1A: 8:30-12:30 **Medical Ultrasound Transducers**
Instructors: **Douglas G. Wildes, L. Scott Smith**, GE Global Research

1B: 8:30-12:30 **Hydrophone-based Measurement of Ultrasonic Fields for Biomedical, Non-Destructive Testing, and Regulatory (US FDA) Applications**
Instructors: **Keith A. Wear,** US Food and Drug Administration, **Andrew M. Hurrell,** Precision Acoustics Ltd, **Peter A. Lewin,** Drexel University, **Volker Wilkens,** Physikalisch-Technische Bundesanstalt, **Bajram Zeqiri,** National Physical Laboratory

1C: 8:30-12:30 **Signal Processing and System-on-Chip Designs for Ultrasonic Imaging, Detection and Estimation Application**
Instructors: **Jafar Saniie**, Department of Electrical and Computer Engineering at Illinois Institute of Technology, **Ramazan Demirli**, Center for Advanced Communications, Villanova University, **Erdal Oruklu**, Department of Electrical and Computer Engineering, Illinois Institute of Technology

1D: 8:30-12:30 **Nondestructive Materials Characterization by Ultrasonic Techniques**
Instructors: **Walter Arnold,** Saarland University

1E: 8:30-12:30 High Frequency Transducers and Their Applications
Instructors: **Jeffrey C. Bamber**, Institute of Cancer Research and Royal Marsden Hospital, **Timothy Button**, University of Birmingham, **Christine Demore**, University of Dundee

1F: 8:30-12:30 **Acoustic Tweezing: Modelling, Implementation and Applications**
Instructors: **Bruce W Drinkwater,** University of Bristol, **Charles Courtney,** University of Bath**, Sandy Cochran**, University of Dundee , **Martyn Hill**, Sounthampton University

2A: 1:30-6:00 **Biomedical Photoacoustics: From Bench to Bedside**
Instructors: **Stanislav Emelianov**, **Richard Bouchard**, University of Texas

2B: 1:30-6:00 **Comparing Piezoelectric Materials for Sensors, Actuators, and Ultrasound Transducers**
Instructors: **Susan Trolier-McKinstry** Materials Research Lab, Penn State University, **Sandy Cochran**, University of Dundee

2C: 1:30-6:00 **Ultrasonic Characterization of Advanced Materials**
Instructors: **Michal Landa, Hanuš Seiner, Petr Sedlák**, Institute of Thermomechanics, Academy of Sciences of the Czech Republic

2D: 1:30-6:00 **Quantitative Acoustic Microscope – Measurement, Analysis, Biological and Materials Science Application**
Instructors: **Naohiro Hozumi,** Toyohashi University of Technology**, Kazuto Kobayashi**, Honda Electronics, **Sachiko Yoshida**, Toyohashi University of Technology, **Roman Gr. Maev,** Institute for Diagnostic Imaging Research, **Fedar Seviaryn**, University of Windsor

2E: 1:30-6:00 **Plane Wave Imaging and Applications for Ultrafast Doppler, Elastography, and Contrast**
Instructors: **Mathias Fink, Mickael Tanter,** Langevin Institute, ESPCI ParisTech

2F: 1:30-6:00 **Ultrasound Contrast Agents: Theory and Experiment**
Instructors: **Nico de Jong**, Erasmus MC, **Michel Versluis**, University of Twente

Title: **Medical Ultrasound Transducers**

Instructors: **Douglas G. Wildes, L. Scott Smith**, GE Global Research

Course Description

Ultrasound has grown to be the most commonly performed medical imaging procedure in the world because it is fast, safe, portable, and inexpensive. This course will provide an introduction to ultrasound imaging focused on the design, fabrication, and testing of medical ultrasound transducers. Starting from an overview of the basic types of phased-array transducers (linear, convex, sector), we will show how the probe's design is derived from its target application. We will describe how engineering tools, like equivalent-circuit, finite-element, and acoustic field models, can be used to predict transducer performance accurately, and then to optimize the design. A discussion of the structure of an ultrasound probe will lead to a survey of the different types of materials used in probes and their critical properties. Typical fabrication processes will be reviewed and common problems in probe manufacturing will be summarized. Methods for evaluating completed transducers will be described. The course will include recent developments in probe technology, including single crystal piezoelectrics, cMUT transducers, catheters, 2D arrays, and electronics in probes, and will address some of the performance advantages and fabrication difficulties associated with them.

Douglas G. Wildes is a physicist with GE Global Research. He earned an A.B. in physics and mathematics from Dartmouth College and a Ph.D. in low-temperature physics from Cornell University, then joined GE in 1985. Since 1991, Dr. Wildes' research has focused on aperture design, fabrication processes, and high-density interconnect technology for multi-row and 4D imaging transducers for medical ultrasound. Dr. Wildes has 35 issued patents and 24 external publications. He is a member of the American Physical Society and a Senior Member of the IEEE.

