists of transmitting a triggering signal using the thickness mode resonance of a substrate covered on each side of cMUTs array. The present study focuses on modeling and characterizations of these devices in order to identify transmitted energy optimization strategies between the two cMUTs arrays through the substrate.
A Finite Element Model was developed to predict the electromechanical responses of these devices. Thanks to symmetry conditions, modeling one cMUT placed on both sides of a silicon block is sufficient to solve the problem. In addition, double-sided device prototypes having a surface of 100mm^2 were fabricated using square cMUTs of 22x22μm^2. The substrate thickness was chosen to ensure that its thickness mode resonance was as close as possible to that of the membrane. Laser interferometry and electrical measurements were undertaken to characterize the fabricated devices.

Experimental and computational investigations have so far yielded promising results. In particular, relevance of the model was demonstrated by comparing measurements with simulations. A method to accurately measure the electromechanical coupling coefficient of the substrate's resonance peak from electrical impedances curves was implemented. High values were measured with a maximum of 40%. Theoretical investigations indicated that this maximum is obtained when the resonance frequency of the membrane falls to a value just below that of the substrate.

[1] S.Ngo *et al.*, "Galvanically-Isolated Data Transmission Device", US Patent 20130135970A1

Thu 15:45 Esplanade Micro/nano technology-based transducers, acoustic microsystems, and applications

Recent Progress on Flexoelectric Devices – (Invited, 000425)

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Motivation: Flexoelectricity refers to a fundamental electromechanical coupling effect between electric polarization and mechanical strain gradient, or vice versa between electric polarization gradient and mechanical gradient. Scaling effect associated with gradient suggests that flexoelectric effect could be significant in micro/nano electromechanical devices, comparable to or even exceed piezoelectricity. In addition, unlike piezoelectricity, f;exoelectricity does not involve poling and de-poling processes, which may lead to a broad operation temperature range for devices. Therefore, flexoelectric devices are important for many applications including acoustic sensing.
Methods: In this review, flexoelectricity in those studied materials and flexoelectric structural characterizations will be summarized and compared. Flexoelectric sensing devices including strain gradient sensors, microphone, and vibration sensors are next introduced with sensor designs, prototyping and characterizations. Converse flexoelectric effect recently demonstrated in our group will be presented for future flexcoelectric actuation devices.

Results: Flexoelectric characterizations of bulk barium strontium titanate (Ba0.65Sr0.35TiO3 or BST) ceramic and BST thin films were successfully characterized, showing promising flexoelectric properties. Flexoelectric accelerometers, strain/stress gradient sensors using bulk BST ceramics showed comparable performances with their piezo counterparts. It is believed that miniaturized flexoelectric devices will play a significant role a broad range of applications.

Thu 16:15 Esplanade Micro/nano technology-based transducers, acoustic microsystems, and applications

Fabrication of ZnO Nanowire Based Piezoelectric Generators and Related Structures – (Contributed, 000205)

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Single crystalline ZnO nanowires (NWs) grown via hydrothermal techniques offer several advantages, including low-cost synthesis, scalability over large area substrates such as plastics. Wurzite ZnO NWs exhibits a number of appealing properties, potentially making it an ideal material in many technologies (transistors, optoelectronics, sensors and energy harvesting etc.). ZnO's high piezoelectric coefficient, has led to the demonstration of a new type of energy scavenging system called the "piezoelectric nanogenerator" (NG), which has seen unprecedented advancement in recent times. NGs are categorised by two configurations, "vertically integrated" and "laterally integrated" (VING and LING, respectively). In VING, array of vertical ZnO NWs on conductive substrates are effectively encapsulated by a polymer matrix. Metallic layers are then deposited on the matrix surface and copper wires are attached to conductive surfaces thereafter. In LING, metallic layers are defined on to the ends of horizontal ZnO NW-arrays on flexible insulating. Application of force along the NW's polar axis results in an apparent voltage generation through capacitive coupling (VING) and/or coupling between piezoelectric and semiconducting properties (LING). To fully realise practical ZnO NW energy harvesting systems, we address some key issues related to the piezoelectric voltage generation in VING structures. This presentation will be focussing on: (1) low temperature synthesis and structural characterisation of ZnO NWs; (2) suppression of excess free carriers in hydrothermal ZnO NWs; (3) formation of reliable contacts and (4) anomalous response of NGs, seldom reported in literature. Effective strategies offering precise NW alignment for the LING structure is briefly discussed.

Thu 16:30 Esplanade Micro/nano technology-based transducers, acoustic microsystems, and applications

Development of GaN Based Surface Acoustic Wave Sensor for Gas Sensing – (Contributed, 000608)

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GaN based materials have been widely used in electro-optics, while its physical properties such as high thermal and chemical stability, high electromechanical coupling coefficient and surface acoustic wave (SAW) velocity promise its potential application in the development of SAW sensor for gas sensing. This work presents the development of SAW gas sensors based on GaN/sapphire and AlGaN/sapphire structures. The GaN based structures are fabricated using MOCVD. Inter-digital transducers for the SAW delay lines are designed to work at both a low frequency of 130 MHz and a high frequency of 1.5 GHz. The low frequency devices are fabricated using conventional photo lithography, while the high frequency devices are fabricated using customer designed e-beam lithography. The electrical response to pulse excitation will be shown for both low frequency and high frequency SAW structures. And the preliminary results of the sensing performance of the designed SAW device to ammonia and nitrogen monoxide will also be shown and discussed.

Thu 16:45 Esplanade Micro/nano technology-based transducers, acoustic microsystems, and applications

LiTaO3/Silicon composite wafers for the fabrication of low loss low TCF high coupling resonators for filter applications – (Contributed, 000586)

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SAW devices are widely used for radio-frequency (RF) telecommunication filtering and the number of SAW filters, resonators or duplexers is still increasing in RF stage of cellular phones. Therefore, a strong effort is still dedicated to reduce as much as possible their sensitivity to environmental parameter and more specifically to temperature. Several contributions have been developed for proposing composite wafers combining several materials to compensate the natural thermal drift of pseudo surface acoustic waves (PSAW) on lithium tantalate. For all the proposed technologies, solidly bounding heterogeneous materials is a quite complicated issue as thermal budget

must be limited to avoid irreversible damage of the wafers. Bounding processes have been developed at FEMTO-ST and CEA-LETI using either Au/Au or direct bonding techniques for the fabrication of composite wafers combining materials with very different thermoelastic properties, yielding innovative solutions for about-zero temperature coefficient of frequency (TCF) bulk acoustic wave devices. In the present work, this approach has been applied to (YXl)/42° lithium tantalate plates, bounded onto (100) silicon wafers and thinned down to 25 μm. The leading idea already explored by other groups as mentioned in introduction consists in impeding the thermal expansion of the piezoelectric material using silicon limited expansion. 2 GHz resonators have been built on such plates and tested electrically and thermally, first by tip probing. Although wave parameters was found only half the expected ones (coupling factor of about 4%) partly due to unoptimized electrode height, a dramatic reduction of the TCF is observed for all the tested devices, allowing to reduce the thermal drift of the resonators down to a few ppm.K-1 within the standard temperature range. We then propose an analysis of the frequency-temperature behavior of the device to improve the resonator design to use these wafers for industrial applications.

Thu 17:00 Esplanade Micro/nano technology-based transducers, acoustic microsystems, and applications

Surface acoustic wave measurements in ultra wideband acoustic devices using a heterodyne interferometer – (Contributed, 000286)

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Ultra wideband (UWB) acoustic transducers provide improved measurement resolution as passive sensors, and find applications in various fields like electronics and telecommunications, non-destructive evaluation, signal processing, and biomedical research. The signal strength of such devices can be controlled by changing the number of fingers (electrodes) of the inter- digital transducers (IDTs), the spacing between them, and the area of the sensor depending on the application requirements. Optical interferometry is a well-known and an effective tool for measurements using interference phenomena. The objective of this work is to obtain optical measurements of propagating short SAW pulses generated by UWB transducers.
For a given UWB acoustic device with input (chirp) and output (receiving) IDTs, electrical measurements are first performed. The amplitude and the phase information of the surface acoustic waves is measured at the position of the output IDT and serves as a reference. Optical measurements are then made by replacing the output (receiving) IDT with a heterodyne interferometer and recording the beating signal in time.
It is first shown that using a heterodyne interferometer for the measurements allow us to relieve the constraints on stabilization of the optical interferometer, making measurements more robust. Second, use of a heterodyne interferometer allows us to not only measure the response at the position of the output IDT, but also at different positions in between the input and output IDTs. This allows us to investigate the changes in the propagation of surface acoustic waves within the device and especially their dispersion.

Thu 10:30 Saint Pierre Soft Tissue Quantitative Ultrasound

A Temporal View of Soft Tissue Quantitative Ultrasound – (Invited, 000172)

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The objective of soft tissue quantitative ultrasound (QUS) is to improve diagnostic ultrasound imaging via quantitative outcomes. Over the past three or so decades, there have been an increasing number of QUS successes. A temporal view moves us back in history almost six decades when techniques and theoretical developments were in their earliest stages that impacted modern QUS successes. The earliest techniques and theoretical developments some six decades ago can be attributed to John Wild, Jack Reid, Bill Fry, Frank Fry and Lev Chernov. Later, Floyd Dunn developed important views as to how connective tissue affected the interaction between ultrasound and soft tissue. Then, as the theory of wave propagation in soft tissues with random inhomogeneities was extended and applied by Fred Lizzi, Jim Zagzebski and Mike Insana (and their colleagues), contemporary QUS successes started to emerge. This contribution will develop the temporal aspects of QUS, and provide the most recent preclinical results.

Thu 11:00 Saint Pierre Soft Tissue Quantitative Ultrasound

Tissue characterization of NASH relative to speed of sound and acoustic impedance - Measurement of fatty acids and rats/mice livers - – (Contributed, 000284)

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Quantitative ultrasound diagnostic techniques of fatty liver, hepatitis and liver fibrosis include Non-alcoholic steatohepatitis (NASH) which can be alternative to biopsy is not completely established yet. The main problem is that the mixing structure in diseased liver makes ultrasound interaction and propagation complex. To quantitatively assess these ultrasound phenomena, well-understanding the change of acoustic characteristics with the change in histological characteristics of tissue is really required in both clinical and engineering aspect. Therefore, it would be invaluable to know and understand acoustic properties at the micrometer scale. In this study, we measured acoustic impedance of representative five fatty acids (oleic acid, palmitic acid, palmitoleic acid, linoleic acid, and Alpha-linolenic acid) that have different molecular weight or density and vary according to the type of NASH. Fatty acids were measured by using scanning acoustic microscopy with 80-MHz center frequency ultrasound. Acoustic impedance of oleic acid that have strongest association with NASH was significantly lower as compared to other fatty acids. Additionally, speed-of-sound (SOS) and acoustic impedance from several types of rats/mice livers (normal, fatty, and fibrosis include NASH) were measured with 80- and 250-MHz ultrasound to confirm the relationship between the pathologic state of liver and acoustic properties. Results indicated that SOS values of normal liver was much smaller than other livers at any frequencies. In the fatty liver, SOS was 20 m/s slower than in the normal liver. In fibrosis, SOS had values between those of normal and fatty liver.

Thu 11:15 Saint Pierre Soft Tissue Quantitative Ultrasound

Attenuation Coefficient Estimation of the Healthy Human Thyroid In Vivo – (Contributed, 000188)

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Previous studies have demonstrated that attenuation coefficients can be useful towards characterizing thyroid tissues. In this work, ultrasonic attenuation coefficients were estimated from healthy human thyroids in vivo using a clinical scanner. The selected subjects were five young, healthy volunteers (age: 26 +/- 6 years old, gender: three females, two males) with no reported history of thyroid diseases, no palpable thyroid nodules, no smoking habits, and body mass index less than 30 Kg/m2. Echographic examinations were conducted by a trained sonographer using a SonixTouch system (Ultrasonix Medical Corporation, Richmond, BC) equipped with an L14-5 linear transducer array (nominal center frequency of 9 MHz, transducer footprint of 3.8 cm). Radiofrequency data corresponding to the collected echographic images in both transverse and longitudinal views were digitized at a sampling rate of 40 MHz and processed with Matlab codes (MathWorks, Natick, MA) to estimate attenuation coefficients using the spectral log difference method. The estimation was performed using an analysis bandwidth spanning from 1.5 to 9.0 MHz. The size of the regions of analysis was 20 by 20 wavelengths at 5.25 MHz with a 75% overlap. The average value of the estimated ultrasonic attenuation coefficients was equal to 1.26 ± 0.33 dB/(cm.MHz). The relatively high standard deviation of the average attenuation coefficient across different volunteers suggests a non-negligible inter-subject variability in the ultrasonic attenuation coefficient of the human thyroid.

Thu 11:30 Saint Pierre Soft Tissue Quantitative Ultrasound

Effective medium model for ultrasound backscattering from aggregating red blood cells – (Contributed, 000272)

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The Effective Medium Theory (EMT) combined with the Structure Factor Model (EMTSFM) was recently developed to model the ultrasound backscattering from aggregating Red Blood Cells (RBCs). The EMT assumes that aggregates can be treated as homogeneous effective spheres and is combined with the structure factor to consider the interaction between the effective spheres. The goal of this work was to further develop the EMTSFM and to extend its validity into a larger frequency range. The EMT was modified to decompose the backscattering cross section of one aggregate into the coherent and incoherent components. In the previous work, only the coherent component was taken into account. The coherent component corresponds to the average wave emerging from the effective scatterer, and the incoherent component corresponds to the fluctuation of the scattering wave around its average within the effective scatterer. Virtual RBC aggregates were built in order to perform computer simulations and to produce simulated backscatter coefficients (BSCs). The BSCs computed with the new EMTSFM and with the computer simulations were compared for different aggregating conditions. The new EMTSFM formulation is in good agreement with the computer simulations for a product of the wavenumber times the aggregate radius kRag<2.4, whereas the former EMTSFM was only valid for kRag<1.6. The mean relative error between the theoretical and simulated BSCs in the 1-50 MHz frequency bandwidth was around 19%, versus 38% with the former EMTSFM. This suggests that the new EMTSFM is an adequate model for blood characterization in high frequencies.

Thu 11:45 Saint Pierre Soft Tissue Quantitative Ultrasound

Characterization of the tissue microstructure in excised canine livers using the structure factor model – (Contributed, 000164)

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Quantitative UltraSound (QUS) techniques utilize the amplitude and frequency dependence of the backscatter coefficient (BSC) to determine the physical properties of the average tissue microstructures. QUS techniques typically rely on theoretical scattering models to fit the BSC from biological tissues to an estimated BSC using an appropriate theoretical model. The Structure Factor Model (SFM) was recently shown to better explain the BSCs from tissue-mimicking biophantoms (Franceschini et al JASA 2014). The aim of this study is to use the SFM to estimate the tissue microstructure in excised canine livers.
Ultrasonic backscatter measurements were performed in excised canine livers at frequencies ranging from 12 MHz to 38 MHz using an ultrasound scanner (Vevo 770, Visualsonics, Toronto, Canada) equipped with the RMV 707 probe. The mean scatterer radius r*, scatterer concentration ϕ* and impedance contrast γz* were estimated using the SFM. The estimated parameters were classified according to the concentration estimates as a diluted medium ($\phi^*<0.08$) or a concentrated medium ($\phi^*\geq0.08$).

The structural parameters classified as diluted medium ($\phi^*<0.08$) were equal to $r^*=5.43\pm0.95$ μm, $\phi^*=0.022\pm0.013$ and $\gamma z^*=0.12\pm0.04$ for most estimates (77%). The estimated scatterer radius closely corresponded to the actual radius of the hepatocyte nuclei. By assuming that the hepatocyte cells occupy a volume fraction around 0.74 and that 15% of the cells are binucleated, the nuclear concentration is expected to equal approximately 0.039. A good match was thus obtained between the estimated and expected nuclear concentrations using the SFM.

Thu 13:30 Saint Pierre Soft Tissue Quantitative Ultrasound

Quantitative Characterization of Concentrated Cell Pellet Biophantoms using Statistical Models for the Ultrasound Echo Envelope – (Contributed, 000107)

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Statistical distributions have been used extensively for ultrasound tissue characterization in the past decades, but limited studies have investigated concentrated media. The aim of this work was to perform statistical analysis on the envelopes of ultrasonic backscattered signals from concentrated cell pellet biophantoms. Two statistical distributions (Nakagami and Homodyned-K) were used to evaluate scatterer concentration. The Nakagami distribution is mathematically simple and parameter estimation is robust and straightforward. The Homodyned-K distribution is more complex but allows better fitting as well as the separate estimation of the coherent and diffuse backscattered components (parameters ε and σ) [Destrempes et al, SIAM 2013]. The Nakagami parameter m and Homodyned-K parameter α are related to the number of scatterers/resolution cell. Data acquisition on the biophantoms, consisting of human leukemia K562 cells, was performed using two single-element transducers centered at 25, respectively 35 MHz. Seven cell concentrations ranging from 0.006 to 0.30 (corresponding to 3 to 250 scatterers /resolution cell) were considered. The Nakagami m parameter increased (from 0.71 to 1) with increasing density from 3 to 15 scatterers/resolution cell, and plateaued around 1 for densities greater than 15 scatterers/resolution cell. The Homodyned-K α parameter increased (from 2.4 to 79) with increasing density from 3 to 250 scatterers/resolution cell. The parameters ε and σ respectively increased and decreased with increasing scatterer density. In conclusion, the Homodyned-K distribution allowed better quantitative characterization of biophantoms at high concentrations than the Nakagami distribution. The Homodyned-K could thus prove invaluable for clinical applications involving concentrated media (blood, tumors).

Thu 13:45 Saint Pierre Soft Tissue Quantitative Ultrasound

In vivo characterization of tumor heterogeneity under antiangiogenic and cytotoxic therapy using ultrasonography modalities: Shear Wave Elastography (SWE), Contrast Enhanced Ultrasound (CEUS) and Quantitative Ultrasound (QUS) – (Contributed, 000444)

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Robust, novel image-based information on the tumor microenvironment would improve therapeutic follow-up in oncology. Shear wave elastography (SWE) evaluates tissue stiffness, contrast enhanced ultrasound (CEUS) assesses microvascular flow using intravascular microbubbles and quantitative ultrasound (QUS) reflects tissue microstructure. Our goal was to evaluate sensitivity and complementarity of these techniques during cytotoxic and antiangiogenic therapies in ectopic, murine tumors.

An antiangiogenic drug inhibiting vascularization (sunitinib, N=24, 40mg/kg/day), an alkylating cytotoxic agent (cyclophosphamide, N=26, 150mg/kg for 3 days) and placebo (N=26) were administered in murine Lewis Lung Carcinoma-bearing C57BL6 mice. Six days after implantation, tumors were imaged (SWE, CEUS and QUS) prior to therapy (Day0) and on Days 1, 3, 7, 9 and 13. Tumors were harvested at Day13 (N=12 per group) and stained to evaluate percentage necrosis and fibrosis. Wilcoxon unpaired test was performed to evaluate significant differences.

At Day13, tumors treated with sunitinib presented a heterogeneous structure with more fibrosis (14.5±9.9%) and necrosis (20.5±11.3%) than for cytotoxic (fibrosis: 5.6±5.0 %, p=0.04; necrosis: 7.8±5.3 %, p=0.01) and placebo groups (fibrosis: 6.4±6.9%, p=0.01; necrosis: 7.6±5.5%, p=0.0004). This heterogeneous structure for the antiangiogenic group may be related to heterogeneity observed in vivo, simultaneously in SWE and CEUS with, respectively, the highest standard deviation of stiffness (10.8kPa) and the highest percentage of unperfused area (29.0±16.3%) compared to cytotoxic (4.8kPa, p<0.0001; 7.3±15.3%, p=0.002) and placebo groups (6.8kPa, p=0.0007; 7.5±13.5%, p=0.005). The sensitivity of CEUS to microvascular modifications and SWE to biomarkers such as necrosis and fibrosis, in this model, underline potential for monitoring complementarity aspects of the tumor microenvironment during therapy.

Thu 14:00 Saint Pierre Soft Tissue Quantitative Ultrasound

Relevance of adipose tissue stiffness evaluated by transient elastography (AdipoScan^{TM}) in morbidly obese patients before bariatric surgery – (Contributed, 000620)

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Motivation: Subcutaneous adipose tissue (scAT) in human obesity undergoes severe alteration such as fibrosis which is related to metabolic alterations and to less efficiency in losing weight after bariatric surgery. There is currently no non-invasive tool to assess fibrosis in scAT. Vibration Controlled Transient Elastography (VCTE) using FibroScan® is widely used to assess liver fibrosis in clinical practice. A novel device named AdipoScan™ which is based on VCTE has been developed by Echosens (Paris) so as to assess scAT. The objective of this work to show clinical AdipoScan™ results. Methods: 74 morbidly obese patients candidate for bariatric surgery were enrolled in the Pitié Salpêtrière hospital. AdipoScan™ and Fibroscan® were assessed on patients before surgery. Liver and scAT biopsies were collected from 54 and 32 patients during surgery, respectively and fibrosis was quantified histologically. Fat and fat-free mass were assessed by DXA before surgery and for 25 patients, 6 months after surgery. Results: scAT stiffness was successfully assessed on all patients. scAT stiffness is positively correlated to scAT fibrosis (ρ=0.52, p=0.002), liver fibrosis (=0.29, p=0.006), liver stiffness (ρ=0.28, p=0.03), fat-free mass before surgery (ρ=0.30, p=0.01) as well as metabolic variables such as fasting glycemia (ρ=0.24, p=0.04), insulin (ρ=0.24, p=0.04), HDL cholesterol (ρ=-0.36, p=0.002), apolipoprotein A1 (ρ=-0.29, p=0.02). Furthermore, scAT stiffness assessed before surgery is positively correlated to fat mass loss 6 months after surgery (ρ=0.49, p=0.01). Results show that AdipoScan™ is linked to cardiometabolic risk factors associated with obesity and could be a promising tool to better phenotype morbidly obese patients.