L. Scott Smith leads the Ultrasound Probes Lab at GE Global Research. He earned B.S. and Ph.D. degrees in physics from the University of Rochester and the University of Pennsylvania respectively. Joining GE in 1976, he developed phased array probes for medical ultrasound. More recently, he led projects on adaptive acoustics and novel probe materials and methods. Dr. Smith has 53 issued patents and over 35 refereed publications. He is a member of the American Physical Society and a Senior Member of the IEEE where he serves as an Associate Editor for the Transactions on UFFC, and on this symposium's Technical Program Committee.

Title: **Hydrophone-based Measurement of Ultrasonic Fields for Biomedical, Non-Destructive Testing, and Regulatory (US FDA) Applications**

Instructors: **Keith A. Wear,** US Food and Drug Administration, **Andrew M. Hurrell,** Precision Acoustics Ltd, **Peter A. Lewin,** Drexel University, **Volker Wilkens,** Physikalisch-Technische Bundesanstalt, **Bajram Zeqiri,** National Physical Laboratory

Course Description

This course will consider the use of hydrophones to measure ultrasonic fields. The following topics will be discussed: 1) comparison of hydrophone designs (membrane, needle, capsule, fiber-optic, etc.), 2) models for hydrophone characteristics, 3) signal processing methods for correcting for non-uniform hydrophone sensitivity, 4) challenges with measuring high-intensity fields, such as those encountered in high-intensity therapeutic ultrasound, 5) international (IEC) standardization of hydrophone-based ultrasonic output measurements, and 6) US Food and Drug Administration (FDA) regulatory parameters for establishing safety for medical applications.

Andrew M. Hurrell was born in Ashford, Kent, England in 1972. He received a B. Sc. (Hons) Degree in Physics and Modern Acoustics from the University of Surrey in 1994 and a PhD in Underwater Acoustics from the University of Bath in 2002. From 1994 to 1996, he was a member of the Acoustic Materials Team at the Defence Research Agency (Holton Heath). In 1996, he joined Precision Acoustics Ltd, Dorchester where he is now a Senior Research Physicist. His current interests include design and construction of transducers, hydrophones and piezo-electric arrays, development of novel sensor systems and the use of finite difference techniques to model acoustic phenomena. Dr Hurrell has more than 35 publications and text book chapters to his name and has won two prizes for the development of ultrasonic devices. He is a peer reviewer for numerous journals and grant funding authorities. He also serves as one of the UK members of IEC Technical Committee TC87 (Ultrasonics), and the British Standards Committee EPL/87 that shadows it.

Peter A. Lewin is R.B. Beard Distinguished University Professor of Electrical and Computer Engineering and Director of the Ultrasound Research and Education Center in the School of Bioengineering, Bioscience and Health Systems at Drexel University. He obtained his M.S. degree in Electrical Engineering in 1969 and his Ph.D. in Physical Acoustics in 1979 in Copenhagen, Denmark. Dr. Lewin has authored or co-authored over 220 scientific publications, most of them on topics in ultrasound and is co-editor (with Prof. M. C. Ziskin) of a book Ultrasonic Exposimetry (CRC Press, 1993). His current interests are primarily in the field of biomedical ultrasonics and industrial applications of ultrasound, including the design and testing of piezoelectric transducers and sensors, power ultrasonics, ultrasonic exposimetry, tissue characterization using nonlinear acoustics, biological effects of ultrasound, power ultrasonics and applications of shock waves in medicine and image reconstruction and processing. Dr. Lewin is a Fellow of the IEEE, the American Institute for Medical and Biological Engineering (AIMBE), American Institute of Ultrasound in Medicine (AIUM) and Acoustical Society of America (ASA). He has served on AIUM's Board of Governors (2004-2006), and as a Chair (1997-1999) of the AIUM's Technical Standards Committee. He currently serves as a consultant to the U.S. Food and Drug Administration, Center for Devices and Radiological Health and as a member of the US TAG participating in the work of the International Electrotechnical Commission, Technical Committee on Ultrasonics. Most recently he was appointed for life as consulting resource member of the prestigious Franklin Institute Science and Awards Committee, Philadelphia.

Keith A. Wear received his B.A. in Applied Physics from the University of California at San Diego in 1980. He received his M.S. and Ph.D. in Applied Physics with a Ph.D. minor in Electrical Engineering from Stanford University in 1982 and 1987. He was a post-doctoral research fellow with the Physics department at Washington University, St. Louis from 1987-1989. He has been a research physicist specializing in biomedical ultrasound at the US Food and Drug Administration / Center for Devices and Radiological Health since 1989. He was the Technical Program Chair of the 2008 IEEE International Ultrasonics Symposium in Beijing, China. He is an Associate Editor of two journals: 1) IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, and 2) the Journal of the Acoustical Society of America. He is a Fellow of the Acoustical Society of America, the American Institute of Ultrasound in Medicine and Biology, and the American Institute for Medical and Biological Engineering. He is a senior member of IEEE.