Thu 14:15 Saint Pierre Soft Tissue Quantitative Ultrasound

Investigation of Stem Cell Differentiation into Osteoblasts, Chondroblasts and Adipocytes using high frequency Acoustic Microscopy – (Contributed, 000517)

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Objective: The application of human mesenchymal stem cells (hMSCs) in regenerative medicine will depend on methods for non-invasive monitoring of cellular processes and quality control of tissue differentiation. Conventional optical methods require invasive staining, and only surface related structures can be observed. Acoustic microscopy overcomes these limitations, and provides additional information of the acoustic-mechanical properties [1,2]. The goal of this study was to investigate acoustic microscopy to characterize stem cell differentiation and tissue maturation.
Methods: To achieve this goal the differentiation of hMSCs into osteoblast, chondroblasts and adipocytes in 2D and 3D tissue-like cultures was characterized with acoustic microscopy at 1 GHz. Life cell images were taken at 37°C with a SASAM (scanning acoustic microscope) integrated on a conventional microscope platform. From the recorded ultrasound images (B-scan) the acoustic reflectance and attenuation (A-scan) were analyzed and investigated as a differentiation marker.
Results: The acoustic scans of the stem cell showed morphological changes on the cellular level associated with changes of the actin cytoskeleton. Further, we detected lineage specific expression of a fibrillar extra cellular matrix (ECM), and at 1GHz, we archived a resolution to detect the mineralization of the ECM fibers during bone development. Aside imaging of cells and subcellular structures we found distinctive changes of the acoustic-mechanical properties. The osteogenic cultures showed higher reflectivity values than chondroblasts demonstrating the stiffness of these structures, while adipocytes having low sound attenuation.
These findings indicate the high potential of high frequency ultrasound for the investigation of stem cells and tissue cultures providing additional mechanical information associated with lineage maturation.
[1] Weiss EC et al. : Mechanical properties of single cells by high-frequency time-resolved acoustic microscopy. IEEE Trans Ultrason Ferroelectr Freq Control. 2007 Nov;54(11):2257-71.
[2] Brand S, Weiss EC, Lemor RM, Kolios MC.: High frequency ultrasound tissue characterization and acoustic microscopy of intracellular changes. Ultrasound Med Biol. 2008 Sep;34(9):1396-407.

Thu 14:30 Saint Pierre Soft Tissue Quantitative Ultrasound

500MHz Micro-machined Single-element Transducer for Acoustic Microscopy of Biological Tissue – (Contributed, 000343)

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Quantitative acoustic microscopy at 500MHz permits measuring the acoustic properties, such as speed of sound (SOS) and acoustic impedance (Z), of soft biological tissue with a resolution of 4μm. Such properties provide valuable information for investigating several diseases and help to improve and develop new ultrasound-based diagnostic tools. However, only limited data exist for most relevant tissues, such as human cornea or lymph nodes. Because of the attenuation inside the coupling medium, the focal distance of a 500MHz transducer allows a maximal focusing lens radius of 175μm. The fabrication of lenses by mechanical grinding has low reproducibility and high cost. Compared to grinding, wafer-based processing allows high reproducibility. Therefore, we evaluated an etching technique for fabricating 500MHz transducers with a lens radius less than 175μm on a silicon wafer. This technique permits low-cost batch processing. The transducer was fabricated on silicon wafer using photolithography technology. The piezoelectric layer was produced by reactive sputtering of zinc oxide (ZnO). The lens was produced by isotropic etching using a mixture of hydrofluoric and nitric acid (HNA). The transducer was characterized on an acoustic microscope at IBMT. Focusing lenses with radii between 75 and 135μm and 500MHz piezoelectric layers were successfully fabricated. The 500MHz transducer had a 6dB-bandwidth of 238MHz and an insertion loss of 70dB. The 6dB-focal length was 29μm. The lateral resolution permitted resolving 2.2μm-thick line structures. Fixed 12-μm thin sections of biological samples, including rabbit cornea, mouse ocular tissues, rat liver and a human lymph node, were imaged at the Lizzi Center of Riverside Research using a custom-made scanning system. Imaging of these fixed tissue samples successfully produced maps of SOS, Z and maximum signal amplitude, which were compared to corresponding acoustic-property maps obtained using a 250MHz transducer.

Thu 10:30 Gouv — Waves in granular media and structures

Strongly nonlinear discrete metamaterials: origin of new wave dynamics – (Invited, 000606)

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Presentation will describe dynamic behavior of discrete strongly nonlinear metamaterials which can be characterized as "sonic vacuum". The term was coined to emphasize a specific class of systems where sound does not propagate. One dimensional granular systems with Hertzian interaction between particles were the first examples of such behavior. Granular systems may be easily tuned to support also weakly nonlinear solitary wave (FPU type solitons, KdV solitons). They may also support shock waves, periodic waves and breathers depending on initial disturbance and initial state of system controlled by static prestress. New results related to attenuation of short, strongly nonlinear stress pulses excited by the same striker on chain of spheres and cylinders will be presented for two ratios of their masses. The reverse of mitigation performance will be discussed in details. Another strongly nonlinear system composed of soft toroidal elements (Nitrile O-ring) and rigid steel cylinders will be presented. It has stronger than the Hertzian-type nonlinearity of interaction force between steel cylinders coming from strongly nonlinear behavior of O-rings. Stronger nonlinearity allows greater tunability than in the systems with the Hertzian interaction. At the same time this metamaterial is strongly dissipative, thus with a better potential for higher absorption of impact energy. Models of nonlinear non-Newtonian dissipation will be presented and compared with experiments. A new class of strongly nonlinear metamaterials based on tensegrity concepts and the corresponding solitary wave dynamics under impact loading will be also considered.

Thu 11:00 Gouv — Waves in granular media and structures

Wave propagation in weakly compressed wet granular media – (Contributed, 000047)

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Wave propagation in dry granular media, in which elastic particles interact via the Hertz potential, is relatively well known and understood; for instance, one can predict quite accurately the speed of compressional waves in a dry granular medium as a function of the static load applied on the medium and the elastic and geometric properties of the grains. In turn, the dynamics of wet granular media is still less understood. Here, we present preliminary experiments and analysis performed on wet one-dimensional granular media, in which a very small drop - only about few times the typical size of the dry contact area - of viscous fluid is set at every contact between grains. We show that the presence of an interstitial fluid completely modifies the interaction between grains and induces non-intuitive behaviors; for instance, waves are substantially faster in wet granular media than in dry granular media,

and the wave speed significantly less depends on the static load applied on the medium. Our observations tend to suggest that Hertz potential must be reassessed in favor of more complex elasto-hydrodynamic mechanisms in order to account for the interplay between elastic grains through the highly squeezed interstitial fluid.

Thu 11:15 Gouv Waves in granular media and structures

Laser-Doppler acoustic probing of granular media with varying water levels – (Contributed, 000136)

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Laboratory physical modelling and non-contacting ultrasonic techniques are frequently proposed to tackle theoretical and methodological issues related to geophysical prospecting. Small-scale physical models are for instance built to mimic various Earth structures as a complement of usual analytical or numerical modelling techniques. Most of the time, these studies involve homogeneous and consolidated materials, but the obtained models cannot depict specific properties such as porosity or permeability. The latter issues are for instance obvious when studying seismic methods targeting near-surface hydrogeological applications. In this context, we used an innovative experimental set-up to perform laser-Doppler acoustic probing of granular materials with varying water levels. Three different physical models with simple geometries were built using micrometric glass beads of various sizes. A mechanical source and a laser-Doppler vibrometer were used to record small-scale seismic lines at the surface of the three models. We also used a time domain reflectometry probe to look for vertical water saturation profiles in the granular medium. The results present a clear influence of the water level on both first arrival times and dispersion of guided waves, and significant differences in terms of amplitudes. They thus validate the use of such approach to benchmark recently developed methods for water saturation detection in hydrogeophysics.

Thu 11:30 Gouv Waves in granular media and structures

Granular Phononic Crystals as Tunable Functional Switches – (Contributed, 000445)

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In this work, we discuss a strategy for spatial and modal wave manipulation in nonlinear phononic crystals based on the use of nonlinearity as a trigger to reversibly activate different combinations of wave modes in the crystal's response. Our approach revolves around the concept of modal mixing, whereby, through the generation of higher harmonics in crystals with complex modal structures, we can induce jumps in the response across the available propagation modes; as a result, the system experiences a blend of modes and the simultaneous activation of complementary functionalities. Since the generation of higher harmonics leads to mode hopping from lower acoustic modes to higher optical modes, the phenomenon enables the activation of processes that are typically associated with high-frequency modes even while we operate at relatively low frequencies, in regimes of potentially vast interest for a variety of acousto-elastic engineering applications. To elucidate the versatility of the approach, we numerically study a broad family of nonlinear crystal configurations that spans a wide spectrum of crystal topologies and wave control functionalities. This approach based on modal mixing features the ability to yield a wide variety of functional configurations without changes in the shape, size or topology of the nonlinear phononic crystal.

Thu 11:45 Gouv Waves in granular media and structures

Anomalous Diffusion of Ultrasound in Close-Packed Suspensions of Aluminum Beads – (Contributed, 000193)

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Interest in the physical properties of heterogeneous materials continues to grow, especially in the mesoscopic regime where the behaviour at intermediate length scales can be probed and tuned to reveal novel properties. One powerful way of studying such materials is through measurements of wave transport. During propagation in disordered media, waves may undergo many scattering events. As a result, wave transport may become diffusive, and if the scattering is sufficiently strong, the waves may even become trapped by the disorder, or localized.
We investigate ultrasonic wave transport in this regime by measuring the time-dependence of the transverse width of the acoustic intensity near the sample surface after a pulse is incident at a small spot on the other side. For diffusive behaviour, the transverse width grows with the square root of time, while for localized waves, the intensity becomes trapped and the width saturates. In our experiment, the sample consists of aluminum beads randomly packed in silicone oil, a two-component medium where diffusion was expected, based on previous work with glass beads suspensions in water. Contrary to expectations, we find that the transverse width goes through a maximum as a function of time, and varies more slowly afterwards. This novel behaviour may be due to the existence of two coupled diffusive propagations: the faster diffusive mode travels mainly through the liquid, with the propagating waves being multiply scattered off the beads, while the slower mode involves transport via the bead network and is strongly influenced by the bead resonances.

Thu 12:00 Gouv — Waves in granular media and structures

Dynamics of Granular Chains Magnetically Coupled to a Substrate – (Contributed, 000202)

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Granular crystals are periodic arrangements of elastic particles in contact. An especially appealing characteristic of such structures is the ability to tune their dynamic response, from linear to strongly nonlinear, by an applied static load. Here we report the design and the study of a new granular structure composed of a granular chain of steel beads on top of permanent magnets which are located within a substrate.
This new setup has the advantage of the readily directed assembling (no need for external static load), the engineering of its dispersion, and the tuning of its dynamic response by modifying the magnetic forces of the magnets. In particular, we will present the dispersion relation of the structure considering the magnetic coupling to the substrate and taking into account the translational and rotational degrees of freedom. The strongly nonlinear propagation originating from the contact nonlinearities (Hertzian and frictional) will be also presented.

Thu 13:30 Gouv — Waves in granular media and structures

Non linear conduction via solitons in a mechanical topological insulator – (Invited, 000635)

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Networks of rigid bars connected by joints, termed linkages, provide a minimal framework to design robotic arms and mechanical metamaterials with intriguing acoustic properties. Here, we investigate a chain-like linkage that, according to linear elasticity, behaves like a mechanical topological insulator whose zero-energy modes are localized at the edge. Simple experiments we performed using prototypes of the chain vividly illustrate how the soft mode, initially localized at the edge, can in fact propagate unobstructed all of the way to the opposite end. Using real prototypes, simulations, and analytical models, we demonstrate that the chain is a mechanical conductor, whose carriers are nonlinear solitary waves, not captured within linear elasticity. Indeed, the linkage prototype can be regarded as the simplest example of a topological metamaterial whose mechanical excitations are moving domain walls between distinct topological mechanical phases.

Thu 14:00 Gouv — Waves in granular media and structures

Experimental asymmetric acoustic propagation for wide band signal – (Contributed, 000270)

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The possibility to break symmetry of acoustic systems has been demonstrated by many recents works, theoretically and experimentally. One of the interesting consequence of asymmetry is the acoustic transmission through the device in one direction of propagation but not in the other.
Several proposed asymmetric systems are composed by two parts : one selecting some modes of propagation (for example, a phononic crystal with frequency stop bands) and another one converting the acoustic energy (for example, a strong nonlinear media inducing a frequency conversion). In this work, we realized a non-reciprocal transmission device based on this principe and composed of two solid media : a multilayer playing the role of an acoustic filter and a non consolidated tridimensional granular medium, converting the acoustic frequency. The implemented nonlinear process is the amplitude self- demodulation. This effect has the advantage of converting the incident wave packet to lower frequencies, which are,in general, in the acoustic band pass of the phononic crystal. This simplifies greatly the design of this type architecture of asymmetric systems.
After characterized the two parts of this rectifier, a experimental setup adapted to Hopkinson bar is proposed in order to precisely determine the asymmetric properties of this system for wide band signals and to prouve the large rectification ratio.

Thu 14:15 Gouv Waves in granular media and structures

Dynamics of homogeneous and inhomogeneous nonlinear lattices formed by repelling magnets – (Contributed, 000593)

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Nonlinear lattices, represented by nonlinear mass-spring systems, exhibit a number of fascinating physical phenomena, such as chaos, bifurcations, nonlinear resonances, or the formation of solitary waves and breathers. Understanding and exploiting nonlinearity in these kinds of systems has led to the design of materials with unprecedented properties. For instance, nonlinearity in granular materials, arising from the Hertzian contact between particles, has enabled the design of acoustic diodes and logic gates. In this work we investigate the nonlinear dynamic response of a one-dimensional lattice composed of repelling magnets. We consider a homogeneous chain as well as a chain containing mass defects. The chains are built experimentally using neodymium magnets placed on an air-bearing table, and the dynamics of the system is measured using Digital Image Correlation. The system is modelled as a Fermi-Pasta-Ulam lattice with nearest neighbour interactions. We demonstrate experimentally and theoretically the formation of solitary waves with profile and propagation speed depending on the excitation amplitude, and the existence of localized vibrational modes induced by mass defects. Potential applications of these systems to vibration energy harvesting will be discussed.

Thu 14:30 Gouv Waves in granular media and structures

Measurement of wave propagating in 1D micro-scale Granular chain – (Contributed, 000616)

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In this study, we investigated the propagation of mechanical impulses in 1D chains of micro-particles aligned in a micro-fabricated groove. The particles tested were made of stainless steel 440C and had a diameter of 300 micrometers. The micro-particles were initially positioned using a robotic micro-positioning system with sub-micrometer accuracy. Mechanical impulses were induced using a pulsed laser beam focused on the surface of selected particles at the end of the chain. Surface ablation enabled the transfer of controlled momentum to the system and the end-particles served as the strikers to generate wave in the chain. The particles' coordinates and vibrations were monitored using high speed micro-photography and laser vibrometry. We varied the initial momentum of the striker and measured the corresponding speed and dissipation of impulses in 1D chain of micro-granular particles at free boundary condition. The final results are compared with computer simulation.

Thu 14:45 Gouv Waves in granular media and structures

Nonlinear Pulse Propagation through Ordered Granular Networks – (Contributed, 000617)

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We study the dynamic force transmission through 2D and 3D ordered networks of interconnected chains of particles through experimental, numerical and theoretical investigations. This work builds on the well-studied phenomenon of solitary wave propagation in 1D granular chains. The unique behavior of the compact solitary waves traveling through the networks allows us to derive theoretical expressions for the pulse splitting, bending, and recombination by modeling traveling pulses with effective particles possessing identical momentum and kinetic energy. Additionally, we use a discrete particle model to simulate the nonlinear dynamic behavior of ordered granular networks and explore the role of the network geometry.
In the experiments, a single branching angle was chosen for both 2D and 3D systems, to maximize the force transmission, while maintaining experimental feasibility. The experimental results are found in good agreement with both numerical simulations and theoretical predictions based on the quasi-particle model. We observe an exponential decay in the leading pulse amplitude, both with distance from the impact and in the spatial distribution of acoustic energy in a plane perpendicular to the line of impact. The rapid amplitude decay exhibited by these granular networks makes them highly attractive for impact mitigation applications. Additionally, the observed exponential decay can be related to the dynamic load transfer along force chains in disordered granular media described in recent studies.
In summary, this work provides both insight into the behavior of natural granular packing and demonstrates the potential of granular ordered networks for controlling wave propagation pathways through material design.

Thu 15:00 Gouv — Waves in granular media and structures

Nonlinear shear wave propagation in dense granular media near unjamming – (Contributed, 000451)

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The shear elastic wave propagation along the free surface of glass bead packings immersed in water is investigated using ultrasound speckle interferometry. We monitor the nonlinear softening of the shear wave velocity from a jammed state to an unjammed state as the shear driving is increased. It is found that unjamming takes place between two stages: one involves irreversible sound-induced softening but without detectable motion of grains, the other one happens at highest driving and is accompanied with a plastic granular flow via dilatancy. The plastically fluidized zone is localized close to the driving source where the shear modulus softening is up to 85%. Effective medium models fail to quantitatively account for such softening.

Thu 15:15 Gouv — Waves in granular media and structures

Spontaneous Energy Channeling in the 2D, Inertially Coupled, Granular Metamaterials – (Contributed, 000124)

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As of date, there is a growing interest in the dynamics of higher dimensional granular crystals. One of the central objectives of the current research activity in the area of granular meta-materials is to achieve an efficient mechanism for attenuation, absorption and redirection of nonlinear stress waves. Dynamics of locally resonant, granular meta-materials is a subject of intense theoretical and experimental study of the past few years and from the theoretical view point remains a relatively young and also hardly explored area. As of today there is a lack of a substantial theoretical understanding of the dynamics of locally resonant metamaterials, incorporating highly nonlinear resonators.
System under consideration is a 2D, locally resonant (inertial coupling), granular metamaterial comprising discrete spheres assuming a nonlinear inter-chain interactions (between the adjacent elements) and incorporating internal rotators. In the present talk we present the recent results of the analytic and numerical study of the intrinsic mechanisms of complete, energy channeling (unidirectional energy transport from axial to lateral vibrations of the metamaterial), one directional wave localization as well as the bi- directional energy transport (i.e. rotational waves).

Thu 15:30 Gouv Waves in granular media and structures

Extreme stiffness tunability in nonlinear lattices with defects – (Contributed, 000622)

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Defects in periodic materials result in localized modes of vibration. In a linear lattice, the excitation of a defect mode has no effect on the material's properties at the boundary, due to the localization of the mode and the superposition principle. In the presence of nonlinearity, the superposition principle does not hold, and the excitation of defect modes introduces extreme changes in the static force-displacement relation of the material. The extreme stiffness arises from the nonlinear coupling between the defect vibration, the force at the boundary, and the strain of the lattice.This phenomenon is unrelated to the extreme effective stiffness of metamaterials, because it affects the static response of the material instead of the dynamic response near a local resonance frequency. By selecting the defect's excitation frequency and amplitude, the material's stiffness can be tuned to arbitrarily large positive or negative values. The changes in the force-displacement relation can be introduced selectively at precisely controllable deformation values. The presentation will discuss the underlying nonlinear mechanism that allows a material to attain extreme stiffness and present experimental results on a granular chain whose stiffness is tuned down continuously to minus infinity.

Thu 13:30 Grande Salle Instrumentation and signal in acoustics

Use of coded excitation method for measuring geometrical and acoustical parameters in wood specimens – (Contributed, 000068)

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Conventional methods for measuring ultrasonic wave velocity in an elastic sample require knowledge of the thickness of the sample or the distances between the transducers and the sample. In general, the precision of this knowledge determines the accuracy of the experimental technique for measuring velocity. With the same restriction, measuring thickness of a material require a knowledge of the time-of-flight of the wave propagating. This problem is particularly acute in measuring parameters in wood specimen with an acoustical impedance contrast higher than the surrounding media (coupling gel or water). The aim of the present study was to compare coded excitation methods using chirps to determine time-of-flight, and to evaluate the precision of the measurement in function of several time durations. The apparent thicknesses and ultrasonic wave velocities in parallelepiped plates of elastic manufactured and wood material were measured using the method, and using, as reference, a conventional pulse-mode approach. The relative errors of thickness measurement comparing to the results from caliper measurement are 0.3% to 3%. For velocity, the coded excitation method shows differences with reference method, from 26 to 226m/s. Even though the discrepancies are shown, the results from coded excitation method present interesting consistency for wood groups.

Thu 13:45 Grande Salle Instrumentation and signal in acoustics

Comparison Between Time and Frequency Domain ToF Estimators for Signals in Close Proximity – (Contributed, 000442)

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Estimation of the time-of-flight (ToF) is a frequent procedure in material thickness, mechanical properties measurement, ranging, robotic vision or imaging. Quite a frequent case is when two reflections are in close proximity. We show that such proximity introduces bias errors in ToF estimators for all interfering signals. Error is directly proportional to the temporal distance between the signals: the closer are the signals, the larger is the error. Error is also in inverse proportion to the ratio of affected and interfering signals: larger signal introduces larger error. Bias errors for different signal types are investigated. Insight into possible algorithms capable to reduce those er-

rors will be presented. Purpose of this investigation is the comparison of the time and frequency domain estimation algorithms with the aim to establish the insight into possible algorithms which are capable to reduce those errors. Evaluation is based on simulation using the pre-recorded real single reflection. Copies of a single reflection placed at different temporal spacing are simulating the case. Once artificially introduced distance between signals is known, any deviation in measured distance is the bias error. Simulation is supported by additional experimental results.

Thu 14:00 Grande Salle Instrumentation and signal in acoustics

A metrological based realization of Time-of-Flight Diffraction technique – (Contributed, 000497)

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ToFD is a technique of non-destructive testing by ultrasound used for detecting faults and discontinuities in different components. The development and implementation of this technique was based on ISO 16828:2012 (Non-Destructive testing - Ultrasonic Testing - Time-of-Flight Diffraction Technique as a Method for Detection and Sizing of Discontinuities). Controlling the different characteristics of the system, from the specification of the ultrasonic characteristics, to the imaging technique, it was possible to identify the sources of uncertainty and estimate the ToFD measurement uncertainty. For a 25 mm deep stainless steel test object, expanded uncertainties less than 0,5% was achieved with ToFD. For larger ultrasonic paths, the technique is able to depict even lower uncertainties, regarding some care are taken in the ultrasonic measurement setup.

Thu 14:15 Grande Salle Instrumentation and signal in acoustics

Study on Non-contact Acoustic Inspection Method for Concrete Structures by using Strong Ultrasonic Sound Source – (Contributed, 000162)

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Hammering test is widely used to inspect the defects in concrete structures. However, this method has a major difficulty in inspect at high-places, such as a tunnel ceiling or a bridge girder. Moreover, its detection accuracy is dependent on a tester's experience. Therefore, we study about the non-contact acoustic inspection method of the concrete structure using the air borne sound wave and a laser Doppler vibrometer. In this method, the concrete surface is excited by air-borne sound wave emitted with a long range acoustic device (LRAD), and the vibration velocity on the concrete surface is measured by a laser Doppler vibrometer. A defect part is detected by emergence the same flexural resonance as the hammer method. It is already shown clearly that detection of a defect can be performed from a long distance of 5 m or more using a concrete test object. Moreover, it is shown that a real concrete structure can also be applied. However, when the conventional LRAD was used as a sound source, there were problems, such as restrictions of a measurement angle and the surrounding noise. In order to solve these problems, basic examination which used the strong ultrasonic wave sound source was carried out. In the experiment, the concrete test object which includes an imitation defect from 5-m distance was used. From the experimental result, when the ultrasonic sound source was used, restrictions of a measurement angle become less severe and it was shown that circumference noise also falls dramatically.

Thu 14:30 Grande Salle Instrumentation and signal in acoustics

Fast Inversion Calculation for Full-field Measurement of Material Properties with Laser Ultrasound Technique – (Contributed, 000357)

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This research employs a quantitative laser ultrasound visualization system (QLUVS) for the full-field mechanical property mapping in plate-like structures. The QLUVS has the advantage of fast, full-field and quantitative inspection. The QLUVS uses a pulsed laser generate acoustic waves with fast scanning mechanism to reach two dimensional scanning goal and then detected with a piezoelectric longitudinal transducer. By utilizing QLUVS, the spatial and temporal information of guided wave can be obtained with further signal processing, the velocity map can be extracted. Finally the analytical model and inversion algorithm will be integrated into QLUVS for the full-field mechanical property mapping purpose. The QLUVS employs a mirror-controlled scanning pulsed laser to generate guided acoustic waves traveling in a two-dimensional target. Guided waves are detected with a piezoelectric transducer located at a fixed location. With a gyro-scanning of the generation source, the QLUVS has the advantage of fast, full-field and quantitative inspection. The application of our algorithm to the thickness inversion of QLUVS data acquired on 1mm thick aluminum plate with machined defect. The wavefront deformation obviously. Utilizing the mechanical property mapping reconstruction algorithm. For the aluminum block is heated with different heat source in different position. When specimen is heated, the direct influence is Young's modulus variation. From this case, the relationship between temperature and Young's modulus must be established. Young's modulus and temperature variation are observed obviously. The QLUV provides many interesting observations in real-time image form. The QLUV system combined with mechanical property mapping reconstruction algorithm provides qualitative and quantitative study for more complex guided mode propagating behavior and a full-field mechanical property mapping.

Thu 14:45 Grande Salle Instrumentation and signal in acoustics

Ultrasonic Direction Measurement Method Using Sensitivity Compensated Transmitting Signal and Pulse Compression – (Contributed, 000308)

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Ultrasonic pulse echo method for high accuracy target detection is discussed. For pulse compression with high resolution, a Sensitivity Compensated Transmitting (SCT) signal has been proposed. The SCT signal is calculated from inversed filtering of a spectrum mainly influenced by sensitivities of ultrasonic transducers. Therefore, by using the SCT signal, the signal with flatter and broader spectrum can be received. Two types SCT signals, i.e. an amplitude modulated chirp wave (SCAM signal) and a non- linear FM signal (SCFM signal), were discussed. We had studied high accuracy target detection such as target ranging and speed measurement of moving target by using the SCT signal. In this paper, 2-D direction measurement using the SCT signal and pulse compression is discussed. For direction measurement, a transmitter and two receivers are employed. The angle of target is calculated from two Time-Of-Flight (TOF) of compressed pulse measured from each receivers. Direction measurement using two types of SCT signal is compared with that using a linear FM signal (chirp wave). The results show that, by using SCT signals, compressed pulse width is shortened to less than 1/4 of that of using the chirp wave. In direction measurement, accuracies of direction measurement using SCT signals are improved than that of using the chirp wave. Furthermore, by using the SCFM signal, accuracy of direction measurement is improved than that of using the SCAM signal when the target is located at the position where the SNR of received signal is lower.

Thu 15:45 Grande Salle Instrumentation and signal in acoustics

Effect of Rayleigh Wave on Ultrasonic Underground Imaging – (Contributed, 000100)

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In order to acquire image with higher resolution and less error for detecting underground objects, a three dimensional ultrasonic underground imaging technique using an electromagnetic-induction type sound source and an amplitude correlation synthesis processing (ACSP) method has been proposed in our previous work. Depending on the conditions of the ground surface, Rayleigh waves propagating along the surface directly may be received with significant amplitude by the receiver array. That will cause interference with the reflect signal of the underground objects and will bring forth error images to the imaging result. In this paper, the Rayleigh wave with comparatively high amplitude is measured experimentally in a model field filled with mountain sands, and its waveform is estimated and simulated approximately by an exponentially decaying sinusoidal wave. The effect on the image of underground object is discussed by synthesizing the received signal with the modeled Rayleigh wave with vari-

ous relative amplitudes. The result images calculated by ACSP method show that the effect of Rayleigh wave is not marked when its peak amplitude is not greater than that of the signal reflected from the underground object.

Thu 16:00 Grande Salle Instrumentation and signal in acoustics

Quantitative Ultrasonic Imaging and Contour Detection by Adaptive Spatial Focusing – (Contributed, 000393)

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Ultrasonic phased arrays (PA) enable to perform ultrasonic examination using variable focusing depths and scanning sectors. In order to increase the spatial resolution, the acquired data with PA can be of-line post-processed by synthetic aperture focusing technique (SAFT) or total focusing method (TFM) algorithms. Usually, applications of the GPU units are caused by possibility of speeding up post-processing algorithms using the parallel computing. However, the limitation, that all data must be loaded in GPU memory, which is relatively small. Therefore, the objective was to develop the adaptive algorithms for managing of computation resources. Using the developed hybrid system of modern CPU - GPU units and the optimal management of computational resources it is possible to perform the real-time SAFT post-processing of the acquired ultrasonic 3D data cube in order to get the advanced quantitative C-scan image with spatially enhanced resolution. The automatically selected particular spatial regions of interest (B-scans), where detailed investigation of the internal non-homogeneities is necessary, is being precisely analysed using TFM algorithm. In order to enhance the boundaries of internal non-homogeneities the optimal thresholding methods were introduced. The boundaries are detected by using histogram shape based (Otsu) or clustering based (K-means) methods. Otsu method has better performance, whereas K-means is more flexible and can be easily extended to 2D version. Such K-means is used when the ultrasonic signals are noisy. By using the following methods it is possible to find the optimal threshold for each slice separately (local) or the optimal threshold (OT) that is common to all slices (global). The results of spatially distributed focusing and post-processing obtained using SAFT, TFM, spatial contouring and rendering techniques of volumetric post-processed image give the sufficient accuracy of quantitative spatial ultrasonic imaging to be used for practical applications.

Thu 16:15 Grande Salle Instrumentation and signal in acoustics

Ultrasonic imaging in liquid sodium: a differential method for damages detection – (Contributed, 000403)

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The fourth generation of nuclear reactor can use liquid sodium as the core coolant. Because molten sodium is optically opaque, ultrasonic imaging techniques using sodium-compatible high-temperature transducers are developed for maintenance activities. Under-sodium imaging aims at checking the health of immersed structures. This work focuses on developing a methodology for detecting damages such as crack defect. Potential surface-breaking cracks or deep cracks are sought in the weld areas which are considered as the weakest zones. The presented approach relies on making use of prior knowledge about the region of interest through the implementation of differential imaging and time-reversal techniques. Indeed, this approach allows to detect a change by comparison with a reference measurement and by focusing back to any change in that region. It is a means of analysis and understanding of the physical phenomena making it possible to design more effective inspection strategies. Difference between the measured signals reveals the acoustic field scattered by a perturbation, which may occur between periodical measurements. The imaging method relies on the adequate combination of two computed ultrasonic fields, one forward and one adjoint. The adjoint field, which carries the information about the defects, is analogous to a time-reversal operation. Numerical simulations have been carried out to validate the practical relevance of this approach. The preliminary numerical results show a nice agreement between the guessed and the actual positions of the defect with a half wavelength accuracy.

Thu 16:30 Grande Salle Instrumentation and signal in acoustics

Comparison of conventional technique and migration approach for total focusing – (Contributed, 000420)

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Synthetic aperture focusing technique (SAFT) and total focusing method (TFM) have become popular tools in the field of ultrasonic non destructive testing. In particular, they are employed for detection and characterization of flaws. From data acquired with a transducer array, those techniques aim at reconstructing an image of the inspected object from coherent summations. In this paper, we make a comparison between the conventional technique and a migration approach. Using synthetic and experimental data, we show that the developed approach is faster than the conventional total focusing method but is less flexible. Indeed, the migration approach is adapted to layered objects whereas the standard technique can fit complex geometries. The methods are tested on homogeneous pieces containing artificial flaws such as side drilled holes and notches.

Thu 16:45 Grande Salle Instrumentation and signal in acoustics

Investigation of Pulser-Transducer Matching Networks for Power Delivery Efficiency of Spread Spectrum Signals – (Contributed, 000450)

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Application of wideband signals is offering several advantages in ultrasonic measurements and imaging: better temporal and spatial resolution, higher measurement accuracy. Replacement of a single pulse to the spread spectrum signals allows getting higher energy without loosing the bandwidth. Higher spread spectrum signal energy also means higher requirements for energy delivery to test object. If pulser efficiency for single pulse is not essential, going to high energy signals also means that if pulser-transducer power delivery efficiency is low, then pulser stress is large due to the mismatch. Therefore either pulser size has to be increased or techniques for better pulser-transducer match have to be applied. In narrowband case natural solution is to use the matching network, but transducer impedance usually varies with frequency so matching circuit effect will be different in case of wideband excitation. Aim of the investigation presented is to evaluate the matching techniques for power delivery efficiency increase without loosing the bandwidth. It is suggested to account not only the AC response of the transducer impedance but also the output impedance of the pulser. Techniques for impedance measurement are presented, various matching networks are investigated and results for power delivery efficiency are given.

Thu 17:00 Grande Salle Instrumentation and signal in acoustics

Shape of Short Ultrasonic Echo-Pulses Focused in Solid Plate – (Contributed, 000546)

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Application of broadband probing impulses in acoustic microscopy allows to increase depth resolution of visualization system and to improve measuring possibilities at fixed frequencies. The echo-pulse method with measuring the delay times is a basis of quantitative techniques of the pulse acoustic microscopy. To improve the accuracy of the method the attention should be paid to the changes in the echo-pulse shape that is caused by the focusing of elastic waves at the boundaries of a sample. The report is devoted to this problem. The role of aperture function and reflection coefficient in the echo-signal formation is shown. Features of the separated echo-pulses formation, which is caused by reflecting the acoustic waves of various polarizations in the plate, are studied. The method of a stationary phase is applied to analyze the expression for the output echo-signal; dynamics in the shape transformation for individual echo-pulses depending on the focus position are studied. Experiments confirm the theoretical investigations. The technique has been applied to measure bulk elastic properties of some materials.

Thu 10:30 Citadelle 2 NDE / NDT: General I

Multimodal Plane Wave Imaging for Ultrasonic Non-Destructive Testing – (Contributed, 000433)

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Fast ultrasonic imaging with high image quality is of great interest in Non-Destructive Testing (NDT) in order to perform inspections of large components at high speed. Real-time methods exist based on the Synthetic Transmit Aperture (STA), which is the reference imaging technique in NDT, but the expected frame-rate is limited by the number of ultrasonic transmissions and the amount of data to be processed. Thus, we propose a new ultrasonic array imaging method for NDT which is derived from the medical Plane Wave Imaging (PWI) technique. In the PWI approach, all the array elements are excited simultaneously to transmit planes waves with different transmission angles. At each transmission, the back-scattered signals are recorded and focused in receive mode on every point of the region of interest. In this talk, we generalize the medical PWI to immersion inspection setups where water acts as a coupling medium. Secondly, the method is generalized to multimodal imaging (imaging with direct and half-skip modes by taking into account mode conversions) to improve the characterization of crack-type defects. Experimental results were obtained with the two methods (STA and generalized PWI) for different types of flaws. An excellent agreement between the STA and the PWI is observed, but three to ten times less transmissions are required for the PWI.

Thu 10:45 Citadelle 2 NDE / NDT: General I

Acoustic microscopy for visualization and evaluation of ceramic-ceramic contact zone – (Contributed, 000571)

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Adhesion strength between materials is one of the main criteria for reliability of a product in total. Therefore special efforts are directed to evaluate the contact zone of materials including opaque ones. The adhesion force is determined primarily by defects in the contact zone (delamination or air bubbles). Also, strength between joining materials is characterized by additional structural elements at the interfaces - surface inclusions, and intermediate layers of the film. Mechanisms of their influence on the adhesion strength are varied. Impulse acoustic microscopy technique has been applied for investigation of features of ceramic-ceramic contact zone. At the interface identified and localized detachment and extended partial contact area shows the distribution of the thickness of the buffer layer and its homogeneity.

Thu 11:00 Citadelle 2 NDE / NDT: General I

Detection of small stress relaxation in tightened metallic structures by ultrasounds – (Contributed, 000283)

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Experimental data are presented here to highlight the performances of ultrasounds for the control or the better understanding of the quality of the mechanical contact between tightened plates. Thus, variations of the mechanical load as small as those induced by creep effect are potentially detectable by simply monitoring the amplitude of the reflected acoustic plane wave reflected at this interface. To illustrate this, two 3 cm thick aluminium plates are firstly tightened with a given torque and next, the amplitude of the acoustic wave is monitored for several days. All long this test, the temperature of the sample is controlled as well as the compression load applied to the plates using a thermocouple and a force sensor. The reflected amplitude decreases quickly during first hours and then stabilises after a week approximately. The total variation reaches -28% of the initial value of the reflected amplitude. During this test, temperature is remained almost constant and its fluctuation around the ambient temperature is not correlated with the reflected amplitude. As expected from classic stress relaxation tests, the compres-

sion load has slowly decreased by an amount of only -1% but this should have logically increased the reflected amplitude. Further investigations have shown that instrumentation drift were negligible. Consequently, this large decrease of the reflected amplitude has been interpreted as the indication of the increase of the contact area between the two tightened plates. This test attests the high sensitivity of ultrasonic reflection measurement to investigate quality of mechanical contacts for non destructive testing.

Thu 11:15 Citadelle 2 NDE / NDT: General I

Industrialization of bolt strenght measure by Ultrasound in Railway Maintenance – (Contributed, 000084)

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Checking of the tightening of the bolted assemblings in railway maintenance at SNCF is based on a control at 80% of nominal tightening torque. The main problem of this method is its weak reliability. After development and use of an ultrasound method in laboratory to validate instruction of assemblages bolt, the problematic is to transfer this technique in production for the control of the sensitive assemblings of the trains. The challenges are numerous to overtake the limits of the production as the restricted train immobilization in workshop, the logistic support, the maintenance rules and the operator competences. This technique is now validated and the interest for workshop is demonstrated. SNCF is now in the step of pre-industrialization on a sensitive assembling on TGV. The feedbacks from this pre-industrialization step will allow to evaluate the opportunity to demultiply this technique into the national level.

Thu 11:30 Citadelle 2 NDE / NDT: General I

Detection of flat bottom holes using sparse deconvolution – (Contributed, 000407)

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Ultrasonic non destructive testing (NDT) is an efficient method to detect flaws in industrial parts. The detection of flat bottom holes (FBH) is a typical problem, which serves as a reference standard in the NDT community. It is nevertheless a hard task if the FBH is short - i.e. close to the back of the piece - because its echo overlaps with the backwall echo. In this paper, we propose to use a sparse deconvolution approach to separate the FBH echo from the backwall echo and hence to detect the FBH with high resolution. From experimental data acquired with a FBH drilled in an aluminum plate, we show that the FBH echo can be modeled as a high-pass filtered version of the incident ultrasonic wave. Therefore, we build a propagation model depending on the instrument response and of a specific attenuation function. A sparse deconvolution technique is then proposed to precisely locate the flaw and the backwall positions. In application to real data, we show that this approach is more efficient than conventional techniques such as thresholding or maximum detection. In particular, the conjugation of a precise FBH model with advanced deconvolution methods achieves correct detections in cases where conventional methods are likely to fail.

Thu 11:45 Citadelle 2 NDE / NDT: General I

Surface Acoustic Wave based Characterization of Randomly Distributed Surface Cracks – (Contributed, 000085)

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Non-destructive detection and characterization of surface and subsurface cracks can be achieved by measurement and interpretation of their interaction with surface acoustic waves (SAWs). In the presence of a large amount of small defects, such as microcracks at grain boundaries, the scattered field cannot be used to reconstruct the origin of the scattered waves. The macroscopic, homogeneous material behavior however can be evaluated by observing attenuation and / or dispersion of SAWs. These parameters can be used to characterize the density and depth distribution of the cracks. The quality-inspection of steel is a typical application for this approach.
We use experimental and numerical tools to study the scattering of SAWs on surface microcracks which arise between the boundaries of the individual grains in steel. For the experimental evaluation, we generate SAWs with plane wave fronts using a line-focused pulsed-laser. The propagating waves are detected interferometrically at different distances from the excitation. A homogenized behavior of the randomly scattered field is gained by spatially averaging the measurements. Fast Fourier Transformation (FFT) is applied for quantitative analysis of the dispersive behavior. For theoretical description, two and three-dimensional time-domain Finite Element (FEM) simulations are used. Those numerical models describe the scattering of the SAWs on randomly distributed surface cracks.
The experimental results, as well as the numerical models, show the expected attenuation of the SAWs due to the scattering of the waves. The strongly distorted shape, as well as FFT analysis of the waveforms, indicates the presence of dispersion.