Volker Wilkens was born in Oldenburg, Germany, in 1969. He received the diploma degree in physics from the University of Oldenburg, Germany, in 1997, where he had worked in the field of optical metrology and interferometry. Since 1997, he has been engaged in optical measurement of ultrasound and fiber-optic sensors at the Physikalisch-Technische Bundesanstalt (PTB) in Braunschweig, the national metrology institute (NMI) of Germany. He received the Dr. rer. nat. degree in physics from the University of Oldenburg in 2001 for his work on optical multilayer hydrophones. In 2005 he became head of the ultrasonics working group at the PTB, which may be characterized by both having a long time tradition in ultrasonic metrology and being largely involved in several national, European, and international research projects today. Dr. Wilkens is responsible for customer services like calibrations and acoustic output measurements as well as for the maintenance of the national primary standard measurement setups. His interest in ultrasound exposimetry and safety aspects of medical ultrasound including the development of ultrasound sensors and calibration techniques, has been amended by active work for international standardization in IEC TC87 “Ultrasonics” starting in 2006. Currently he is the chairman of the corresponding German mirror committee “Medical ultrasonic equipment”.

Bajram Zeqiri joined the National Physical Laboratory in 1984, following the completion of a PhD in solid-state chemistry at the University of Kent. His work at NPL has seen him contribute to the development of ultrasonic measurement techniques and standards, including: determination of the acoustic properties of materials; calibration and the use of ultrasonic hydrophones; and characterisation of ultrasonic power along with the development of standards for physiotherapy equipment. Dr Zeqiri is a member of IEC Technical Committee 87, as Convenor of Working Group 3, and is the author of almost 70 scientific papers, including three book chapters. In 2003, one of these publications, describing the NPL cavitation sensor, won the prestigious IEEE Ultrasonics, Ferroelectrics and Frequency Control Outstanding paper award. He has published or filed five patents relating to novel developments in ultrasonic metrology.

Title: **Biomedical Photoacoustics: From Bench to Bedside**

Instructors: **Stanislav Emelianov**, **Richard Bouchard,** University of Texas

Course Description

This short-course will provide a comprehensive overview of biomedical photoacoustic (PA) imaging, with particular attention given to the latest preclinical (i.e., mouse model) and clinical endeavors of the technology. The course starts with a presentation of optics (e.g., laser-tissue interactions) and PA fundamentals necessary for an ultrasound-orientated audience. An in-depth summary and analysis of current photoacoustic imaging techniques, transducer technologies, imaging/laser systems, contrast agents, and reconstruction algorithms is then provided. Using these techniques and technologies as a framework, PA imaging applications – ranging from functional imaging to visualization of targeted nanoparticles – will then be introduced within a variety of preclinical and clinical contexts. Lastly, a thorough detailing of current preclinical and clinical PA imaging pursuits will be provided with a discussion concerning both the potential opportunities of PA imaging in a clinical setting and barriers toward such realizations.

Stanislav Emelianov received his Ph.D. degree in Physics in 1993 from the Moscow State University and the Institute of Mathematical Problems of Biology of the Russian Academy of Sciences. Following his graduate work, he moved to the University of Michigan, Ann Arbor, where Dr. Emelianov was involved primarily in the theoretical and practical aspects of elasticity imaging using ultrasound and MRI. Dr. Emelianov is currently teaching and conducting research in the Department of Biomedical Engineering at the University of Texas at Austin. In addition, Dr. Emelianov established and directs the Center for Emerging Imaging Technologies at the University of Texas at Austin. His research interests are in medical imaging and therapeutics, including ultrasound, photoacoustic, elasticity and multi-modality imaging, photothermal therapy, cellular/molecular imaging and therapy, functional imaging, etc.

Richard Bouchard earned his B.S.E. and Ph.D. degrees in biomedical engineering from Duke University in 2004 and 2010, respectively. His doctoral thesis focused on ultrasound-based cardiac elasticity imaging. In 2011, he completed a postdoctoral fellowship in photoacoustic imaging in the Ultrasound Imaging and Therapeutics Research Laboratory at the University of Texas at Austin. Dr. Bouchard currently holds a faculty position in the Department of Imaging Physics at the University of Texas MD Anderson Cancer Center where he is conducting research on novel clinical and preclinical applications of photoacoustic-ultrasonic imaging.