Thu 12:00 Citadelle 2 NDE / NDT: General I

Ultrasonic Fingerprinting of Structural Materials: Spent Nuclear Fuel Containers Case-Study – (Contributed, 000331)

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Nowadays, NDT is mainly focused on safety purposes, but it seems possible to apply those methods to provide national and IAEA safeguards. The containment of spent fuel in storage casks could be dramatically improved in case of development of so-called "smart" spent fuel storage and transfer casks. Such casks would have tamper indicating and monitoring/tracking features integrated directly into the cask design. The microstructure of the containers material as well as of the dedicated weld seam is applied to the lid and the cask body and provides a unique fingerprint of the full container, which can be reproducibly scanned by using an appropriate technique.
The echo-sounder technique, which is the most commonly used method for material inspection, was chosen for this project. The main measuring parameter is an acoustic noise, reflected from material's artefacts. The purpose is to obtain structural fingerprinting. The noise in different specified position was measured and converted to mathematical function (40 highest peaks in a position). Reference measurement and additional measurement results were compared.
Obtained results have verified the appliance of structural fingerprint and chosen control method. The successful authentication demonstrates levels of the feature points' compliance exceeding the given threshold, which differs considerably from the percentage of the concurrent points during authentication from other points. Since reproduction or doubling of the proposed unique identification characteristics is impossible at the current state science and technology, application of this technique is considered to identify the interference into the nuclear materials displacement with high accuracy. Since reproduction or doubling of the proposed unique identification characteristics is impossible at the current state-of-art, application of this technique is considered to identify the interference into the nuclear materials handling procedure with high accuracy.
The reported study was partially supported by Federal special-purpose program, Research Project No.14.575.21.0048

Thu 12:15 Citadelle 2 NDE / NDT: General I

Dry Storage Casks Monitoring by Means of Ultrasonic Tomography – (Contributed, 000325)

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Spent nuclear fuel (SNF) is one of the most hazardous type of nuclear power plant waste. This fact emphasizes the importance of careful handling and storage of SNF. There are two current state-of-the-art technologies of SNF storage facility: wet and dry. It is important to mention, that IAEA do not determine which kind of handling strategy should be chosen, however it is noted that dry storage of SNF could be used for hundred years. Mining and Chemical Enterprise (MCE) is one of the leading Russian company, dealing exclusively with the dry storage of SNF. This company has implemented a long-term storage scheme. At the same time, MCE faced a challenge of nondestructive monitoring the degradation process of structural material of cask and its sealing weld seam. Currently, X-ray testing is used for this purpose, but in an order to provide an effective nonradioactive method of monitoring, MCE has initiated a collaborative R&D project with TPU, which is supported by the Russian government.
Ultrasonic industrial tomography technique was proposed as a solution. The method is based on application of phased and sparse arrays transducer with real-time visualization algorithm. Received acoustic data is processed and realized by means of Digital Focusing Array technology, which is a collaborative development of TPU and I-Deal Technology, GmbH. The multichannel ultrasonic set-up of immersion control was assembled for performing testing of seven experimental specimens with representative defects (side drill-holes, notches, natural welding flaws). X-ray tomography of high-resolution was chosen as reference method.
All indications were successfully reconstructed in B, C-scans and 3D image. The next step is to automate the monitoring procedure completely and to introduce an evaluation tool for current flaw state and prediction of its further behavior.
The reported study was partially supported by Federal special-purpose program, Research Project No.14.575.21.0048

Thu 10:30 ESAL 2 Physical acoustics: inhomogeneous media

Computation of the diffracted field by an elliptic rigid or elastic scatterer: an overview of the numerical limitations – (Contributed, 000348)

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In the frame of a general study on the propagation of ultrasound in trabecular bone, we have been interested in the numerical simulation of the ultrasonic field scattered by an elliptic scatterer, used as a simplified elementary component of the trabecular structure. This simulation is based on a modal decomposition of the incident and scattered fields. Semi-analytical solutions are available to calculate the modes for cylinders of circular cross sections, in the case of rigid as well as elastic scatterers. Usually, conventional numerical arithmetics is enough to reach the scattered field, if we do not try to take into account an excessive number of modes.

In the more general case of a scatterer of arbitrary cross section, semi-analytic approaches can be extended and the scattered field can be obtained numerically. Although the computation is more complex than for a circular cross-section, it becomes possible to calculate the field resulting from an elliptic scatterer.
If the aspect ratio of the ellipse is close to 1, this approach works well. Unfortunately, we show here that this solution suffers from strong numerical instabilities for high aspect ratios, resulting from the limited precision with standard computer arithmetics. However, we have developed a numerical simulation based on GMP (The GNU Multiple Precision Arithmetic Library, https://gmplib.org) and we demonstrate that these instabilities can be handled using extended precision. The immediate inconvenient of this approach is the computation time, and more generally the computational resources that are needed.
We will present the general approach and the numerical solutions that have been developed, and give an overview of the reachable results dependent on the size and aspect ratio of the elliptic scatterer.

Thu 10:45 ESAL 2 Physical acoustics: inhomogeneous media

Experiments on gradient-index lenses in elastic plates – (Contributed, 000371)

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We explore the possibility to fabricate gradient-index lenses in a Duraluminium thin plate with a thickness profile varying radially. The dispersion relation of flexural waves in plates offers several degrees of freedom to engineer at will the refractive index. Among them, the thickness of the plate is an easy parameter to tune enabling to obtain the desired index profile. By this mean, we have built an equivalent to the Maxwell fish-eye lens in optics, but for flexural waves. The resulting lens possesses imaging properties very similar to those predicted by ray trajectories. However, the refocusing time depends on the carrier frequency as a direct consequence of the dispersive nature of flexural waves in thin plates. Importantly, experimental results are in good agreement with Finite-Difference-Time-Domain simulations. This experimental demonstration opens the way to a lot of potential devices in the same vein, based on index variation.

Thu 11:00 ESAL 2 Physical acoustics: inhomogeneous media

Ultrasound propagation in concentrated suspensions: shear-mediated contributions to multiple scattering – (Contributed, 000391)

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Ultrasonic techniques offer many advantages for process monitoring for suspensions of particles; this type of material occurs in a wide variety of process industries. However, the application of ultrasonic techniques has been limited by the inaccuracy of the models used to interpret the measured ultrasonic propagation parameters (typically speed and attenuation spectra) in terms of particle size, concentration and physical properties. Multiple scattering models have been used with great success in relatively dilute suspensions (up to 10%w/w) for colloidal particles, but are inadequate at higher concentrations, smaller particles, and low frequencies. The principal reason is believed to be the shear-mediated contributions to multiple scattering which have previously been neglected.
We report analytical and numerical results for a modified scattering model that includes these shear-mediated effects. The model is a development of the multiple scattering formulation published by Luppé, Conoir and Norris (J Acoust Soc Am, 2012 (131) 1113) which incorporates thermal and shear wave mode conversions to and from the compressional wave mode. We consider a silica-in-water suspension, identify the dominant scattering contributions and develop analytical forms for them. Numerical calculations demonstrate the contribution of the additional shear-mediated effects to the compressional wave speed and attenuation through the suspension. The calculations are compared with previously published experimental data.

The work follows a similar formulation to a recently published model for concentrated emulsions in which thermally-mediated effects are considered (Pinfield, J Acoust Soc Am, 2014 (136) 3008).

Thu 11:15 ESAL 2 Physical acoustics: inhomogeneous media

Study of the resonant interaction between gas bubbles by using the spherical harmonics expansion – (Contributed, 000522)

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This work comes within the framework of the scattering of sound waves in concentrated suspensions of gas bubbles or liquid droplets. The model used is based on the spherical harmonics expansion of the incident and scattered waves and on the use of the addition theorem. The thermal and shear waves are also modeled in order to take into account interactions with the compressional waves for particles very close to each other. The first step of this general work is to study the interactions between two gas bubbles. In this case, it is well known that if the bubbles are sufficiently close together, the Minnaert frequency splits into two resonant frequencies. This phenomenon is generally described by a model based on the coupled Rayleigh-Plesset equations for which only the radial motion of bubbles is taken into account. With our acoustic model, the two resonant frequencies are calculated analytically by using the first mode of vibration associated to radial motions. Moreover, when additional harmonics are taken into account in the calculations we observe that the couplings between all waves (compressional, thermal, and shear waves) have influences on these resonant frequencies. Similar results are obtained for the interaction between three or more gas bubbles for which additional resonances appear.

Thu 11:30 ESAL 2 Physical acoustics: inhomogeneous media

High-order acoustic Bessel beam generation by spiral gratings – (Contributed, 000563)

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We report zero-th and higher order acoustic Bessel beam formation by means of novel passive devices. Using an axisymmetric diffraction grating composed of toroidal rings a zero-th order Bessel beam is generated in transmission. Moreover, focusing of this beam can be achieved by changing the distance between the scatters according to geometrical laws (analogous to the well- known Fresnel zone plates), where acoustic gains up to 34 dB have been observed. On the other hand, scattering by an Archimedean spiral grating is exploited for inverting the phase of the field at each half turn, leading to the creation of a node on-axis. The generated field is a first order Bessel beam which present vorticity. Moreover high-order Bessel beam formation is achieved by incrementing the number of spiral branches, where the number of spiral arms directly correspond to the order of the generated Bessel beam. Focusing of these chiral beam is also possible by using non-uniform Archimedean spirals as the Fermat's spirals. The results obtained allows the control of the vorticity of Bessel-like beams by passive devices, which have potential applications on low-cost acoustic tweezers and acoustic radiation force applications.

Thu 11:45 ESAL 2 Physical acoustics: inhomogeneous media

The Phenomenon of Secondary Diffraction of Sound on Periodically Corrugated Surface – (Contributed, 000590)

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When a sound beam is incident onto a periodically corrugated surface, diffraction of the incident sound will be generated. The major diffraction phenomenon, which can be well explained by the classical grating equation, can be easily observed and has been intensively studied. In this work, we report an observation of diffracted waves whose intensity is much weaker than the major diffraction, and who are not expected to appear in the diffraction field. This secondary diffraction can be experimentally observed in the general diffraction configuration as well as in the Bragg diffraction configuration. The analysis of the direction and frequency of the diffracted waves based on the classical grating equation suggests that this diffraction is originated from a propagating wave along the corrugated surface. Such a propagating wave is possibly the experimental evidence of the existence of surface acoustic wave on corrugated interface generated by diffraction.

Thu 12:00 ESAL 2 Physical acoustics: inhomogeneous media

Homogenization of rough interfaces – (Contributed, 000489)

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Homogenization is a powerful tool to predict the effective properties of periodic layered structures with sub wavelength microstructures. We extend the homogenization theory to case of roughness at an interface between two media. Indeed, the imperfect interface can be considered as a slab composed of a layers which mimic the roughness, leading to an effective homogeneous but birefringent layer. Results are exemplified, notably in the case of the perfect transmission observed at the Brewster angle in the case of a perfect interface between two penetrable materials. When the interface is not perfect, but suffers from random irregularities in the shape, it has been shown using perturbative approaches that the perfect transmission is lost, and the angle realizing the minimum in reflection is slightly smaller than the Brewster angle. We show the the reflexions observed for various realizations of the rough interfaces (with given amplitude and correlation length) are correctly described by the reflexion of the equivalent, homogenized, birefringent slab when using for the slab thickness the RMS value of the rough surface.

Thu 10:45 Citadelle 1 Bio-medical: Imaging methods

High Frame Rate Super Resolution Imaging Based on Ultrasound Synthetic Aperture Scheme – (Contributed, 000496)

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In order to perform high resolution ultrasound imaging, we have proposed a super resolution FM-Chirp correlation method (SCM) so far. However, in this method multiple transmissions of an ultrasound pulse with slightly different frequency are required for generating each line in an image. This increases the amount of processing and puts a strict limit on the frame rate. On the other hand, studies for synthetic aperture imaging (SAI) are being vigorously advanced. SAI can perform high frame-rate imaging, and hence, it is useful for improvement of accuracy in diagnosis of heart disease and its various modifications for high- performance are examined. The compressed sensing strategy, which is recently receiving a lot of attention, is adopted to improve the frame-rate of SAI furthermore by several studies. In this study, we attempt to solve the above mentioned multiple transmissions problem through application of SAI. We introduce the synthetic aperture version of the SCM called the SA-SCM. The time required for the SCM imaging can be reduced by the synthetic aperture strategy, but image degradation is concerned because the total number of times of the transmission is reduced. We examine the degree of such the degradation in the images obtained by the SA-SCM throughout FEM simulations and experiments. Those results indicate that the SA-SCM has superior performance for both of spatial and temporal resolution. We also confirm that the SA-SCM improves the azimuth resolution in addition to the range resolution which is increased conventionally by the SCM.

Thu 11:00 Citadelle 1 Bio-medical: Imaging methods

A Unified PCIe Streaming and Processing Architecture for Ultrasound Systems – (Contributed, 000070)

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A fast increase in computational performance of new GPU chips enables a change in the paradigm of traditional hardware-based signal processing for ultrasound image formation. Hardware beamforming is a limiting factor in the implementation of new imaging methods (eg. synthetic aperture, vector Doppler). A direct access to raw RF ultrasound echoes empowers the implementation of these advanced signal processing algorithms, whereas powerful GPUs facilitate and speed up the development process. The objective of this work is a unified scalable streaming and processing architecture for the next generation of ultrasound scanners. We proposed a novel architecture for ultrasound scanners based on software-only processing on GPUs. Nowadays, we are implementing that architecture in two different ultrasound systems: a high performance 192-channels research platform and a low-power portable 32-channels system. Both systems use PCIe as a communication backbone between acquisition modules and PC/GPU. The Big system is composed of up to three 64-channels acquisition modules, two transmit-control modules, an analog backplane and up to three high performance GPU cards. The Small system is limited to 32- channels and uses embedded GPU for the processing. A range of synthetic aperture imaging algorithms were implemented on GPU for testing the feasibility of real-time imaging on today's hardware. The developed prototypes of ultrasound scanners show the feasibility of real-time, software-only ultrasound processing for systems in range of 32-192 channels. The implemented software framework and GPU kernels for imaging provide a fast path for new algorithm development. A unique feature of this architecture is its easy scaling, both in number of acquisition channels and processing power. The separation of acquisition/control modules from the processing modules enables heterogeneous (CPU/DSP/GPU), scalable and upgradable processing resources. Both prototype systems are at the final stage of integration. They will be offered to the scientific community as research platforms in the near future.

Thu 11:15 Citadelle 1 Bio-medical: Imaging methods

Low frequency and high resolution medical ultrasound imaging using APES adaptive beamforming – (Contributed, 000072)

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Motivation and objective: A trend in medical ultrasound imager designs is gearing towards the use of wide frequency band by extending the transmit bandwidth to include more high frequency components in order to produce higher definition images. However, tissues absorb high frequency signals as acoustic wave travels through the body. Thus, only low frequency signal components are capable of reaching targeted sites that are located far away from ultrasound probes. We challenge to overcome the trade-off between signal penetration and image quality that is essential for imaging targets far away from the surface of patients' body.
Methods: We examine the effects of a combination of the amplitude and phase estimation (APES) adaptive beamformer and the transmission of low frequency broadband signals. We extend the frequency spectrum to include low frequency components in the transmit signal, aiming to increase retention of signals for imaging at deep region, where high frequency components deteriorates due to frequency-dependent attenuation. Furthermore, received signals are processed using APES adaptive beamforming techniques in order to suppress undesired signals. Using digital phantoms, we simulated B-mode images using Field II simulator.

Results: The results indicated that use of an APES-beamformed, broadband signal centered at 3.35 MHz improves contrast resolution by 17 dB and 28 dB for shallow and deep regions, respectively, when compared to a delay-and-sum (DAS)-beamformed 70% beamwidth signal centered at 5 MHz. We confirmed that the combining APES adaptive beamformer and low frequency transmit impulses is useful to improve B-mode image quality at the deep inside the body.

Thu 11:30 Citadelle 1 Bio-medical: Imaging methods

Novel Imaging Method of Continuous Shear Wave by Ultrasound Color Flow Mapping – (Contributed, 000075)

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Objective: Several methods have been proposed for tissue stiffness imaging. However, elastic modulus cannot be evaluated in strain elastography and a complicated and expensive imaging system is required in ARFI method. To obtain quantitative shear wave image by low-cost system, a novel shear wave imaging for continuous shear wave is proposed. Methods: When continuous shear wave is excited by vibrator, the shear wave propagates inside the tissue. In the proposed method, the shear wave's wave-front is directly observed by flow velocity estimator equipped in general-purposed ultrasound color flow mapping. Shear wave velocity and the propagation direction images are derived by Fourier analysis method. To obtain shear wave image, two conditions, a shear wave frequency condition and a shear wave displacement amplitude condition, are needed. But, since the frequency can be chosen among several frequencies which are available for shear wave imaging and the minimum displacement amplitude is a few tens μm, these conditions are not severe restrictions in most applications. Results: In phantom experiments, the coefficient of variation (CV) of the measurement decreases to 19 % compared with strain elastography. In vivo experiments are carried out for trapezius muscle. A hybrid-type probe which consists of a small-sized multilayer piezo-electric actuator, a vibration isolator and an US probe is adopted for one-hand operation. Shear wave frequency is 273.6 Hz. Shear wave velocity measured by the method is 6.6 m/s when the muscle is in the relaxation state. But it increases to 12.3 m/s when the muscle is in the contraction state.

Thu 11:45 Citadelle 1 Bio-medical: Imaging methods

A novel contrast-enhanced ultrasound imaging technique with superior detection specificity using quasi counter-propagating wavefronts – (Contributed, 000080)

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Contrast detection methods implemented in present clinical ultrasound scanners show high sensitivity but a poor specificity due to pseudo-enhancement produced by nonlinear wave propagation in regions containing contrast agent. Even at low transmit pressure (<200kPa peak pressure), significant nonlinear ultrasound propagation occurs in these regions because contrast agent enhances the medium elastic nonlinearity. All current detection techniques require linear propagation to reveal nonlinear scattering of contrast agent microbubbles. As a

consequence of false contrast detection caused by the pseudo-enhancement, tissue can be misclassified as contrast agent microbubbles and contrast agent concentration can be overestimated. This artifact hinders development of contrast-enhanced ultrasound imaging towards reliable quantitative measurement of local contrast agent concentration, and hence blood perfusion.
We propose in this work a new detection method, with specific beamforming and pulsing scheme, that produces contrast images with highly reduced pseudo-enhancement due to nonlinear ultrasound propagation in regions containing contrast agent. It is based on the interaction of the two wavefronts broadcasted by two separate sub-apertures of a linear array probe. The contrast image is formed line by line, one single image line is the line segment bisector defined by the centers of the two sub- groups of transmitting elements. The method was implemented in a programmable ultrasound system, the proof of principle is shown in vitro in a phantom mimicking the configuration of the scanning of a carotid artery. It is shown that the amplitude of the artifact relative to true contrast signal amplitude can be reduced by up to 13 dB compared to a conventional method based on amplitude modulation.

Thu 10:45 ESAL 1 NDE / NDT: material characterization

Effects of Interlayer Interfacial Stiffness on Ultrasonic Wave Propagation in Composite Laminates at Oblique Incidence – (Contributed, 000118)

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Carbon-epoxy composite laminates have been extensively used in mainly aerospace industries due to their advantages of high specific stiffness, high specific strength, low coefficient of thermal expansion, and so on. To ensure their structural safety, the ultrasonic nondestructive testing for their damage assessment and property characterization is necessary. It is well-known that polymer-based composite laminates have thin resin-rich regions between neighboring plies, and that such interlayer imperfections have significant influence on the mechanical performance of the layered structure. It is hence important to understand the effects of such regions on the wave propagation behavior so as to evaluate the soundness of interlayer interfaces ultrasonically. In this study, the propagation characteristics of ultrasonic wave impinging obliquely on carbon-epoxy composite laminates is analyzed theoretically. Assuming that the interlayer resin-rich regions can be modeled as spring-type interfaces with finite interfacial normal and shear stiffnesses and the unidirectionally reinforced plies as homogeneous anisotropic viscoelastic media, the amplitude transmission coefficients are calculated by the stiffness-matrix method. It is found that there are certain frequency ranges where the transmission coefficient takes almost zero, and that such frequencies depend on the interlayer interfacial stiffnesses. Using Bloch's theorem, the dispersion relation for the infinitely- layered structure is also calculated and compared with the transmission spectrum obtained above. This reveals that the frequency band-gaps seen in the dispersion relation agree well with the low-transmission frequency ranges of finite layered structure. The theoretical results are verified by comparing with the experimental transmission spectrum for an actual carbon-epoxy composite laminate.

Thu 11:00 ESAL 1 NDE / NDT: material characterization

Evaluation of Multiple Reflections in the Characterization of Anisotropic Materials by Through Transmission Ultrasonic Technique – (Contributed, 000167)

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Ultrasonic through-transmission techniques for determining the elastic constants of anisotropic composite materials have been widely used since the seventies. The usual methodology consists in measuring the time of flight of the transmitted ultrasonic wave inside a material sample for different incident angles, and then using this data to adjust the Christoffel tensor. Although this technique is well known, its application depends on the correct identification of the wave types inside the sample. This works presents a new characterization methodology that takes into account not only the transmitted waves but also the multiple wave reflections inside the sample. There are two main advantages of considering the multiple wave reflections. First, all superposition of different reflected waves are theoretically and experimentally identified, which facilitates the selection of the sub-sets of experimental data

without distortion caused by superposition. Second, the result of the Christoffel tensor optimization is evaluated both in the first transmission and in the reflected waves, improving the results validation. Experimental results using unidirectional carbon-matrix composite samples used in the aeronautical industry are presented. The elastic constants are obtained by minimizing the error between the experimental and adjusted propagation times. This approach is equivalent to the minimization of the error in the phase velocity. However, explicit formulas to compute de propagation time for multiple reflections are straightforward to obtain. In order to reduce the number of simultaneous parameters in the optimization process, a sensitive analysis is performed reducing from five to three the number of simultaneous parameters in the optimization.

Thu 11:15 ESAL 1 NDE / NDT: material characterization

Determination of Elastic Constants of Natural Fiber Composite Materials using Ultrasonic through - Transmission technique – (Contributed, 000276)

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The ultrasonic measurement of the elastic properties of anisotropic materials is an interesting research topic because it allows the accurate characterization of some composite materials. The use of composite materials has increased in recent years, specially in the aerospace and automotive industries, where parts of reinforced fiber composites are widely manufactured. However, the nondestructive characterization of these composites is a nontrivial and required task. In the case of reinforced natural fiber composites, an important type due to economic and environmental advantages, there is few information in literature about mechanical properties and the implementation of the ultrasonic characterization technique could be useful. This paper shows the application of the ultrasonic through-transmission technique to determine the elastic constants of fiber-reinforced polymer samples which contains vegetable fibers of two different types: coconut (cocos nucifera) and fique (furcraea andina). For preparing the samples, natural fibers were chemically treated to stimulate the compatibility between the epoxy matrix and the reinforced fibers. Velocity of the ultrasonic waves were obtained for unidirectional transversely isotropic samples (coconut-epoxy, fique-epoxy) using an experimental setup which allows for normal and oblique incidence. To calculate the elastic properties we solve the inverse problem associated using the Christoffel equation. A good agreement was obtained between the constants experimentally obtained and those estimated with the method of the rule of mixtures.