Title: **Signal Processing and System-on-Chip Designs for Ultrasonic Imaging, Detection and Estimation Application**

Instructors: **Jafar Saniie**, Department of Electrical and Computer Engineering at Illinois Institute of Technology, **Ramazan Demirli**, Center for Advanced Communications, Villanova University, **Erdal Oruklu**, Department of Electrical and Computer Engineering, Illinois Institute of Technology

Course Description

In this short course, we present signal processing algorithms and system-on-chip designs for ultrasonic imaging applications. Topics includes (1) ultrasonic signal modeling and echo classification, (2) time-frequency analysis and split-spectrum processing, (3) order statistics and neural networks for flaw detection, (4) chirplet echo estimation, (5) detection and deconvolution using expectation-maximization and matching pursuit methods, (6) discrete wavelet transform for 3D ultrasonic data compression, and (7) system-on-chip implementation of detection, estimation, and compression algorithms using FPGA devices. This course will cover several case studies such as detecting defects in steam generator tubes used in nuclear power plants, transducer pulse-echo wavelet estimation, thickness sizing of thin layers, and flaw detection in large grained materials.

***Jafar Saniie**,* IEEE Fellow for contributions to ultrasonic signal processing for detection, estimation and imaging, received his B.S. degree in Electrical Engineering from the University of Maryland in 1974. He received his M.S. degree in Biomedical Engineering in 1977 from Case Western Reserve University, Cleveland, OH, and his Ph.D. degree in Electrical Engineering in 1981 from Purdue University, West Lafayette, IN. In 1981 Dr. Saniie joined the Department of Applied Physics, University of Helsinki, Finland, to conduct research in photothermal and photoacoustic imaging. Since 1983 he has been with the Department of Electrical and Computer Engineering at Illinois Institute of Technology where he is the Filmer Endowed Chair Professor, Director of the Embedded Computing and Signal Processing (ECASP) Research Laboratory, and Associate Chair. Dr. Saniie's research interests and activities are in ultrasonic signal and image processing, statistical pattern recognition, estimation and detection, data compression, time-frequency analysis, embedded digital systems, digital signal processing with field programmable gate arrays, and ultrasonic nondestructive testing and imaging. Dr. Saniie has been a Technical Program Committee member of the IEEE Ultrasonics Symposium since 1987 (currently he is the chair of Sensors, NDE and Industrial Applications), Associate Editor of the IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control since 1994. Dr. Saniie is the General Chair-elect for 2014 IEEE Ultrasonics Symposium in Chicago. He has over 250 publications and supervised 29 Ph.D. dissertations.

Ramazan Demirli received his MS and Ph.D. degrees in 1995 and 2000 respectively, both in Electrical Engineering from the Illinois Institute of Technology, Chicago, IL. From 2000 to 2010 Dr. Demirli has worked in the industry, first at BrainMedia, LLC., New York, NY, assuming a major role in the development of a proprietary audio codec, then at Canfield Scientific, Inc., Fairfield, NJ, as a senior scientist involved in the research and development of skin imaging systems and software. Since June 2010, he has been with the Center for Advanced Communications, Villanova University, Villanova, PA, where he is now a Research Assistant Professor and the Director of the Acoustics and Ultrasound Lab. He specializes in statistical signal processing with extensive emphasis on ultrasound signal modeling and parameter estimation. His research interests include acoustic signal processing, ultrasound imaging and nondestructive evaluation, and image processing. Dr. Demirli is a Senior Member of IEEE.

Erdal Oruklu received his B.S. degree in Electronics and Communications Engineering from Technical University of Istanbul, Turkey in 1995, his M.S. degree in Electrical Engineering from Bogazici University, Istanbul, Turkey in 1999 and his Ph.D. degree in Computer Engineering from Illinois Institute of Technology, Chicago, Illinois in 2005. He joined Department of Electrical and Computer Engineering, Illinois Institute of Technology as an Assistant Professor in 2005 where he is the director of VLSI and SoC Design Research Laboratory. Dr. Oruklu's research interests are reconfigurable computing, advanced computer architectures, hardware/software co-design, embedded systems and high-speed computer arithmetic. In particular, he focuses on the research and development of system-on-chip (SoC) frameworks for FPGA and VLSI implementations of real-time ultrasonic detection, estimation and imaging applications. Dr. Oruklu has more than 100 technical publications. He is a senior member of IEEE.

Title: **Quantitative Acoustic Microscope – Measurement, Analysis and Biological Application**

Instructors: **Naohiro Hozumi,** Toyohashi University of Technology**, Kazuto Kobayashi**, Honda Electronics, **Sachiko Yoshida**, Toyohashi University of Technology, **Roman Gr. Maev,** Institute for Diagnostic Imaging Research, **Fedar Seviaryn**, University of Windsor

Course Description

The course will deal with recent progress in measurement technique and quantitative analysis of quantitative acoustic microscope for biological use, as well as its medical and biological applications. The presentation will be performed by both electrician and biologist.

Hozumi and Kobayashi will present principles of several types of scanning acoustic microscopes for medical and biological use.

The sound speed microscope is available to characterize tissues that are sliced and mounted on a slide glass. It evaluates the time difference of reflections from front and rear surfaces of the tissue. As these reflections are overlapped, an analysis is required to separate them.

The acoustic impedance microscope can visualize the acoustic impedance of a cross section in touch with a plastic substrate by transmitting an acoustic beam from the rear side of the substrate. This type of microscopy has an advantage that the measurement can be performed in vivo introducing no contamination into the target system.

With a wide frequency range up to 400 MHz, both types of microscopes can observe with a special resolution as fine as cell structure. As the beam is strongly focused and the system includes several interfaces, the response to the pulsed signal is complicated, which brings the difficulty in calibration. In the presentation a precise calibration method for acoustic impedance based on sound field analysis will be explained.

Both sound speed and acoustic impedance can be interpreted into elastic parameters such as bulk modulus and shear modulus. In addition several new trials for finer cell observation by means of quasi-transmission mode and quicker tissue observation by using an array transducer will be presented.

In the latter part, many examples of medical and biological applications will be presented. Yoshida proposes rapid ultrasonic staining by means of metallic dyes. Some specific features such as cancerous part in biological tissue can be highlighted in acoustic microimage. She also proposes that ultrasonic acoustic impedance microscopy is suitable for observing the effect of drugs without giving any other influences to the biological system. As an exhibition, a continuous observation of cultured cancerous cells after being subjected to anti-cancerous drug will be presented.

Naohiro Hozumi was born in Kyoto, Japan on April 2, 1957. He received his B.S., M.S. and Ph.D. degrees in 1981, 1983 and 1990 from Waseda University. He was engaged in Central Research Institute of Electric Power Industry (CRIEPI) from 1983 to 1999. He was an associate professor of Toyohashi University of Technology from 1999 to 2006, and a professor of Aichi Institute of Technology from 2006 to 2011. Since 2011, he has been a professor at the Toyohashi University of Technology. He has been engaged in the research of insulating materials and diagnosis for high voltage equipment, acoustic measurement for biological and medical applications, etc. He received awards from IEE Japan for his outstanding research papers in 1990 and 1999. He is a member of IEEE, IEE Japan and the Acoustic Society of Japan.

Kazuto Kobayashi was born in Aichi, Japan on June 8, 1952. He received B.S. degree in electrical engineering from Shibaura Institute of Technology, Tokyo, Japan in 1976, and Ph D. degree from Tohoku University in 2011. He is currently a director of Department of Research and Development at Honda Electronics Co. Ltd. in Toyohashi, Japan. His research activities and interests include medical ultrasound imaging, signal processing and high frequency ultrasound transducers.

Sachiko Yoshida was born in Toyama, Japan on January 24, 1961. She received B.S., M.S, and Ph.D. degrees in 1983, 1986, 1990 from University of Tokyo. After Research Fellowship for Young Scientists of Japan Society for the Promotion of Science（JSPS）, she was a researcher of PRESTO in Japan Science and Technology Agency (JST) from 1992 to 1995. She was a research assistant of Toyohashi University of Technology in 1995, and since 1996, she has been a lecturer there. Her research interests focus the morphological transformation through differentiation. She is a member of International Brain Research Organization, Society for neuroscience, Japan neuroscience Society, and the Physiological Society of Japan.

Roman Gr. Maev is the founding Director-General of The Institute for Diagnostic Imaging Research - a multi-disciplinary, collaborative research and innovation consortium. The Institute was formed in 2008 by the Ontario Ministry of Research and Innovation. Dr. Maev is holds the title of University Professor, Distinguished in the Department of Physics at the University of Windsor, Canada. In 2002 Dr. Maev became the DaimlerChrysler/NSERC Industrial Research Chair and in 2008 the Fiat/Chrysler/NSERC Industrial Research Chair in Advanced Materials Characterization. In 2004, a new initiative by Chrysler, “Tessonics Corporation” was created with its main mission for the commercialization of the research products developed by Maev’s R&D team at the University of Windsor. Dr. Maev was one of the founders of Tessonics. Tessonics submitted a proposal in the field of Nanotechnology for the Rusnano fund for a total of $23 million dollars with the topic: Hydroxyapatite Nanostructured (Nanocrystalline) Implant Coatings. Dr. Maev is the author of 4 monographs, editor and co-editor of 9 books, has published over 380 articles in leading international journals, and holds 25 international patents. Dr. Maev, was appointed as an Adjunct Professor in Oxford University (UK), Johns Hopkins University (Baltimore, USA), McGill University (Montreal, Canada), University of Michigan, (Ann Arbor USA) as well as being a member of the Brockhouse Materials Research Institute, (McMaster University (Canada). Currently serving as a member of the Editorial Advisory Board of the *Journal of Research in Nondestructive Evaluation* and served as an associate editor of IEEE Transaction in Ultrasonics, Ferroelectrics and Frequency Control. He is involved in and served on organizing committees of various prestigious international conferences. Roman Gr. Maev was born in Russia, and received his Master of Science degree in Theoretical Nuclear Physics from the Moscow Physical Engineering Institute followed by a Ph.D. on the Theory of Semiconductors from the Physical P.N. Lebedev Institute of the USSR.