Thu 11:30 ESAL 1 NDE / NDT: material characterization

Forced Delamination Characterization of Glass Fiber Composites Using Terahertz and Ultrasonic Imaging – (Contributed, 000477)

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Glass fiber composite laminates with multi-layers in polyetherimide resin have been studied via terahertz and ultrasonic imaging. The forced delamination is created by inserting Teflon film between various layers inside the samples prior to consolidating the laminates. Using pulsed terahertz imaging, we find higher-resolution, low-artifact terahertz C-scan and B-scan images locating the delamination and even three-dimensional imaging results. Furthermore, with the terahertz time-domain waveform, we can also calculate the thickness of the delamination and of the layers constituting the laminate. Ultrasonic C-scan images are also successfully obtained, however, we failed to get effective ultrasonic B-scan images with both 5 MHz and 10 MHz transducers. Comparative analysis between terahertz and ultrasonic imaging results is carried out which proves that terahertz imaging can be used as an alternative or complementary modality to ultrasonic imaging to provide more information in depth and three-dimensional imaging for glass fiber composites.

Thu 11:45 ESAL 1 NDE / NDT: material characterization

Ultra resolution in acoustic imaging of bulk microstructure in solids – (Contributed, 000554)

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The paper subject is application of impulse acoustic imaging for displaying small-sized details of bulk microstructure in solids. The special attention is paid to elements, which sizes are much smaller than the probe ultrasound wavelength. Impulse acoustic visualization of internal microstructure in the bulk of solid specimens is performed in the dark-field regime - images are formed by echo pulses reflected from particular phase interfaces or scattered (diffracted) by small inclusions, trips and edges. The permanent background signal is lacking - the reference echo signal reflected at the specimen face does not participate in forming images of bulk microstructure. The dark-field regime is able to provide displaying small details of microstructure and their distribution over the specimen bulk - spatial resolution of the method is derived by efficiency of ultrasonic scattering at small obstacles and sensitivity of an ultrasonic radiation-reception system, but not by the probe radiation wavelength (ultramicroscopic technique). Such a technique is attractive when efforts are concentrated at revealing presence and location of bulk microstructure elements - microdefects, specific elements of volume structure in composite media and so on. Detailed knowledge of their configuration and architecture is not so important for these applications. In the paper the theoretical analysis of interaction of the probe ultrasonic radiation with diverse types of small inclusions, both acoustically soft and hard, has been done. Ultrasound interaction with soft obstacles that is much more effective than interaction with hard inclusions (the Rayleigh scattering proper) is main sources of acoustic contrast in acoustic images of bulk microstructure for diverse types of solid objects, including ceramic materials, ordinary composites and nanocomposite materials. Performed theoretical assessments have been employed for interpreting acoustic images of bulk microstructure in these materials.

Thu 13:45 ESAL 1 NDE / NDT: material characterization

Application of a full hybrid ultrasonic system to improve the steelmaking practices – (Contributed, 000377)

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Cleanliness is a key parameter for the fatigue performance of high loaded engineering steel, like those dedicated to gears or bearings. Depending on the loading conditions, the size, shape and density of inclusions govern directly the fatigue lifetime of components. For such application, the specifications of customers are more and more stringent. To cope with such requirements, the steelmakers continuously improve its steelmaking practices. One of the keys stages is the implementation of control techniques and quantification of the inclusion macro and meso cleanliness of products.
ABS centre métallurgique, R&D center of the ABS group, developed with Metalscan a full hybrid and automatic control system for characterizing by ultrasonic immersion with one installation the macro and the meso cleanliness of steels.
Two working modes are available: - Low-frequency ultrasonic control (10MHz - not focused probe). This control mode allows controlling the macrocleanliness of steels: in this case we deal with defects size superior or equal to 300microns of equivalent diameter. - The second possible mode is the high-frequency control (50MHz - focused transducer). This allows controlling the meso cleanliness of steels: defects which can go down up to 40microns.

This paper exposes the performances of the installation in terms of precision, sensibility, pooled volume, size of defect and time of analysis. The contributions of the high-frequency control with regard to the low frequency ultrasonic control and the conventional characterization techniques of steels are also explained.

The fine analyses obtained allow advanced study of the manufacturing processes as well as their optimization. Some applications will be presented more in detail. This technique adapted to the challenging markets allows handling the most demanding customers. It opens new perspectives in terms of product selection and experimental techniques development. It could also probably replace some technologies currently used by high quality steel grade customers.

Thu 14:00 ESAL 1 NDE / NDT: material characterization

Noise Filtering in the Synthetic Transmit Aperture Imaging by Decomposition of the Time Reversal Operator: Application to Flaw Detection in Coarse-grained Stainless Steels – (Contributed, 000410)

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In ultrasonic imaging, the Synthetic Transmit Aperture (STA) is a time-domain algorithm that provides an optimal focusing and spatial resolution everywhere in a region of interest. This algorithm is particularly interesting in non- destructive testing (NDT) to enhance the characterization of crack-type defects. In the present work, the STA technique is applied to coarse grained austenitic-ferritic steels of the nuclear industry using a contact phased array probe. The highly heterogeneous structure of these materials may produce a strong noise in ultrasonic imaging. Furthermore, interface guided waves interfere with the bulk waves. In order to overcome these problems, the method of Decomposition of the Time Reversal Operator (DORT) is applied before calculating the STA image. The DORT method consists of the analysis in the frequency domain, of the singular values and vectors of the inter-element impulse response matrix. The noise filtering is obtained by separating the signal sub-space from the noise sub-space for each frequency in the transducer band-width. The signal sub-space identification is based on cross-correlations of the singular vectors with a reference one (e.g., the singular vector at the central frequency or a theoretical one). Then a filtered matrix is built and an inverse Fourier transform is applied to return in the time domain. Finally, the STA algorithm is applied to the filtered matrix to form an image with a reduced structural noise. Experiments performed with coarse grained steel specimens demonstrate that the DORT filtering may improve the signal-to-noise ratio of 30 dB compared to the initial image.

Thu 14:15 ESAL 1 NDE / NDT: material characterization

Nondestructive Ultrasonic Inspection of Friction Stir Welds – (Contributed, 000579)

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Friction Stir Welding (FSW) is a relatively new solid state welding procedure developed at The Welding Institute (TWI-UK) and is widely considered for welding aluminum alloys in various applications. In order to inspect the quality of the welds and to detect a variety of welding flaws such as wormholes, Lack of Fusion (LOF) and Lack of Penetration (LOP) defects, it is required to develop a methodical examination technique that can be used for the identification and the localization of all such defects.
The most prevalent and risky defect in this type of welding is the unrevealed lack of penetration (also known as the root flaw with a length varying from 100-700 μm). Due to the characteristics of the flaw, conventional ultrasonic methods are not always able to readily detect such fine Lack of Penetration (LOP) defects.
Here, we propose a novel approach to characterize root flaws using an oblique incident ultrasonic C-scan backscattering analysis. The implementation consists of an immersion ultrasonic testing method in pulse echo (i.e. backscatter) mode with a 3.5 MHz transducer, and makes use of an empirical method to allow focusing and gating the received signal for root flaw examination. By scanning the surface above the welded component, a "slanted C-scan" image, displaying the backscattering response from the root surface of the nugget zone, can be obtained which allows a simple interpretation of the root flaw status of the weld.

Thu 14:30 ESAL 1 NDE / NDT: material characterization

High Frequency Acoustic Sensor dedicated to the High Resolution Measurement of Mechanical Properties – (Contributed, 000183)

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The quantification of mechanical properties of a medium at a micro-meter scale is possible thanks to surface waves, mostly Rayleigh waves, generated by a high frequency focused sensor in an acoustic microscope. Despite being quite effective, this method requires many acquisitions at different focus plane for a single point mechanical property evaluation. This means acquiring a 3D acoustic image data set in order to reconstruct a 2D image of the mechan-

ical properties and, regarding time, it is hardly adaptable on a macroscopic scale. This is why a solution was to be found to consequently speed up the method.
The considered solution was to design a multi-element sensor with a spherical lens which would allow extracting information on Rayleigh waves with a reduced number of acquisitions.
The work is conducted on two axes. As a first step, a model allowing to simulate the behavior of acoustic waves at a fluid/solid interface using this new kind of sensor is realized. This model will lead to a better understanding of the characterization of mechanical properties and to the optimization of the focused transducer. In a second step, an experimental method for acoustic field reconstruction is used to measure mechanical properties of materials with this new device.

Thu 14:45 ESAL 1 NDE / NDT: material characterization

Assessment of Thermal Aging of Aluminum Alloy by introducing the Cumulative Ultrasonic Nonlinear Parameter – (Contributed, 000324)

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The second-order ultrasonic nonlinear parameter β has been studied for the evaluation of material degradation. However, there are some limits to the assessment of thermal aging of aluminum alloy due to the fluctuation in the value of nonlinear parameter β with the aging time, which is because the value of nonlinear parameter β strongly depends on the behavior of precipitate that can evolve and dissolve while exposed to high temperature. That is, the value of the nonlinear parameter does not one-sidedly increase with the thermal aging. In this case, it is difficult to evaluate the damage level from the measured value of the nonlinear parameter. In order to overcome such limitation, we propose a new parameter β_c which is defined by accumulation of the measured nonlinear parameter β over the aging time. In order to verify the usefulness of the proposed parameter, the relative nonlinear parameters were measured in aluminum alloy specimens heat-treated with different aging temperature and aging time, and their accumulated values were obtained in accordance with the aging time. Thereafter, the tensile tests were conducted to obtain the stress-strain curves of all specimens, which provided information on the strength variation induced by thermal aging. Results showed that the cumulative nonlinear parameter one-sidedly increased in accordance with the aging time, which was agreed well with the reduction in the strength.

Thu 16:15 ESAL 1 NDE / NDT: material characterization

Thickness Measurement of Nikel Thin Film using Dispersion Characteristics of Surface Acoustic Wave with Scanning Acoustic Microscopy – (Contributed, 000547)

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Surface acoustic wave has a dispersion characteristics in multilayered thin film structure. Using this characteristics, we nondestructively measured the surface acoustic wave velocity of thin film for the thickness measurement by V(z) curve method of scanning acoustic microscopy and compared the results with the dispersion curves. To verify this method, we deposited Ni thin film on the Si(100) substrate with different thickness(200, 400, 600, 800, 1000nm) using DC magnetron sputtering process. The thickness of Ni thin film was measured by scanning electron microscope. Surface wave velocity of thin film decreased as the film thickness increased and it was similar to the dispersion curve results. Consequently, the thickness of thin film can be determined by measuring the surface acoustic wave velocity and simulating the surface acoustic wave dispersion curve.

Thu 16:30 ESAL 1 NDE / NDT: material characterization

Photoacoustic Study of Optical Properties of Thin Silicon Films – (Contributed, 000476)

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Until now, there has been no practical alternative for silicon as a basic material for nano- , microelectronics, microelectro-mechanical systems, etc. Thus, the difficulties of bulk silicon application in optoelectronic and photovoltaic devices are main deceleration factor in their efficiency improvement and costs reduction. From another point of view, thin film of nanocrystalline (with the crystallite sizes 2-5 nm) and amorphous silicon has serious advantages over bulk silicon. In particular, the direct band gap of such materials makes them perspective for photovoltaic applications. However, the investigation of optical properties of strong absorbed silicon films (with 200-300 nm thickness range) by convenient methods is problematic.
Since the magnitude of photoacoustic signal is proportional to the absorbed light energy, we applied photoacoustic technique to study optical properties of thin silicon films deposited on the glass substrate. The piezoelectric configuration was chosen to ensure best sensitivity of the technique. This allows us to evaluate absorption coefficients of thin amorphous films with the nanocrystalline fraction. The obtained results were in good correlation with the results estimated from the optical transmittance and ellipsometric measurements.

Thu 16:45 ESAL 1 NDE / NDT: material characterization

Thermal Elasticity Stresses Study in Composite System 'Porous Silicon - Liquid' – (Contributed, 000472)

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Nanocrystalline porous silicon and its various modification are successfully applied in different area of modern material research. In particular, these materials are widely used in the devices of micro-, nano-, optoelectronics, sensorics etc. However, the formation of porous silicon is stochastic, therefore, development of methods of this process in-situ study is crucially important.
In this report, study of the elasticity stresses in the composite system "porous silicon - low viscount fluid" will be discussed. For this purpose, photoacoustic technique with piezoelectric registration was applied. It was shown that thermal induced pressures of liquid in the pores and its relaxation influenced dramatically on the time-domain shape of photoacoustic signal.

Moreover, these thermally induced pressures were observed in the process of porous silicon preparation. The dependence of theirs magnitude and time delay on the etching conditions and parameters of porous silicon was stated. Thus, the experimental results and numerical simulations give us the possibility to investigate the process of porous silicon formation in real time.

Thu 13:45 Citadelle 1 Bio-medical: Microbubbles and contrast agents

Nanoparticle-Shelled Microbubbles Used for Medical Ultrasound Harmonic Imaging – (Contributed, 000008)

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The nonlinear property of gas bubble is important for microbubble used as medical ultrasound imaging contrast agent. And many technologies have been proposed to enhance the harmonic and subharmonic emission ability of the microbubble, such as increasing the exciting sound intensity, employing the dual-frequency pulse and so on. In this study, nanoparticle-shelled microbubbles with strong nonlinear character are prepared and their backscatter behaviors when they attach to an ultrasound transparent membrane or move freely in liquid are investigated as well. The three different kinds of microbubbles are, 1) encapsulated with Tween80 and Span60 surfactant, 2) same as 1 but with oil-soluble particles attached to inside of the surface, 3) same as 1 but with water soluble particles attached to the outside of the surface. The nanoparticle is 4 nm diameter FeO particle coated with oleic acid (oil soluble) or DMSA (water soluble). For the both cases of free-moving and attached, the MBs-oil-particles possess excellent nonlinear acoustic properties and longer life time than the MBs without nanoparticles. This may be due to the reason that the nanoparticles attached on the surface affect the vibrating habit and the viscoelastic property of the microbubbles surface.

Thu 14:00 Citadelle 1 Bio-medical: Microbubbles and contrast agents

Dynamic behaviour of microscopic antibubbles encapsulated by Newtonian fluids – (Contributed, 000031)

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An antibubble consists of a liquid droplet, surrounded by a gas, often with an encapsulating shell. Antibubbles of microscopic sizes suspended in fluids are acoustically active in the ultrasonic range. The objective of this study is to understand the dynamics of micron-sized antibubbles encapsulated by a shell consisting of a Newtonian fluid subject to 2.5 MHz ultrasound. The theoretical behaviour of an encapsulated antibubble is compared to that of an antibubble without an encapsulating shell, a free gas microbubble, and an encapsulated gas microbubble. We derived a Rayleigh-Plesset-like model for antibubble dynamics to study the radial pulsation, where droplet core sizes are in the range of 0-95% of the equilibrium antibubble inner radius at mechanical indexes of 0.1 (low), 0.3 (intermediate) and 0.6 (high). We found that the antibubble resonance frequency, the phase difference of the radial oscillations with respect to the incident acoustic pulse, and the presence of higher harmonics are strongly dependent of the core droplet size. The influence to the radial dynamics from a zero-thickness shell is significant for the bubble sizes analysed. At high acoustic amplitudes antibubbles oscillate highly nonlinearly independent of the core droplet size. Therefore, antibubbles of microscopic size might be suitable for harmonic imaging in a clinical setting or ultrasound-guided drug delivery.

Thu 14:15 Citadelle 1 Bio-medical: Microbubbles and contrast agents

Experimental Method for Microbubbles Dynamics Monitoring and Radius Sizing – (Contributed, 000376)

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Rationale and aim: Within the context of divers desaturation accident prevention, ultrasonic detection and sizing of circulating microbubbles in blood is of great interest. In order to be representative of the divers health and thus, to optimize decompression stages, the measurements should be performed during a short period of time (<20 ms), efficient to detect a broad range of bubbles' radii population (radius from 20 to 200 μm) and harmless (MI<0.3).
Materials and methods: Based on a bi-frequency ultrasound excitation, the purpose of our method is to measure the relative and the absolute microbubble size variations. Because of our research interests, the experimental investigations were conducted on natural microbubbles, with radius ranging between 20 and 200 μm, excited around their resonance frequencies by a low frequency transducer. Different types of excitation were tested (sweep, burst, pulse). A pair of high frequency transducers were arranged to focus at a common point. One of the transducers was used to transmit a 2 ms long, high-frequency (1 MHz) pulse while the other was used to passively receive backscattered signals. The scattered signal was visualised on a digital oscilloscope and transferred for offline calculations. Signal treatment were conducted in order to recover the amplitude and frequency modulations.
Results: Using the same experimental setup, simple signal processing applied on both the amplitude and the frequency modulations leads to a double characterization of the microbubble dynamics. Moreover, under the assumption of small radial oscillations, the equilibrium radius of the microbubble can be accurately estimated.

Thu 14:30 Citadelle 1 Bio-medical: Microbubbles and contrast agents

Optimized bias voltage modulation sequence for cmut and nonlinear contrast imaging – (Contributed, 000426)

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Rationale and aim: In the field of ultrasonic contrast agent imaging, Capacitive Micromachined Ultrasonic Transducer (cMUT) are of great interest because of their wide frequency bandwidth. However, due to their intrinsic nonlinear behaviour, their use with classical nonlinear imaging techniques (pulse inversion, amplitude modulation, harmonic imaging...) is still limited. Different approaches have been proposed to supress the nonlinear part of the emitting signal from a cMUT. Recently, a new imaging sequence called Bias Voltage Modulation (BVM) [1] has shown very good potential but is limited to the conventional regime of the probe (well below the collapse voltage). Thus the probe's sensitivity is not optimized.

Materials and methods: An improved version of the BVM sequences is proposed to allow the use of bias voltages close to the collapse voltage. The principle is to change the coefficients associated with the successive pulses of the sequence. Experiments have been performed using a 128-element cMUT probe connected to an open scanner. For microbubbles measurements, Sonovue contrast agents have been imaged through a flow phantom. A contrast to tissue ratio (CTR) and a signal to noise ratio (SNR) were calculated to assess the efficacy of the new approach.

Results: The application of BVM sequence with new coefficients show an increase of the CTR of 19 dB at high bias voltage (90% of the collapse) compared to the classical BVM [1] sequence. Due to the high sensitivity of the probe in this regime, the SNR is also increased by 9 dB. These results reveal that the BVM sequence can be optimized further and applied at bias voltage close to the collapse and thus fully exploit the potential of the cMUT technology for contrast agent imaging.

[1] Anthony Novell et al, 2014, Phys. Med. Biol. Vol59, p48-79.

Thu 13:45 ESAL 2 Naval, marine and underwater ultrasonics

Single Particle Scattering used for characterization of Suspended Sediments – (Contributed, 000187)

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The investigation of sediment transport by use of ultrasound scattering technique demands knowledge about ultrasound interaction with irregularly shaped bodies. Even for low concentration suspensions of sand in water, the nature of the individual sand particles starts to play a dominant role in the scattering process. By mathematical modeling of scattering from single particles, the different particle shapes may be grouped as regular or as irregular. A typical and frequently used regular shape of a single particle is a sphere. One of the available approaches to investigate the irregularly shaped targets is to consider targets of symmetry like spheres, and to introduce a specific surface roughness. This is done in this paper. Another approach to irregularly shaped particles is to consider the particle surfaces as being composed of angular facets and edges. The cube, which is the simplest symmetrical shape for description of the influence of facets and edges on the scattering process, has also been used in the study behind this paper. The general aim of the studies to be presented is to develop a model for description of ultrasonic scattering from irregularly shaped individual particles. Laboratory experiments have been used to verify the theoretical and numerical predictions.

Thu 14:00 ESAL 2 Naval, marine and underwater ultrasonics

Processing signal of side-scan sonar for a sea bottom imaging – (Contributed, 000017)

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In this paper authors researched problems about construction of sonar images which based on signal from side-scan sonar. Authors use explicit formula for signal processing which was get from the kinetic model. It based on integro-differantional radiative heat transfer equation. It includes influence of volume scattering in the medium. Moreover, authors use an additional filter for signal. It is logarithm-filtration. Nowadays, a lot of autonomous unmanned underwater vehicles (AUV) was created in the Institute of Marine Technology Problems FEB RAS (IMTP). They allowed to solve different problems. There are mapping the seabed, monitoring of underwater constructions and mineral exploration. Sonar image is constructed by signal from side-scan sonar (SSS) which is located at AUV. Authors chooses the phenomenological approach, which based non-stationary integro-differential transfer equation for density distribution of sound waves with applicable boundary and initial conditions. Further, author researches the problem of determining of scattering properties of seabed by signal from SSS which moves with constant velocity along a predetermined path. Moreover, author deduces the equation for determining of coefficient of seabed scattering. Further, author analyzes it using narrow-beam antenna and single scattering in the medium.