Fedar Seviaryn was born in 1963 in Belarus. He received combined B.Sc. and M.Sc. degrees in physics from the Chair of Acoustics at Moscow State University. After defending his Ph.D. thesis, “Nonlinear acoustical phenomena in layered structures” in 1989, he held the position of researcher in B. I. Stepanov’s Institute of Physics of National Academy of Science of Belarus. Since 1998 Dr. Seviaryn has worked as a research associate at the Department of Physics in University of Windsor, Windsor, ON, Canada. As a member of the Institute for Diagnostics Imaging Research he participated in numerous research projects in physical acoustics and development of ultrasonic nondestructive evaluation applications and devices including advanced models of acoustic microscope.

Title: **Ultrasonic Characterization of Advanced Materials**

Instructors: **Michal Landa, Hanuš Seiner, Petr Sedlák**, Institute of Thermomechanics, Academy of Sciences of the Czech Republic

Course Description

This course will review the recent progress in resonant ultrasound spectroscopy (RUS) which is a technique developed primarily for investigation of elastic properties of solids based on the inversion of natural frequencies of free elastic vibrations of a small simply shaped specimen. Specific attention will be given to laser-based modification of standard RUS experimental setup by replacing the piezo-crystal transducers by a pulse-laser as the source of ultrasonic vibrations and by using a scanning laser interferometer as the receiver, which has brought the following improvements:

1) There is not any mechanical coupling between the specimen and transducers, which improves resonance quality and measurement reproducibility.
2) The measurement is more appropriate to be carried out in temperature and vacuum chambers.
3) The scanning laser interferometer provides information on shapes of the eigenmodes, which enables mode identification and, thus, considerably improves the inverse procedure.
4) The temperature evolution of one individual mode can be observed, which allows evaluation of elastic constants and their temperature derivatives with the same relative accuracy.
5) Reliable measurements of quality of resonances, attenuations, and evaluations of internal friction coefficients are enabled.

Above improvements of the RUS method enable to evaluate elasticity and internal friction of layered materials, thin films on substrates, FGMs (functionally graded materials), polycrystalline materials, and the detection of phase transitions in solids.

Application of the RUS method for each such specific system requires a dedicated modification of the mathematical model of dynamical behavior of the material sample (the forward problem), which is then inverted for fitting the experimental dynamic response by the calculated spectrum (the optimization procedure of the inverse problem). Furthermore, the RUS spectra can be complemented by results of other ultrasonic methods: bulk acoustic wave propagation (pulse-echo) and surface acoustic wave measurements. The joint processing of these data enables the extension of the RUS method for more complex material properties: structure, texture, homogeneity, porosity.

Illustrative examples of the use of laser-based RUS methods will be presented.

Michal Landa received his M.S. degree in mechanical engineering from the Czech Technical University in 1989. Since 1989, he has been working in Institute of Thermomechanics (IT ASCR), Academy of Sciences of the Czech Republic in the field of acoustic emission, where he received his CSc (PhD equiv.) degree in 1996. His research interests include development of quantitative ultrasonic methods (ultrasonic spectroscopy, nonlinear acoustics, photo-acoustics, laser-ultrasonics, surface acoustic waves) for material investigation (mechanical properties of materials, characterization of material structures, phase transformations and damage). In 2001, he founded the Laboratory of ultrasonic methods (http://lum.it.cas.cz) at the IT ASCR.

Hanuš Seiner received his Masters (2004) and Ph.D. (2008) degrees in Materials engineering at the Czech Technical University in Prague. Since 2003 he has been working in the Laboratory of Ultrasonic Methods at the Institute of Thermomechanics (Academy of Sciences of the Czech Republic). His main research interests cover the mechanics of advanced materials and its investigation by ultrasonic methods and in particular by resonant ultrasound spectroscopy. He is also interested in mathematical models of elasticity of microstructured materials (especially thermoelastic martensites) within the frame of continuum mechanics.

Petr Sedlák received his Masters (2002) and Ph.D. (2008) degrees in Solid State Physics at the Czech Technical University in Prague. He joined the Laboratory of Ultrasonic Method at the Institute of Thermomechanics in 2004 and he is responsible for the development of the software toolbox for resonant ultrasound spectroscopy there. His research interests cover also mathematical simulations of materials including ab-initio calculations and molecular dynamics.