The main emphasis for authors is analyzing of the influence of volume scattering to the accuracy of determination the bottom scattering coefficient. The analytical results are supported by numerical experiments on the real data. Moreover, authors developed the logarithm-filtration algorithm for construction of sonar images. Thus, authors performed a series of numerical experiments which prove the efficiency of model. Deducing explicit formula includes the volume scattering in the medium. Moreover, combination with the additional filter gives the best result for visualization of SSS-signal.

Thu 14:15 ESAL 2 Naval, marine and underwater ultrasonics

Shape-Preserving Accelerating Underwater Acoustic Beams – (Contributed, 000153)

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We present the first experimental generation of an underwater acoustic shape- preserving accelerating beam. The beam exhibits transverse acceleration along a parabolic trajectory whilst preserving its cross-sectional shape. These features are exhibited along a propagation range of more than 800 wavelengths, which is in excess of 6 Rayleigh lengths of propagation of a Gaussian beam. The beam is generated in the Rafael Underwater Test Facility using a tailored phase mask and a single projector. Such beams have promising applications in the fields of SONAR, hydrography, medical ultrasound, and microparticle manipulation, and could provide new means to study non-linear interactions of acoustic beams.

Thu 15:30 Claude Lefebvre Phononic crystals and metamaterials

Towards Reconfigurable Acoustic Metamaterials – (Invited, 000611)

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Acoustic metamaterials capture the imagination with breathtaking promises of super-resolution in imaging and invisibility cloaking. Here we describe a new class of acoustic metamaterial that is reconfigurable in real-time and demonstrate its ability to rapidly alter its frequency filtering characteristics. Our reconfigurable acoustic metamaterial is made up of micrometre-sized polystyrene spheres suspended in controllable patterns within a fluid and held in place with acoustic radiation forces. The acoustic radiation force is governed by an energy landscape, determined by an applied high amplitude acoustic standing wave field, in which particles move swiftly to energy minima. Here we use five ultrasonic sources to from an energy landscape that resembles a crystal lattice. This creates a metamaterial with spheres arranged in an orthorhombic lattice in which the acoustic wavelength can be used to control the lattice spacing. When illuminated with acoustic waves, the new metamaterial is shown to exhibit a complex distribution of band-pass and band-stop frequencies in-line with simulation, which can be adjusted in real time.

Thu 16:00 Claude Lefebvre Phononic crystals and metamaterials

Experimental demonstration of Epsilon-Near-Zero water waves focusing – (Contributed, 000490)

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We demonstrate experimentally the ϵ-near-zero (ENZ) analogue for water waves in the nonlinear regime. In the context of electromagnetic waves, ENZ media are known to realize super lensing effect, because they are associated to very large wavelength. A lens made of such material with, say, circular edge shape, produces focused waves at the center of the circle (focal point of the lens). In the context of water waves, we demonstrate the analog of these media by tuning the bathymetry of the bottom sea owing the analogy between electromagnetic waves:

$\nabla\left(\frac{1}{\epsilon}\nabla H\right)+\omega^2\mu H=0,$

(with ω the frequency, H the magnetic field, ϵ and μ the permittivity and permeability respectively) and water waves in the shallow water regime

$\nabla (h\nabla\eta) + \frac{\omega^2}{g}\eta = 0$,
Experimentally, we obtain uniform phase of the water wave at the edge of the semi circular lens, resulting in the expected lensing effect. By using time space resolved measurement of the two dimensional field of surface elevation, we are able to separate the linear component of the wave and the harmonics generated by non linearities. Interestingly, we observe a cascade of highly focused harmonics. These harmonic components are analyzed in term of free-waves and bound-waves, revealing the predominance of free waves.

Performed experiments suggest that ENZ analogy could be used in a real life application, where one could design bottom surface of the ocean coast to focus water waves very efficiently.

Thu 16:15 Claude Lefebvre Phononic crystals and metamaterials

Controllable Acoustic Rectification in Piezoelectric Composite Structures with Different Electric Boundary Conditions – (Contributed, 000247)

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Different one-way transmission structures for elastic waves have been reported during the past years. It is worth noting that most modes conversion and selection mechanisms are based on different elastic structures. Obviously, it is necessary and troublesome to change the elastic structures of models in order to reverse the direction of one-way transmission or break the one-way transmission mechanism. Here, a simple piezoelectric composite structure model is proposed to achieve one- way transmission or other status without changing any elastic structures. Theoretical studies are presented for the band structures and power transmission spectra for both symmetric and asymmetric Lamb wave modes in a one-dimensional piezoelectric composite plate consisting of piezoelectric ceramics placed periodically in epoxy by the plane wave expansion method and the harmonic response analysis method, respectively. The one-way transmission, two-way transmission, and two-way forbidden models of acoustic rectification for Lamb waves can be established in specific frequency ranges by introducing corresponding modes conversion and selection mechanisms, and the steady-state displacement fields of these models are also calculated for the proposed plate. The numerical results show that the power extinction ratio for one-way transmission model is up to 10^4. The piezoelectric composite plate can be switched between these models rapidly and efficiently only by applying the open-circuit and short-circuit electric boundary conditions antisymmetrically or symmetrically on the piezoelectric ceramic unit's boundaries instead of changing any geometrical structure.

Thu 16:30 Claude Lefebvre Phononic crystals and metamaterials

Quasistatic Band Gap and Other Unusual Features in Electrically Tunable Piezoelectric 1D Phononic Crystals – (Contributed, 000456)

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Electroded piezoelectric layers are known to have different dynamical behaviours according to the type of electrical connections of the electrodes (open/short-circuit or linked by an electrical impedance). This principle is very often used in noise and vibration control. Some works of the nineties showed that structures involving identical piezolayers separated periodically by thin metallic electrodes may exhibit Bragg scattering due to induced internal electric conditions at the electrodes (zero electric potential for instance) [1]. More recently, it has been experimentally reported that the band-structure of such phononic piezoelectric crystals (PPC) may be tuned when connecting the electrodes with varying impedances (here capacitors) [2]. The main focus of the present theoretical study is to infer the peculiarities of the low-frequency Floquet spectrum of longitudinal waves through such a tunable PPC according to the value of the electrical capacitance C. Using recent derivations on the effective properties of such PPC [3], it is shown that if $C < 0$ then the Floquet-Bloch spectrum $\omega(K)$ in a certain range of negative C may possess a quasistatic absolute stopband starting at $\omega = 0$. Other unusual features of the spectrum occurring at certain fixed values of $C < 0$ are the infinite group velocity of the first branch at the origin point $\omega = 0$, $K = 0$ and the flat bands $\omega = \text{const}$.

[1] V.I. Alshits & A.L. Shuvalov, JETP 76(4), 663-670 (1993) [2] S. Degraeve et al., J. Appl. Phys. 115, 194508 (2014) [3] A.A. Kutsenko et al., accepted in J. Acoust. Soc. Am. (2014)

Thu 16:45 Claude Lefebvre Phononic crystals and metamaterials

Optimization of a tunable piezoelectric resonator using phononic crystals with periodic electrical boundary conditions – (Contributed, 000057)

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Piezoelectric phononic crystals with periodic electrical boundary conditions exhibit Bragg band gaps. Electrical boundary conditions influence the frequency range of the gap which can also be switched on or off for short or open circuit conditions respectively. Piezoelectric stacks with periodic electrical boundary conditions are used to design a Fabry-Perot cavity. The design of the device enables a spatial shift of electrical boundary conditions and a modification of cavity length. As the frequency resonance of the cavity depends on its length, the resonator is tunable and a frequency shift is obtained. An analytical model based on a transfer matrix formalism is used to model longitudinal wave propagation inside the structure. Analytical results are completed by finite element simulations. Cavity length, phononic crystal and transducer position are optimized to increase resonance and antiresonance frequency shifts as well as coupling coefficient. Numerical and experimental results are presented and discussed

Thu 17:00 Claude Lefebvre Phononic crystals and metamaterials

Negative Refraction of Lamb Waves – (Contributed, 000473)

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Negative refraction has received a considerable attention since the seminal work of Pendry in 2001. A negative index material is defined as a material in which the wave vector is antiparallel to the energy flux direction.
Negative refraction has paved a way towards the notion of perfect lens and the ability of overcoming the diffraction limit. It has also given rise to the notion of complementary media and the ability to cancel the propagation of waves by adjoining two region of opposite refractive indices. Recently, Bramhavar et al. have demonstrated negative refraction of Lamb waves. Designing a plate with a stepped thickness change, they have been able to convert a mode of positive phase velocity into a mode of negative phase velocity, hence mimicking negative refraction.

Here, we propose to implement several devices based on negative refraction that allows to manipulate guided Lamb waves in unusual ways. In particular, a flat negative refracting lens and a negative corner resonator have been designed and implemented experimentally. Such devices are investigated theoretically, numerically and experimentally.

Thu 16:00 Gouv Granular and inhomogeneous media: General

Full Transmission and Reflection of Waves Propagating through a Maze of Disorder – (Contributed, 000475)

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Multiple scattering of waves in disordered media is often seen as a nightmare whether it be for communication, imaging or focusing purposes. The ability to control wave propagation through scattering media is thus of fundamental interest in many domains of wave physics, ranging from optics or acoustics to medical imaging or telecommunications. Thirty years ago, it was shown theoretically that a properly designed combination of incident waves could be fully transmitted through (or reflected by) a disordered medium. Although this remarkable prediction has attracted a great deal of attention, open and closed channels have never been accessed experimentally.
Here, we study the propagation of elastic waves through a disordered elastic waveguide. Thereby, we present experimental measurements of the full S-matrix across a disordered elastic wave guide. To that aim, laser-ultrasonic techniques have been used in order to obtain a satisfying spatial sampling of the field at the input and output of the scattering medium. The unitarity of the S−matrix is investigated and the eigenvalues of the transmission ma-

trix are shown to follow the expected bimodal distribution. Full transmission and reflection of waves propagating through disorder are obtained for the first time experimentally. The wave-fields associated to these open and closed channels are imaged within the scattering medium to highlight the interference effects operating in each case.

Thu 16:15 Gouv Granular and inhomogeneous media: General

Multiple scattering filter: application to the plan defect detection in a nickel alloy media – (Contributed, 000050)

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The ultrasonic inspection of polycrystalline media remains a challenge. The high noise levels due to the interaction between the wave and the microstructure limit the efficiency of classical ultrasonic techniques to detect a defect in a coarse grain structure. The aim of this work is to reduce the influence of multiple scattering in order to increase the information obtained from the defect. The new technique introduced in this presentation is based on array probes for the acquisition of the medium's response matrix by full matrix capture, after which a filter based on random matrix theory is applied. Here the technique is used on a nickel alloy block that presents an unfavorable grain structure and a well known plane defect. In this paper, the results of this new technique, with an angle array probe of 128 elements and 5 MHz of central frequency are compared to classical phased array probe techniques.

Thu 16:30 Gouv Granular and inhomogeneous media: General

Propagation of Ultrasound Impulse in Soft Crystals – (Contributed, 000159)

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The only source of quartz sand is the broken quartz crystal Recent field experiments and researches showed process of formation crystalline trace of completely water-saturated small quartz sand at seepage of water from the saturated massif.The crystal pattern is observed also at wash out the old dense sandy massif formed under water. In soft crystals a number of acoustic researches are carried out - velocity of propagation and spectra of ultrasound impulse (25 kHz) depending on humidity, distance between sensors and from filtration existence is measured. Two velocities of propagation simultaneously in the two-phase media are well visible-they are the first and second wave of Biot The moment of the beginning of an incensing filtration and simultaneous disappearance of the second wave allows explaining some not understood results of monitoring between boreholes.

Thu 16:45 Gouv Granular and inhomogeneous media: General

Multiple Scattering of Elastic Waves in Unidirectional Composites with Coated Fibers – (Contributed, 000502)

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Elastic wave transmission characteristics in unidirectional fiber-reinforced media, consisting of elastic cylindrical fibers arranged in an infinitely extended elastic matrix, are studied numerically by accounting for the multiple scattering effects. The numerical analysis is based on the eigenfunction expansion of the displacement potentials and the numerical collocation technique to obtain the expansion coefficients (Sumiya et al., Wave Motion 50 (2013), 253-270). In the previous analysis, the fibers are assumed to be directly bonded to the matrix. In the present study, the formulation is extended to incorporate the multilayered nature of fibers. The transmission characteristics of plane P and SV waves in a unidirectional composite with square array of fibers are demonstrated for the cases where the fibers are directly bonded to the matrix and where there is a coating layer between each fiber and the matrix. The numerical results are shown to be in good agreement with the foregoing analysis based on the finite element method. The square array of fibers gives rise to the reduction of the energy transmission at a certain range of frequency, which

is analogous to the stop bands in periodic structures. The influence of the presence of the coating layer as well as its stiffness on the transmission spectrum is discussed. The findings of this study can be relevant to the nondestructive characterization of composite materials whose fiber-matrix interfaces have imperfections or can degrade under excessive service conditions.

Thu 17:00 Gouv Granular and inhomogeneous media: General

Density of states and level statistics of brazed aluminum beads – (Contributed, 000141)

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We investigate the vibrational density of states (DOS) of sintered aluminum beads. The DOS is a fundamental intrinsic property of any system, and can strongly influence ultrasound propagation in a system with scatterers in contact. Sintered aluminum bead samples were chosen for study since they constitute the first three-dimensional system to exhibit Anderson localization of ultrasound.
The DOS was measured directly by counting modes in the frequency domain experimentally. Also, mode counting was also performed using COMSOL simulations (FEM). The total number of modes is proportional to the number of beads in a sample. The DOS was approximately independent of frequency below the first resonant frequency of a single bead; on the other hand, the overall frequency dependence was found to be consistent with traditional DOS models at higher frequencies. As the sample size increases, pass bands are formed around the eigenmodes of a bead, as in the tight binding model of electronic energy bands. When the coupling between beads is not too strong, band gaps are formed, where the DOS drops to zero, at frequencies between the pass bands.
This systematic study allowed the conditions to be determined under which level repulsion occurs. For a single bead, the probability distribution of normalized nearest neighbour level separations is close to the Poisson distribution. When the sample is larger and there are more modes, they start to overlap and repel each other so that level repulsion effects become important. Consequently, the level statistics were observed to become closer to GOE predictions as the sample size increased.

Thu 16:00 Saint Pierre NDE / NDT: General II

Evaluation of Industrial Ferritic Steel Boiler Pipes With Creep Damage by EMAR Ultrasonic Attenuation Changes and RUS – (Contributed, 000591)

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Industrial boiler piping of fossil-fuel combustion is exposed to high- temperature and high-pressure environments and failure of piping due to the creep damage has been a concern. A periodic evaluation of the internal defects of material and its mechanical properties, the integrity of the system can be prevented from an unexpected failure. Therefore, a rapid, nondestructive, precise creep damage assessment method of pipes is desired in the field. At the present work, changes in the ultrasonic attenuation and elastic constants in boiler piping of ferritic steel, which failed by the fracture in-service due to the creep phenomenum confirmed by the creep test, were evaluated by the resonance ultrasound spectroscopy (RUS) and with the electromagnetic acoustic resonance (EMAR) methods. A total of ten sections of pipes from an industrial boiler in-service at an oil refinery, taken from the close of fractured region, the hottest region and also taken far from the fractured region, were investigated by the X-ray diffraction, X-ray fluorescence, microhardness testing, imaging by SEM coupled with EBSD, crystal phases determination of submicron segregation by the EBSP analyzing Kikuchi pattern. The two representative samples were prepared in parallelepiped shape and their elastic constants were analyzed by the RUS method at room temperature using the tripod technique. Ultrasonic attenuation measurements were conducted by the EMAR technique in sections of boiler pipe at Osaka University, in Japan. After measurements with RUS method, assuming that the ferritic steels are isotropic, using the inverse calculation method, all the vibration modes were determined and the elastic constants were obtained. As a result, the elastic constant C11 changed from 273.169GPa to 278.799GPa for samples extracted far and close to fractured region; respectively. On the other hand, and C44 showed a slight decrease. Evaluation of sections of boiler pipe with and without creep damage with EMAR, showed substantial changes in the values of ultrasonic attenuation coefficient. Detailed numeric results ultrasonic attenuation coefficient, elastic constants and materials characterizations show potencial application of EMAR techniques in the field.

Thu 16:15 Saint Pierre NDE / NDT: General II

A Void Fraction Characterisation by Low Frequency Acoustic Velocity Measurements in Microbubble Clouds – (Contributed, 000329)

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The fourth generation of nuclear reactors cooled by liquid sodium (Sodium Fast Reactor) - currently under study at CEA - has a normal presence of microbubble clouds in the primary sodium. Methods of characterisation of this microbubbles presence are under development because although innocuous from neutronics and thermal-hydraulics point of view, it may affect the ultrasonic methods deployed throughout the liquid sodium for monitoring and inspection. This paper presents the application of low frequency acoustic velocity measurements on microbubble clouds generated in water. This method, based on the well-known Wood's model links the acoustic velocity throughout a two-phase medium to its void fraction value. Low frequency means below resonance frequencies of the bubbles inside the cloud. For an example, a bubble of radius 10 μm has a resonance frequency of 330 kHz. An original bench - ACWABUL - was developed to allow the qualification of this method. The experiments conducted - the results of which are presented here - allowed us to characterize void fraction values between 10^{-3} and 10^{-7}. The radii of the studied microbubbles are between a few micrometers and a hundred micrometers. The transposition studies of the method to high temperature liquid sodium will be discussed; particularly the difficulty - about to be solved - to generate microbubbles in this medium and the problem of the ultrasonic transducers compatibility. Finally, development perspectives of more complex acoustic techniques for the characterization of multiphase media will be presented.

Thu 16:30 Saint Pierre NDE / NDT: General II

Monitoring Local Solids Fraction Variations in Multiphase Flow Using Pulse-Echo Ultrasound – (Contributed, 000119)

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Multiphase flows, such as particle suspensions are present in a variety of industrial applications and often the monitoring of both the solids fraction and velocity of the particle phase is of interest. There are several techniques available for measuring particle velocities (e.g. ultrasound Doppler or cross-correlation techniques) and global solids fractions (attenuation-based methods).
These techniques can be useful monitoring tools for example in situations where prevention of sedimentation is important or when particle trapping is part of the process (e.g. wet low-intensity magnetic separation in the mining and aggregates industry).
In previous work, we showed that particle velocity profiles can be estimated from backscattered ultrasound, even in flows with a high solids concentration. In previous work, we also showed that, based on short-time spectral analysis of the same backscattered sound, that variations in local solids concentration can be visualized.
In this paper, we extend the previous results and demonstrate how the changes in spectral content of the backscatter signal can be explored in order to follow local solids fraction variations. Specifically, we show that the both the backscatter intensity and the bandwidth of the backscatter signal depends on local and global solids concentration. We also describe how the same configuration can be used to measure also particle velocity profiles.
For demonstration, a magnetite suspension carrying 7-30 wt-% particles (1.7- 6.7 vol-%), mean particle size 34 μm) is pumped through a closed rectangular channel. When the pump is stopped, pulse-echo ultrasound (with a centre frequency of 2.25 MHz) is used to monitor the sedimentation process. The backscattered signal is acquired at a pulse-repetition frequency of 200 Hz, which enables us to study rapid variations in local mass fractions.

Thu 16:45 Saint Pierre NDE / NDT: General II

Modular Ultrasound Array Doppler Velocimeter with FPGA-based Signal Processing for Real-time Flow Mapping in Liquid Metals – (Contributed, 000388)

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Investigating the complex interaction of conductive fluids and magnetic fields is relevant for a variety of applications from basic research in magnetohydrodynamics (MHD) to modeling industrial processes involving metal melts, such as the crystal growth process in the photovoltaic industry. This enables targeted optimizations of the melt flow and allows to significantly increase the yield and energy efficiency of an industrial process. However, experimental studies in this field are often limited by the performance of flow instrumentation for opaque liquids.
We present an ultrasound array Doppler velocimeter (UADV) for flow mapping in opaque liquids at room temperature. It is modular and flexible regarding its measurement configuration, for instance it allows capturing two velocity components in two planes (2d-2c). It uses up to 9 linear arrays with a total element count of 225, driven in a parallelized time division multiplex (TDM) scheme. A FPGA-based signal pre-processing allows to handle the massive data bandwidth of typ. 1.2 GB/s and enables a continuous and near-realtime operation of the measurement system. Combining the velocity information of multiple arrays necessitates precise knowledge of their relative geometric position. We present a novel method for spatial self-calibration by a mutual time of flight measurement that significantly reduces the alignment errors.

The capabilities of the UADV system are demonstrated in a basic MHD research experiment with a metal melt (GaInSn) in a cubic container. The flow induced by a rotating magnetic fields is captured with a temporal resolution of $250\,ms$ for the horizontal and vertical central cross-section of the cube.

Thu 9:30 Main Hall — Acoustic Metamaterials: fundamentals, applications and emerging topics (poster)

Acoustic superfocusing by solid metamaterials for subwavelength imaging – (Contributed, 000049)

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Acoustic imaging is an essential tool for medical screening as well as for detecting the structure and composition of matter. The resolution of a conventional acoustic imaging device is limited by the fundamental diffraction limit to half working wavelength [1]. Imaging resolution below this limit requires measuring the evanescent wave with high spatial frequency, which carries information about the object's fine features but vanishes away exponentially from the object in all natural materials. To overcome this limit, several proposals were dealt, with structured acoustic metamaterials (AMM). The latter have shown, based on their very unique effective properties, the possibility to manipulate the evanescent wave and then contribute to improving imaging resolution [2-3]. AMM with appropriate resonances induced into their constituent building blocks, exhibiting either negative effective mass density or bulk modulus or both have been demonstrated [3]. These unique properties rise from strong coupling of the propagating elastic wave in the hosting medium with the localized resonance in the building blocks. In this work, we propose a solid metamaterial lens capable of acoustic superfocusing beyond the diffraction limit. The unit cell of the crystal is formed by four rigid cylinders in a hosting material with a cavity arranged in the center. Theoretical studies reveal that the solid lens produces both negative refraction to focus propagating waves and surface states to amplify evanescent waves. Numerical analyses of the superfocusing effect of the considered solid lens are presented with a separated source excitation to the lens. In this case, acoustic superfocusing beyond the diffraction limit is evidenced. Compared to the fluid phononic lenses, the solid lens is more suitable for ultrasonic imaging applications.

References 1. Y. Cheng et al, APL, 103 (2013) 224104. 2. S. Zhang et al, PRL, 102 (2009) 194301. 3. J. Zhu et al, Nature Physics, 7 (2011) 52.

Thu 9:30 Main Hall — Instrumentation and signal in acoustics (poster)

Nondestructive Detection of Air Traces in the UHT Milk Package by Using Ultrasonic Waves – (Contributed, 000169)

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In the dairy industry the quality of UHT milk is conditioned by the absence of any trace of air in its package. The manufacturers take, following a very precise sampling, a number of packages per day for a destructive control. The objective of this work is to study the feasibility to characterize UHT milk inside his package without any destruction. We propose to study this possibility by employing the ultrasonic transmission method; this emergent technique is non-destructive, fast and allows the characterization of opaques media like UHT milk. For this we follow the evolution of ultrasonic parameters in different temperatures depending on air intrusion into the package, this is made possible thanks to an infinitesimal hole realized on it. In this study, we make a comparative analysis of ultrasonic parameters found from experiments between the following both cases: the first one is a package with a hole where the presence of air is obvious and the second one is a package without a hole where the presence of air is excluded. We proceed by this comparative study in order to test the suitability, fiability and reliability of this emerging technique as a new alternative to the conventional destructive techniques.

Thu 9:30 Main Hall Instrumentation and signal in acoustics (poster)

Microcontroller Based Control System for Ultrasound NDT in Wood – (Contributed, 000184)

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The ultrasound has been widely used in nondestructive testing (NDT) of materials, which consists in a method of analyzing the properties of a sample without causing damage to it. This work presents a microcontrolled system for transmission, acquisition and processing of ultrasound signals developed for the analysis of wood samples. The developed system is able to generate high amplitude pulses (up to 500 Vpp) to excite an ultrasonic transducer and, after the ultrasound waves have propagated through the wood sample, the signal is received, amplified and then acquired using the analog to digital converter (A/D) of the microcontroller. The obtained data can be sent to a computer via USB communication for data processing. The system was implemented with the F28M35H52C1 microcontroller (Texas Instruments) and a pair of ultrasound transducers (GE 67038, 50 kHz central frequency) was used to transmit and receive the signals. The user can set the frequency and repetition rate of the pulses. The acquisition module can acquire up to 3000 samples of 12 bits at a maximum sampling frequency of 2.88 MHz. Tests showed that the developed prototype meets the application requirements of signal generation and acquisition. The data provided by the system can be used to determine the velocity, attenuation and other parameters of the ultrasound waves in wood samples for material characterization.

Thu 9:30 Main Hall Instrumentation and signal in acoustics (poster)

Determination of the Flight Time of the Acoustic Waves Transmitted by the Cement Paste in Solidification by the Image Processing – (Contributed, 000209)

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The nondestructive control CND by the ultrasonic signals is a materials processing tool. We use the CND to characterize the curing of the cement. The time of flight of the transmitted ultrasonic signal presents a difficulty in its real-time determination of whether the signal is noisy and the sample is very big. In addition, the overlap of signals due to the small thickness of the walls of the vessel containing the cement present any problems in the determination of the velocity of the acoustic wave in the dough. Our solution is to use the juxtaposition of signals to achieve an image which is operable to draw the data necessary for the recovery of all the signal flight time during the solidification of the cement paste.

Thu 9:30 Main Hall Instrumentation and signal in acoustics (poster)

Contrast optimization by metaheuristic for inclusion detection in ultrasound imaging – (Contributed, 000534)

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Nowadays, ultrasound imaging is become an essential tool for diagnosis in industry. This is due to the recent developments of post-processing and pre-processing. Contrast and resolu-tion improvements were made possible by taking into account the wave harmonic generation during the propagation into media. By extracting harmonic compo-

nents, a higher contrast can be obtained. To improve the resolution while maintaining the contrast, encoding imaging has been developed. One of the most used encoding techniques is the non-optimal pulse inversion imaging. In most cases, the solution adopted by manufacturers consists of providing empiri-cally pre-set transmit frequencies, even if it is obvious that the medium to be explored should be taken into account during the optimization process. To resolve the coding waveform opti-mization, transition of stochastic sequences were proposed as a new alternative. This new paradigm did not require any a priori information. To accelerate the convergence of the opti-mization process, a genetic algorithm was proposed. In this study, a medium with an inclusion was compared in term of contrast to a reference medium without defect. To distinguish the two media, the calculation of an Euclidean distance was performed. Our aim was to find automatically the stochastic command that maximized this Euclidean distance. The advantage of the method was that no a priori information was required in order to find the optimal stochastic command and the position of the inclusion. In simulation, by using the optimal stochastic command in pulse inversion imaging, the algorithm converged after 3000 iterations. The distance could be multiplied by 4 in comparison with the distance obtained with an usual excitation at the central frequency of the transducer.

Thu 9:30 Main Hall Instrumentation and signal in acoustics (poster)

Computer-Controlled High Resolution Arbitrary Waveform Generator (HRAWG) for Focusing Beamforming Applications – (Contributed, 000045)

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In ultrasound research, the excitation and control scheme requested to produce complex arbitrary transmit waveforms for each active element of a multi-channel transducer involves a trade-off between hardware complexity, speed and efficiency. This paper presents a computer-controlled 8-channel FPGA-based digital transmit beamformer system that has been designed for ultrasound research, development and teaching at the Federal University of Technology (UTFPR), Brazil. The values of any parameter (8-bit apodization amplitude, aperture windowing, time delay, focusing phase adjustment, waveform, central frequency, single or burst pulses and pulse repetition frequency) can be changed dynamically on the host computer without recompiling the FPGA design. Matlab (Mathworks Inc.) graphical user interface GUI was used to implement a control software application that can be easily modified for the evaluation of novel transmission beamforming techniques. A Cyclone III FPGA Development Kit (Altera Corp.) has been used to provide all logic control signals for eight MD2131 (Supertex Inc.) ultrasound beamforming source drivers. Data communication between the PC and the FPGA board is performed via a USB 2.0 interface allowing fast update of transmission parameters and algorithms. Initial results using RC loads show the feasibility and potential advantages of this computer-controlled approach to generate high voltage waveforms with low second order harmonic distortions suitable for different ultrasonic experimental investigations, including medical ultrasound imaging, HIFU (High Intensity Focused Ultrasound) beamforming, ultrasonic NDT (Nondestructive Testing) and other focusing beamforming applications.

Thu 9:30 Main Hall Instrumentation and signal in acoustics (poster)

Study on the algorithm to detect defects by the non-contact acoustic inspection method using vibration energy ratio and spectrum entropy – (Contributed, 000163)

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Hammer-tapping inspections are widely used to inspect defects in concrete structures. However, this method has a difficulty to inspect at high-places, such as a tunnel ceiling or girder bridges. Moreover, its detection accuracy is depended on tester's experiences. Therefore, we study about the non-contact acoustic inspection method of concrete structures using the air-borne sound wave and a laser Doppler vibrometer. In this method, the concrete surface is excited by air-borne sound wave emitted with a long range acoustic device (LRAD), and the vibration velocity on the concrete surface is measured by a laser Doppler vibrometer. A defect part is detected by emergence of the same flexural resonance as the hammer test. It is already shown clearly that detection of defects can be performed from a long distance more than 5m using concrete test objects. Real concrete structures can also be applied

successfully. However, measurement poor points caused by the optical noise depending on the surface states (reflectance, etc.) at measurement have a problem. The frequency characteristic of this optical noise resembles white noise, which shows high value of spectrum entropy. Therefore, we propose the algorithm to detect a defective part, a healthy part and a measurement poor point on the surface layers of concrete structures. This algorithm are constructed of both feature values of spectrum entropy and vibration energy ratio. Applied the experimental data, it becomes clear that the measurement poor point can be removed and a defective part can be clearly visualized by our method.

Thu 9:30 Main Hall Micro/nano technology-based transducers, acoustic microsystems, and applications (poster)

Fabrication of new Interdigital Transducers for Surface Acoustic Wave Device – (Contributed, 000091)

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1. Research Motivation:
A major part of the research on Love mode surface acoustic wave device operated in liquids, e.g. biosensors, is focused on using different conventional piezoelectric substrates, and different guiding and sensing layers in order to obtain low insertion loss, high power durability, high sensitivities, etc. In a classical fabrication scheme, the metal electrodes of the IDTs are buried between the piezoelectric substrate and the guiding layer. In this work, the metal pattern of the IDTs have been buried in the piezoelectric substrate in order to improve the SAW sensors performance.
2. Method:
Love mode devices with delay lines configuration were built on 500 μm-thick single side polished ST-cut quartz and a 1.2 μm-thick photoresist (AZ 6612) guiding layer atop the quartz. The Love mode is excited and detected using IDTs composed of 50 pairs of 4-fingers-per-wavelength ($\lambda = 40$ μm). Electrodes are made of thick electroplating Ni then polished using CMP process. The grooves were etched in the quartz wafer using three etching techniques: an inductively coupled plasma (ICP), a laser etching (Oxford Lasers) and a reactive ion etching (Electrotech RD600).
3. Results:
A comparative study between conventional SAW sensors and the new ones will be presented. The preliminary results shown here indicate that the insertion loss and the phase of the fabricated devices, observed and recorded using an Agilent N5242A Network Analyzer are suited for sensing purposes with a low insertion loss and a linear phase.

Thu 9:30 Main Hall Micro/nano technology-based transducers, acoustic microsystems, and applications (poster)

Fabrication and Characterization of ZnO Nanowire-Based Piezoelectric Nanogenerators for Low Frequency Mechanical Energy Harvesting – (Contributed, 000156)

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Significant advancements in high end portable electronic products have placed enormous emphasis on electrical energy storage to meet their power demands. This has intensified research dedicated to improving the energy storage capacities of Lithium microbatteries (LiB), which offer unprecedented reliability in terms of duty cycles, durability and charge storage capacities. To charge them in an environmentally friendly manner, various energy scavenging technologies (e.g. photovoltaic or thermoelectric cells) have been proposed. However, both are limited by their incapacity to continuously harness energy either in the absence of light or thermal gradient. Low frequency (1Hz to 1kHz) ambient mechanical vibrations have been identified as alternative sources (human motion, liquid flow or engine vibrations) that can be exploited via direct piezoelectric effect.
The present work investigates the possibility to charge a LiB via direct conversion of ambient mechanical energy into electricity using piezoelectric ZnO nanowire (NW) microgenerators (PGs). Challenges related to the practicalities of tapping into this seamless energy source will be covered as follows: (i) Estimation of the power levels at the different stages of mechanical-to-electrical energy conversion chains, including PG, power management

block(s) and LiB storage; (ii) Assembly strategies enabling PGs manufacturing on polymeric substrates. ZnO NWs of 5μm length and 200 nm diameter were synthesized using a low temperature (<150 oC) hydrothermal process on PET substrates (100μm thick). Substrates containing bilayer metal layers with dissimilar electro-negativities functioned as a galvanic cell in the electrolyte growth medium. This necessitated ZnO NWs growth on conductive surfaces, even in the absence of seed layers and/or substrate with specific lattice parameters. SEM imaging and XRD analysis will be presented, revealing high quality well ordered single crystalline ZnO NWs; Finally (iii) the assembly processes required to realise the functional PGs, and the strategies to overcome the different pitfalls in PG assembly and characterization are discussed.

Thu 9:30 Main Hall Micro/nano technology-based transducers, acoustic microsystems, and applications (poster)

Ultrasonic Subwavelength Focusing Above Micromachined Membrane Array Using Time Reversal – (Contributed, 000174)

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Surface acoustic waves can propagate above of immersed membrane arrays, such as of capacitive micromachined ultrasonic transducers (CMUTs). Similar waves have been studied that are supported on metamaterials and metasurfaces (typically in the kHz range) and have been used for tunable band gaps, negative refraction, and subwavelength focusing and imaging. This work demonstrates that an array of CMUTs can be used for subwavelength focusing utilizing a time reversal method which can be used to develop new methods of ultrasonic subwavelength imaging. The studied structure consisted of the focusing region and eight additional membranes that were offset from the structure to limit acoustic coupling. The focusing region is a dense grid of 7x7 membranes (6.6MHz resonance) that support the slow surface acoustic waves. A linear transient semi-analytic model was developed to calculate the modes of the coupled membrane resonators which show that select modes have subwavelength features. Subwavelength focusing was performed by using a time reversal method in which the external eight membranes were used as the control transducers. Experiments were performed to verify the model with the membranes being actuated electrically and the displacements were measured with a laser Doppler vibrometer. Subwavelength focusing (lambda/5) was achieved on a CMUT metasurface while a modal decomposition of the spatial focus from an iterative time reversal method was done to illustrate that optimal focusing resolution requires efficient excitation of the mode shapes containing subwavelength features.

Thu 9:30 Main Hall Micro/nano technology-based transducers, acoustic microsystems, and applications (poster)

Investigation of Heterostructures for IDTs Protection at High Temperature Conditions up to 850°C – (Contributed, 000511)

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Recent studies have evidenced that Pt/AlN/Sapphire SAW devices are promising for high-temperature and high-frequency applications. However, they cannot be used above 700°C in air atmosphere as the Pt interdigital transducers (IDTs) agglomerate and the AlN layer oxidizes in such conditions. In this study, aluminum nitride coating on IDT/AlN/Sapphire structure was used to protect against the agglomeration of platinum interdigital transducers (IDT) at high temperature (800 - 1000 °C). The additional AlN top layer should increase the life time of the active piezoelectric AlN layer and also should protect the electrodes from agglomeration phenomena or chemical aggression. The influence of AlN thickness was investigated: the performance of conventional IDT/AlN/Sapphire and protected AlN/IDT/AlN/Sapphire heterostructures were compared. The protected and unprotected IDT/AlN/sapphire heterostrutures were annealed in air successively in six steps:

2h at 800°C (1st step), 10h at 800°C (2nd step), 2h at 900°C (3rd step), 10h at 900°C (4th step), 2h at 1000°C (5th step) and finally 10h at 1000°C (6th step). The effects of annealing temperature and time on acoustical performance of protected and non-protected SAW devices were compared. Impact of high-temperature annealing on the microstructure, phase composition and morphology of AlN and Pt has been evaluated. After each annealing step, the frequency response S21 of the devices was measured by a network analyzer (Agilent N5230A). Moreover, the morphology of the AlN layer was observed by optical microscope and scanning electron microscopy (SEM - FEI XL30 S-FEG). Phase composition and microstructures were studied by X-ray diffraction (XRD) in Bragg-Brentano geometry (Bruker D8 advance - CuKα1: λ = 1,54056 Å) and transmission electronic microscopy (TEM - FEI CM200), respectively. The depth profiles of elemental composition were obtained by means of secondary ion mass spectroscopy (SIMS - SIMSLab ion probe).

Thu 9:30 Main Hall Micro/nano technology-based transducers, acoustic microsystems, and applications (poster)

On the modelling of electrical response of SAW resonator-based sensors versus temperature – (Contributed, 000587)

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Surface acoustic wave (SAW) resonators built on Langasite (LGS) revealed capable to withstand temperature in excess of 900°C and demonstration of wireless interrogation of packaged sensors up to 700°C has been achieved for several tens of hours. These promising results indicate the possibility for developing high temperature sensors for harsh environment purposes. They also emphasize the need for effective material coefficients allowing for designing SAW resonators with a high level of confidence in the prediction of the device electrical response and more of its temperature coefficient of frequency (TCF). Several data set have been published for LGS, offering prediction capabilities but also a significant level of data dispersion. Therefore, the evaluation of the effective thermal properties of SAW under periodic gratings turns out less robust than expected. The EC NMP SAWHOT project has yielded numerous experimental results of SAW resonators on LGS crystal cuts, providing an actual data base for a comparative evaluation of the SAW characteristics prediction quality provided by the above-mentioned set of LGS constants (elastic, piezoelectric, dielectric and thermal expansion fundamental coefficients as well as effective thermoelastic constants). Based also on published data, harmonic admittance calculations have been achieved for deriving the evolution of mixed matrix parameters allowing for accurate SAW device simulation at any temperature. Adjusting the temperature coefficients then yield improved sets of material coefficients for design purpose. Considering the experimental data set used to assess the tested coefficients, we propose a combination of data set allowing for accurate prediction of the device behavior at room and elevated temperature. As a conclusion, best practices for SAW-resonator-based sensor design and the completeness of the proposed data set are discussed.

Thu 9:30 Main Hall Micro/nano technology-based transducers, acoustic microsystems, and applications (poster)

Normal mode theory applied to linear arrays of capacitive micromachined ultrasonic transducers – (Contributed, 000531)

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Based on the 2-D matrix representation of cMUT arrays previously developed [1], we propose in this paper to reorganize the matrix relationships governing cMUT by using the normal mode theory and to use the new set of equations in order to define some efficient criteria to assist in the design of cMUT devices.
The normal mode decomposition points out the existence of eigenmodes divided into two categories: one fundamental mode for which all cMUTs vibrate in phase and the others, which correspond to local subwavelength resonances. After a brief description of these modes, we present the implementation of a new equivalent electroacoustic circuit of cMUT based on the normal mode decomposition. This latter has the originality to possess one electrical port and as many acoustic ports as the number of eigenmodes N. More, this circuit simplifies the input/output matrix relationships, since they are transformed into a set of N simple scalar equations. Then, discussion focuses on the fundamental mode and new design rules are proposed to optimize frequency bandwidth and

sensitivity. For a given cMUT pitch, it was demonstrated that a fractional bandwidth of 160% can be reached, provided that the flexural rigidity of the diaphragm is well optimized. With such a wide frequency bandwidth, the choice of the final working frequency can thus be tuned to a wide frequency range. This obviously implies trade-offs to set performances of the probe in terms of directivity pattern. These trade-offs will be discussed in conclusion.

[1] A. Boulmé *et al.*, IEEE UFFC Symposium, 1873-1876, (2010)

Thu 9:30 Main Hall NDE / NDT (poster)

Ultrasonic testing of multiphase metal/ceramic syntactic foams with additives – (Contributed, 000191)

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Lightweight structures with mechanical durability, controlled porosity and absorbing properties are a modern trend in material design. Multiphase ceramic syntactic foams (MCSF) were produced of iron powder (CMS 95, Höganäs AB), homogenized clay (Liepa deposition, Latvia) as a binder and fly ash cenospheres (Biotecha Latvia) as hollow fillers in various proportions. The difficulty of ultrasonic characterization of such materials is complex influence of open and closed porosities, quality of adhesion defined by sintering technology and composition variations. MCSF specimens presenting cylinders with a diameter of 19 mm were examined by through transmission using a pair of quasi-point contact transducers. The propagation signals excited by short tonebursts at work frequencies of 0.4, 0.8 and 1.6 MHz were recorded for analysis. The calculated parameters included longitudinal wave velocity; frequency attenuation coefficient and reverberation time. The experiments showed differential sensitivity of the parameters to different factors of MCSF quality. The rise of sintering temperature from 1050 to 1180 degrees C having effect on particles adhesion resulted in increase of ultrasound velocity by 7-10% that correlated with increased compression strength of the specimens. It had no expressed influence on attenuation and reverberation parameters. Conversely, introduction of cenospheres - air filled scatterers of ultrasound had the most radical influence on frequency attenuation coefficient that changed several times depending on the cenospheres content. Changing ratio between the metallic and clay components affected both ultrasound velocity and reverberation coefficient. The multivariate analysis of ultrasonic propagation parameters can help assessment of specific qualities of interest in multiphase syntactic foams.

Thu 9:30 Main Hall NDE / NDT (poster)

Photoacoustic technique for thermal conductivity study of porous semiconductors – (Contributed, 000471)

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Porous semiconductors are important basis elements of nowadays devices of optoelectronics, micro-electromechanical systems, sensorics etc. These devices often work under significant thermal loads, therefore the information about thermal properties of porous semiconductors are crucial for ensuring their stability and reliability.
In the report, the peculiarities of photoacoustic technique application in gas microphone configuration for investigation of porous silicon and porous germanium will be analyzed. Particularly, the main point on the resolve of inverse photoacoustic problems for evaluation of thermal conductivity on thin porous films will be made. Thus, it will be shown that photoacoustic technique is essential tool for the investigation of thermal transport properties of partially amorphous porous silicon. It will be demonstrated that the usage of such method with Raman technique assistant allows precisely evaluation of thermal conductivity of samples with important amorphous fraction.