Title: **Nondestructive Materials Characterization by Ultrasonic Techniques**

Instructors: **Walter Arnold**, Saarland University

Course Description

This course discusses all important aspects of non-destructive testing and evaluation of materials by ultrasonic techniques. In the wake of non-destructive testing for the detection of defects in materials and components, non-destructive materials characterization (NDMC) techniques have been developed to monitor the properties of materials.

This course discusses ultrasonic scattering methods to characterize the microstructure of materials for homogeneity, texture, hardening depth, grain size determination and agglomeration of small defects. Then, sound-velocity measurements are discussed to determine mechanical stresses and to monitor the sintering process of fine-grain materials, and to determine the state of porosity, for example caused by creep loading. Non-linear effects are presently at the focus of NDMC developments to determine the amount of fatigue or other material damage accumulated in materials. Ultrasonic absorption may also be used as a tool for non-destructive materials characterization. Finally, examples of ultrasonic imaging using both focusing and near-field techniques applied to NDMC will be discussed.

This course is based on the accumulative work of colleagues, master and PhD students and the experience gained in ndt when the presenter worked at the Fraunhofer Institute for Non-Destructive Testing (IZFP) in Saarbrücken, Germany, until his retirement.

Walter Arnold obtained a diploma in physics (equivalent to a master degree) in 1970 and a PhD in Solid State Physics in 1974 both from the Technical University Munich, Germany. He then held various positions as a researcher in Solid State and Applied Physics in academia and industry in France, USA, Switzerland, and in Germany. From 1980 until retirement end of 2007 he was employed at the Fraunhofer-Institute for Non-Destructive Testing, Saarbrücken. W. A. was appointed professor of materials technology in 1989 at the Saarland University. Since 2009 he is a guest professor at the 1. Physikalisches Institut, Universität Göttingen, Germany and in addition works as a self-employed researcher.

Title: **Ultrasound Contrast Agents: Theory and Experiment**

Instructors: **Nico de Jong**, Erasmus MC, **Michel Versluis**, University of Twente

Course Description

The course consists of 4 topics:

Physics of microbubbles

The basic physics of bubble vibration will be discussed. How does the bubble survive in a liquid. Models of the behavior of small bubbles in an ultrasound field. Simple models based on a one dimensional mass-spring system and more complicated models including gas and shell properties. How can we use these models.

Contrast imaging

Imaging methods for contrast agents, e.g. fundamental, harmonic, subharmonic and superharmonic and multi-pulse methods like pulse inversion, power modulation etc. and new methods including chirp excitation, radial modulation, plane wave imaging and counter propagation imaging.

Ultrasound contrast agent characterization

Experimental acoustic methods for UCA will be presented for characterizing the bubbles in suspension, including harmonic and subharmonic scattering, absorption and attenuation. Also the influence of ambient pressure, temperature and gas concentration will be discussed. Further, optical and acoustical methods for characterizing individual bubbles.

Molecular imaging and therapy

Molecular imaging and ultrasound mediated drug delivery: How to make these bubble, what are the characteristic and what is the binding mechanism. How to measure this binding force. What is the interaction between mammalian cells and ultrasound in the presence of (targeted) bubbles.

Nico de Jong graduated from Delft University of Technology, The Netherlands, in 1978. He got his M.Sc. in the field of pattern recognition. Since 1980, he has been a staff member of the Thoraxcenter of the Erasmus University Medical Center, Rotterdam, The Netherlands. At the Dept. of Biomedical Engineering, he developed linear and phased array ultrasonic probes for medical diagnosis, especially compound and transesophageal transducers. In 1986 his interest in ultrasound applications shifted toward the theoretical and practical background of ultrasound contrast agents. In 1993 he received his Ph.D. for "Acoustic properties of ultrasound contrast agents". His current interests are 3D (matrix) transducers, bubble behaviour for (molecular) imaging and therapy and fast framing camera systems. Since 1996 he organizes, together with the cardiologist Dr. Folkert ten Cate, the annual European Symposium on Ultrasound Contrast Imaging, held in Rotterdam and attended by approximately 175 scientists from all over the world. Since 2003 Nico de Jong is part-time professor at the University of Twente and since 2011 part-time professor at the Universitiy in Delft.

Michel Versluis graduated in Physics in 1988 at the University of Nijmegen, the Netherlands, with a special interest in Molecular Physics and Astrophysics. Later, he specialized in the application of intense tunable UV lasers for flame diagnostics resulting in a successful defense of his PhD thesis in 1992. Michel Versluis is now Associate Professor at the University of Twente, the Netherlands, in the Physics of

Fluids group working on microfluidic applications in medicine and in the experimental study of fluid interface dynamics down to the nanoscale. He is particularly interested in the physics of bubbles and drops, both in imaging and in therapy, and in the control of bubbles and droplets in microfluidic applications for the nanotechnology industry. Dr. Versluis teaches various courses in Physics, Biomedical Engineering and Technical Medicine, including Physical and Medical Acoustics and Physics of Bubbles.