Moreover, double wavelength photoacoustic technique for thermal properties study of thin porous germanium layer will be discuss. In this technique, two lasers with different wavelengths for photoacoustic signal excitation were chosen for setting spatial distribution of heat source in investigated sample. This allows us to increase sensitivity of gas-microphone photoacoustic technique for thermal conductivity evaluation of mesoporous germanium. The excellent agreement between experimentally obtained value of thermal conductivity and theoretical one estimated by molecular dynamics and Monte Carlo simulations was stated.

Thu 9:30 Main Hall Phononic crystals and metamaterials (poster)

Acoustic Metamaterial Behavior Of Three-Dimensional Periodic Architectures Assembled By Additive Manufacturing – (Contributed, 000419)

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In acoustic metamaterials, artificially built architectures enable acoustic wave propagation in extremely anomalous fashions that involve acoustic lensing and cloaking, negative dispersion bands, or negative refractive indices. This class of materials has a potential for various advanced applications that require focusing or redistribution of the acoustic energy. In the present contribution, we applied combination of measurements by resonant ultrasound spectroscopy with numerical modelling by finite element method to analyze the elastic and acoustic properties of morphologically complex ceramic bodies. In particular, periodic tetragonal 3D-lattice assembled by the Robocasting technique and densified by Spark Plasma Sintering was used for searching for acoustic anomalies in this structure and for discussion how these anomalies follow from the micromechanics of the scaffold. It was found that robocast scaffolds exhibited several features typical for acoustic metamaterials, in particular, strong energy focusing following from the strong elastic anisotropy and a phononic-like frequency band structure, and additional specific features in wave propagation like the wave mode-mixing in the low-frequency limit, where the effective medium description applies. Simultaneously, the ceramic structure exhibited very low vibration damping, which makes the robocast scaffolds very promising for acoustic focusing applications without significant energy losses. Compared with other fabrication techniques for acoustic metamaterials, the Robocasting as a modern additive manufacturing technology provides higher versatility and enables easy assembly of architectures with prescribed symmetry class of the unit cell, periodicity and size to obtain desired acoustic properties.

Thu 9:30 Main Hall Phononic crystals and metamaterials (poster)

Photons and phonons coupling in piezoelectric periodic structure cavities – (Contributed, 000434)

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Periodic structures enable the localization of waves to small mode volumes. The confinement resulting from Bragg reflection makes it possible to design structures that allow the simultaneous confinement of photons and phonons. In these structures, both waves may interact through one or a combination of the following mechanisms: photoelastic, optomechanic and electrooptic effects. This opportunity has drawn a great interest as a possible way to design compact modulators and sensors. We study the different coupling mechanisms in the emblematic Lithium Niobate material, often used for its piezoelectric, acoustooptic and electrooptic properties. Using the finite element method, we solve the periodic structure dispersion relations for air holes square lattice. Then, L1 cavity modes for both waves are solved using the supercell method. The optical mode eigenfrequency excursions under acoustic perturbations are determined according to the individual then combined coupling mechanisms. The analysis of the results reveals that different behaviors are possible. The choice of the interacting photonic and phononic modes has a drastic effect on the overall modulation. We first observe as in the case of non-piezoelectric materials that the different coupling mechanisms can cancel or sustain each other. Then we point out that the modulation of photonic modes is strongly crystallographic-cut dependent as a consequence of the anisotropy inherent to piezoelectric materials. Since symmetry elements of the perturbation acoustic modes can be broken by the strong anisotropy.

Thu 9:30 Main Hall Phononic crystals and metamaterials (poster)

Study of an hybridization gap in a one dimensional piezoelectric phononic crystal – (Contributed, 000516)

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Phononic crystals (PC) are structures composed of periodic arrangements of a pattern along one or several dimensions that affects the propagation of elastic waves. If the size of the pattern is a multiple of the wavelength, Bragg gaps appear based on interference mechanisms. In the case of a stack of plates made of passive materials, only Bragg gaps are observable. In this study, a 1D PC constituted with piezoelectric plates is considered. The introduction of piezoelectric elements in a PC aims to control the effective properties of propagation in the structure through the electrical boundary conditions on each piezoelectric plates. In particular, the connection of an inductive impedance to the conducting electrodes of a piezoelectric element allows to couple an electric resonance with the elastic propagation mode in the PC thanks to the piezoelectric effect. This leads to an opening of an hybridization gap in the band structure of the PC. In this study, we characterize experimentally and theoretically this hybridization gap based on the analysis of the electrical impedance on a piezoelectric plate electrically connected to an inductive load.

Thu 9:30 Main Hall Soft Tissue Quantitative Ultrasound (poster)

Effect of non-speckle echo signals on tissue characteristics for liver fibrosis using probability density function of ultrasonic B-mode image – (Contributed, 000302)

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A quantitative diagnostic method for liver fibrosis using an ultrasonic B-mode image is required by its real-time and non-invasive properties. In our previous study, a multi-Rayleigh model which is expressed by a combination of several Rayleigh distributions which are probability density functions of echo signals from normal liver, fibrotic tissue, and so on has been proposed. A ratio of liver fibrosis in the B-mode image can be estimated by the multi-Rayleigh model. Then, a probability imaging method of tissue characteristics based on the multi-Rayleigh model has been also proposed. In the clinical data, however, there are non-speckle echo signals whose B-mode images don't show speckle patterns. A probability density function of non-speckle signals isn't expressed by a Rayleigh distribution. Therefore, modeling errors of the multi-Rayleigh model and the probability imaging are increased by non-speckle signals. In this paper, non-speckle signals in B-mode images and its removing are described. Then, multi-Rayleigh models and probability images before/after removing non-speckle signals are evaluated. Non-speckle signals, which are high-amplitude echo signals, are determined from the difference between the probability density function of the B-mode image and its multi-Rayleigh model. Before removing non-speckle signals, the high-amplitude non-speckle signals are judged as fibrotic tissues and the actual fibrotic tissues are erroneously judged as normal liver. On the other hand, the actual fibrotic tissues can be correctly judged after removing.

Thu 9:30 Main Hall Soft Tissue Quantitative Ultrasound (poster)

Estimation of Local Sound Velocity in Pulse Echo Ultrasound Imaging – (Contributed, 000386)

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In standard ultrasound imaging the exact sound velocity in tissue is unknown and therefore, for the purpose of image reconstruction, it is assumed to be uniform and equal to 1540 m/s. This obviously leads to phase aberrations in the reconstructed images. Until now, the known solutions to this issue provided the optimal value of the sound velocity in the whole imaged area or, to address the layered structure of the tissue - in a few layers, which is still far from expectations. Our objective was to develop a novel method which would provide the spatial distribution of the sound velocity in the pulse-echo ultrasound. This would potentially lead to a reduction of the aberrations in the standard ultrasound imaging. The proposed method involves an analysis of the phase of low resolution images obtained with use of the synthetic transmit aperture technique. The phase shifts between the successive low resolution images carry the information on the average sound velocity between the probe and each image pixel. This information can be restored by the developed algorithm and then used for reconstruction of the aberration-corrected images. The presented estimator was verified with use of data obtained from simulations of tissue phantom containing inclusions of various sound velocities. The results suffer from high variance of the phase signal. However, the preliminary study shows that the estimator generates sound velocity maps which allow to visualise the inclusions.

Thu 9:30 Main Hall Soft Tissue Quantitative Ultrasound (poster)

Sound Speed Measurement of Chicken Liver from 22°C to 55°C – (Contributed, 000609)

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Soft tissue acoustic characterization has been widely explored in order to understand the ultrasonic bio-effects. Speed of sound and attenuation are the most frequently measured parameters. In hyperthermia and ablation applications, tissue temperature increases due to ultrasound exposure. Sound speed temperature dependence of a chicken liver sample was measured in order to obtain its behavior at hyperthermia temperature interval. Pulse-echo technique was used for measuring the ultrasound speed of the tissue sample. A 1 MHz transducer (Panametrics®) was driven with a 200 V/ 50 ns pulse delivered by a home-made generator. The biological tissue was fixed parallel to the transducer radiating surface. Two 1.5 mm diameter needles used as reflectors were fixed into a 15 mm diameter Nylamid cylinder. The needles tips distance between each other was 6.45 mm. The reflectors were inserted into a chicken liver sample. Transducer-sample-reflectors system was placed inside a thermostatic bath (Techne, TU-20D Tempunit®) which was filled with degassed water. Ultrasonic echoes were acquired with a digital oscilloscope (Lecroy®, 6100A waveRunner) in the temperature interval from 22°C to 55°C. First, thermostatic bath temperature was incremented from 22°C to 30°C; then it was incremented every 5°C. Sound speed measurement in chicken liver at 22°C was 1568 m/s, while at 55°C was 1602 m/s. Ultrasound velocity temperature dependence in chicken liver fitted to a 4th order polynomial curve of the form $c_s = 0.0002676T^4 - 0.0433T^3 + 2.511T^2 - 60.23T + 2076$, where c_s is sound speed and T is temperature.

Thu 9:30 Main Hall Soft Tissue Quantitative Ultrasound (poster)

In and ex-vivo myocardial tissue temperature monitoring by combined infrared and ultrasonic thermometries – (Contributed, 000180)

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The success of cardiac surgery essentially depends on tissue preservation during intervention. Consequently a hypothermic cardioplegia is applied in order to avoid ischemia. However, myocardial temperature is not monitored during operation. The aim of this study is then to find a relevant and simple method for myocardial global temperature estimation in real time using both infra-red (IR) thermography and ultrasounds.

For IR experiments, a bolometer was used to detect myocardium surface thermal evolution during in-vivo pig heart experiments. Hypothermic cardioplegic solutions were injected and infra-red surface imaging was performed during one hour.

In order to quantify the sensitivity of ultrasonic velocity towards temperature, a 2.25 MHz ultrasonic probe was used for ex-vivo tests. Pig myocards (n=30) were placed in a thermostatically-controlled water bath and measurements of the ultrasound velocity were realized from 10 to 40°C. The results of this study indicate that the specificity and sensitivity of the ultrasonic echo delay induced by the changing temperature can be exploited for thermometry.

In the near future a speckle tracking method will be updated to monitor in-depth temperature during heart surgery. Experiments were already conducted using both ultrasounds and infra-red on the same myocard. Very first results will be presented.

Accurate per operative measurements of myocardial surface temperature in real time and simultaneously on different points are possible then by infra-red thermography. Combined with ultrasounic in-depth measurements this can allow the real time estimation of the global temperature of the heart.

The final objective being to realize ultrasound measurements in vivo on human hearts, this information may have a very high importance in terms of per-operation inspection as well as decision making process during medical interventions.

Thu 9:30 Main Hall Soft Tissue Quantitative Ultrasound (poster)

Automatic Cataract Classification based on Ultrasound Techniques using Machine Learning: A comparative Study – (Contributed, 000521)

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In the present work, ultrasound A-scan signals were acquired from healthy and cataractous porcine lenses. B-mode images were reconstructed from the collected backscattering signals. The parametric Nakagami images were subsequently constructed from the B-mode images. Acoustical and spectral parameters were obtained from the central region of the lens. Image textural parameters were extracted from the B-scan and Nakagami images. Ninety-seven parameters were extracted from a total of 75 healthy and 135 cataractous lenses. Lenses with cataract were split in two groups: incipient and advanced cataract, corresponding to a 60 and 120 minutes of immersion time in a cataract induction solution, respectively. The obtained parameters were subjected to feature selection with Principal Component Analysis (PCA) and used for classification using four different classifiers: Bayes, K-nearest_neighbors (KNN), Fisher Linear Discriminant (FLD) and Support Vector Machine (SVM) classifiers. This paper shows that for the classification of healthy and cataractous lenses (incipient or advanced cataract) the four classifiers show a good performance, with a F-measure ranging from 92.68% to 95.49% for the FLD and KNN classifiers respectively. For incipient versus advanced cataract the SVM classifier shows a higher performance. SVM perform effectively the classification of the cataract severity, with a performance of 90.62% while the performance of the other classifiers is lower than 80% (72.47% to 79.81% for Bayes and FLD classifiers respectively). Our results showed that SVM can be used as a computer-aided diagnosis (CAD) system for the cataract classification based on the ultrasound analysis.

Thu 9:30 Main Hall Soft Tissue Quantitative Ultrasound (poster)

Tissue Characterization on Ultrasound Harmonic Signals using Nakagami Statistics – (Contributed, 000263)

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Quantitative ultrasound (QUS) imaging provides a way to characterize biological tissue. The QUS estimates can be obtained from the backscattered RF spectrum or from the envelope statistics. In the latter case, the distribution parameters of the signal envelope are estimated to distinguish tissue with different characteristics. Previous studies are mainly based on the whole backscattered signals analysis. However, the ultrasound propagation is a nonlinear process and the harmonic signals can therefore reveal the nonlinear nature of a biological medium. The present study investigates the statistics of harmonic signal envelopes to relate the distribution parameters to the nonlinear coefficients. The CREANUIS simulator was used to simulate ultrasound images with different concentrations (2-30 scatterers/resolution cell) and different nonlinear coefficients (β=3.5-50) in the region of interest (ROI). For each concentration, 50 images with randomly distributed scatterers were simulated. The transmitted frequency was 10MHz. The Nakagami statistical model was chosen to analyze the backscattered second-harmonic signal envelopes. This model is defined by two parameters: μ is related to the scatterer density and ω is a measurement of the scattered energy. These parameters were estimated using a maximum-likelihood estimator. The Nakagami parameters versus scatterers concentration were drawn for different β. It can be observed that for each concentration, μ decreases and ω increases with increasing β. The main results demonstrate that the distributions exhibit a different behavior for fundamental and harmonic signals and that media with different nonlinearities can be distinguished, when using Nakagami statistics on the harmonic signal envelopes.

Thu 9:30 Main Hall Soft Tissue Quantitative Ultrasound (poster)

A 3D, 3-Phase, Level-Set Segmentation Method for Quantitative Ultrasound Processing of Human Lymph Node Data – (Contributed, 000431)

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Three-dimensional (3D), high-frequency quantitative ultrasound (QUS) methods were developed to detect small metastatic foci in dissected human lymph nodes (LNs). Successful QUS requires accurate segmentation of LN parenchyma (LNP), fat and normal saline (NS) based on 3D envelope data. However, automatic segmentation of the 3D data-set is difficult because of speckle noise and depth-dependent data inhomogeneity caused by acoustic focusing and attenuation. This paper presents a 3D, 3-phase, level-set method for segmenting the three media based on the LN envelope data. This method uses a Bayesian framework to adaptively integrate the Probability Density Functions (PDFs) of data in an energy function that is minimized. The envelope data are well described by a gamma PDF for LNP and a Weibull PDF for fat and NS. To handle the depth-dependent data inhomogeneity efficiently, PDF parameters are computed once per depth-range-slice for each medium. On 54 representative LNs acquired from colorectal cancer patients, Dice coefficients of 0.935±0.027, 0.820±0.083 and 0.963±0.009 for LNP, fat and NS were obtained, respectively, when comparing automatic with manual segmentations. QUS estimates obtained using the described automatic segmentations were very similar to those obtained using the manual segmentations (e.g., using the 95% limits of agreement approach for the average-effective-scatterer-size, the mean difference was 0.0076 μm, and 92.6% of points lie within the limits). Therefore, the automatic segmentation method permits accurate QUS-based cancer detection in LNs without the need for operator-dependent segmentation. This advance could enable more effective and efficient cancer detection in LNs using QUS.

Thu 9:30 Main Hall — Soft Tissue Quantitative Ultrasound (poster)

Investigation of post-mortem tissue effects using long-time decorrelation ultrasound – (Contributed, 000416)

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Decorrelation ultrasound is being increasingly used to investigate long-term biological phenomena such as response to therapy or slow blood perfusion in the capillaries. A potential application of decorrelation ultrasound is the investigation of postmortem effects in tissue, and in particular postmortem blood circulation. This is a phenomenon that occurs over the timecourse of several minutes (thereby making conventional ultrasound Doppler techniques unusable) and one that is of great interest to understanding the post-mortem redistribution of drugs in forensic toxicology. In the current work, ultrasound images of nude mice were collected under anesthesia as part of a separate investigation into cancer growth of xenografts implanted into their hind legs. Some of the mice did not survive the anesthesia procedure and ultrasound images were obtained post-mortem. To investigate post-mortem changes to tissue, a sequence of ultrasound images were collected at regular intervals and for each spatial location (or image pixel), the autocorrelation over time was calculated. The autocorrelation sequences showed an oscillatory component with a periodicity in the range of 10-15 minutes for regions near vessels, presumed to be due to circulation. In addition, two exponential decreases were observed, one with a time constant of $\sim$100 s (hypothesised to be due to a mixture of temperature cooling and rigor mortis effects), the other over several hours (hypothesised to be due to tissue decomposition). The results show that ultrasound decorrelation imaging is an effective method of observing post-mortem tissue effects and point to further studies elucidating the mechanism behind these effects.

Thu 9:30 Main Hall — Waves in granular media and structures (poster)

Ultrasonic wave transport in weakly confined granular media in the intermediate frequency regime – (Contributed, 000290)

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We present experimental observations of ultrasonic wave transport in non-cohesive randomly close packed granular media under low confinement pressures, near the unjamming transition. Our work is motivated by the possibility that granular media may exhibit unusual wave phenomena due to strong scattering, and the relevance of ultrasonic experiments to investigating the underlying physics of heat transport, which has been a topic of considerable interest recently. Our three-dimensional samples are 10-mm-thick and 165-mm-diameter slabs made of 1.25-mm-diameter aluminium spheres (monodisperse sample) or aluminium spheres of the same size mixed with

0.9-mm-diameter borosilicate spheres (bidisperse sample). The slabs are covered by thin plastic sheets, which allow maintaining a partial vacuum (0.1 to 0.9 atm) in the samples. Wave transport is investigated over a wide frequency range (25 kHz to 1 MHz) by analyzing the coherent ballistic transmitted field (phase and group velocities, attenuation and scattering mean free path) and the incoherent multiply scattered coda [J.H. Page et al., Phys. Rev. E 52, 3106 (1995)]. We find that the time-of-flight intensity profile of the multiply scattered waves is independent of frequency over a wide range of frequencies for which the wavelength is comparable with the sizes of the scatterers. This suggests a plateau in the diffusion coefficient, as predicted by Vitelli and co-workers [Phys. Rev. E 81, 021301 (2010)]. A more in-depth investigation of the multiply scattered wave transport is performed by measuring the dynamic spreading of transmitted intensity along the slab surface when a (quasi-) point source is incident on the opposite side of the sample [Hu et al, Nature Physics 4, 945 2008]. This transverse confinement technique directly probes the renormalization of the diffusion coefficient due to the strong disorder, and provides evidence of a transition to localized modes at the upper band edge.

Thu 9:30 Main Hall — Waves in granular media and structures (poster)

Effect of magnetic field on sound propagation in cohesive powders at low consolidation – (Contributed, 000642)

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In previous experiments on the propagation of sound wave in cohesive powders we studied the ballistic velocity of ultrasound waves at consolidations above 1.25 KPa and solid fraction above 0.47. In this study we use a new experimental setup that allows us to investigate sound propagation at lower consolidations. A new method is used to erase powder memory. This consists in introducing a flow to break all contacts, then cutting off the gas flow and wait for the sample to settle under gravity before measuring. We also apply in the fluidization and settling state a magnetic field to orientate particle's dipole in the vertical direction. In the final sediment there is an anisotropy due to the vertical magnetic field that sound is able to detect.The results show the important role of cohesive forces and network of contacts in these loosely fine powders.

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	SUNDAY 10th MAY
7.00 - 16.30	
16.30 - 20.00	Registration Grand Hall

	MONDAY 11th MAY
7.00 - 9.00	Registration + Breakfast Grand Hall
9.00 - 11.00	Opening Ceremony Grande Salle
11.00-11.30	Time off
11.30-12.30	Keynote speakers Grande Salle
12.30 - 14.00	Lunch Break Orangerie
14.00-15.00	Plenary session Grande Salle
15.00-16.00	Poster sessions + coffee break Grand Hall
16.00 - 18.00	Technical sessions
18.00-21.00	Welcome Reception Grand Hall

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9.30-10.30	Poster sessions + coffee break Grand Hall
10.30-12.00	Technical sessions
12.00 - 13.30	Lunch Break Orangerie
13.30 - 15.00	Technical sessions
15.00 - 16.00	Poster sessions + coffee break Grand Hall
16.00 - 18.00	Technical sessions
18.00-19.30	Time off
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	WEDNESDAY 13th May
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8.30-9.30	Plenary session Grande Salle
9.30-10.30	Poster sessions + coffee break Grand Hall
10.30-12.00	Technical sessions
12.00-13.30	Lunch Break Orangerie
13.30-14.30	Keynote speakers
14.30-15.30	Poster sessions + coffee break Grand Hall
15.30 - 17.30	Technical sessions
17.30 - 19.30	Time off
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	THURSDAY 14th May
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8.30-9.30	Plenary session Grande Salle
9.30-10.30	Poster sessions + coffee break Grand Hall
10.30 - 12.00	Technical sessions
12.00 - 13.30	Lunch Break Orangerie
13.30 - 15.00	Technical sessions
15.00 - 16.00	Poster sessions + coffee break Grand Hall
16.00 - 17.30	Technical sessions
17.30 - 19.30	Farewell reception Grand Hall

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