Title: **Acoustic Tweezing: Modelling, Implementation and Applications**

Instructors: **Bruce W Drinkwater,** University of Bristol, **Charles Courtney,** University of Bath**, Sandy Cochran**, University of Dundee , **Martyn Hill**, Sounthampton University

Course Description

Acoustic tweezers have attracted significant research activity leading to capabilities that rival more established manipulation technologies such as optical tweezers. In parallel, applications of acoustic tweezer technology are growing rapidly. These developments are set against a background of a significant body of work on the acoustic radiation force on particles and the use of devices based on one-dimensional standing waves to perform operations such as particle filtering and sorting. More recently attention has focused on tweezers with increased dexterity. For acoustic tweezers to be dexterous they must be able not only to trap particles but also to manipulate them flexibly, for example by moving different particles or groups of particles independently and producing a variety of different particle distributions. This course starts with the fundamentals, explaining and discussing the origins of the acoustic radiation force and its associated effects such as acoustic streaming, then uses this knowledge to explore a wide range of acoustic tweezing devices. Throughout the course, the developments will be described in the context of micro-manipulation challenges in biomedicine and composite materials. As this is still a rapidly developing field, future directions for acoustic tweezing technology will also be discussed.

Bruce Drinkwater was born in Hexham, England in 1970. He received BEng and PhD degrees in Mechanical Engineering from Imperial College, London, England in 1991 and 1995 respectively. His PhD thesis was on ultrasonic devices for rapid non-destructive evaluation of automotive and aerospace components. In 1996 he founded the Ultrasonics laboratory in the Mechanical Engineering Department at the University of Bristol. He continues to work at Bristol and has now published over 80 journal articles on a range of topics connected with ultrasonics and non-destructive evaluation. Between 2000 and 2005 he was an EPSRC Advanced Research Fellow researching the ultrasonic characterisation of adhesive joints, thin layers and interfaces. During this period his work on both array-wheel probes and on bearing condition monitoring was commercialised. In 2007 he was promoted to Professor of Ultrasonics and in 2010 received the Roy Sharpe Prize for his significant contribution to research in ultrasonic NDE. Since 2005 he has worked extensively on ultrasonic arrays for non-destructive imaging applications and defect characterisation and since 2009 on ultrasonic particle manipulation.

Charles Courtney is a Lecturer in Mechanical Engineering at the University of Bath. He studied physics at the University of Reading, receiving his MPhys degree in 2000 and completing his PhD, on modelling atoms and molecules in intense laser fields, in 2004. In 2005 he joined the Ultrasonics and Non-destructive Testing Group in the Mechanical Engineering department at the University of Bristol, initially researching non-destructive testing methods using non-linearity. He has worked on ultrasonic particle manipulation since 2009. In 2012 he was appointed as a Lecturer at the University of Bath.

Sandy Cochran is Deputy Director and Team Leader in Medical Ultrasound in the University of Dundee's Institute for Medical Science and Technology. He received his B.Sc. degree in electronics in 1986, first working on ultrasound in 1988. He was awarded his Ph.D. for work on ultrasonic arrays in 1990, and MBA in 2001, both from the University of Strathclyde. He has held two independent Research Fellowships, one from the Royal Society of Edinburgh relating to non-destructive testing and the other from EPSRC relating to underwater sonar. His present research interests are focused on ultrasound devices for medicine and life sciences, with applications in diagnosis and therapy. He also maintains interest in relevant materials, systems design and applications issues, and in underwater sonar and industrial processing for medical and life sciences applications. He collaborates extensively with industry and university groups around the world.

Martyn Hill is Head of Engineering Sciences and Professor of Electromechanical Systems at the University of Southampton. He graduated in 1985 from the Institute of Sound and Vibration Research and subsequently worked as a research student then research assistant on a variety of biomedical and industrial parameter estimation and measurement problems. He was appointed lecturer in 1990 and has research interests in ultrasonics and signal processing, particularly as applied to biomedicine. Much of Martyn's research since 1996 has focussed on the manipulation of cells and particles in microfluidic systems, particularly through the use of ultrasonic radiation forces, and as a part of this work he co-founded USWNet (Ultrasonic Standing Wave Network) in 2002. The successor to the successful series of USWNet conferences, Acoustofluidics 2013, will be hosted by his group in Southampton in September 2012.

Title: **Comparing Piezoelectric Materials for Sensors, Actuators, and Ultrasound Transducers**

Instructors: **Susan Trolier-McKinstry**, Materials Research Lab, Penn State University, **Sandy Cochran**, University of Dundee

Course Description

This tutorial will cover the fundamentals of how piezoelectric materials are employed in a wide array of devices, with a focus on ultrasound transducers. Sandy Cochran will cover the integration of piezoelectric materials into typical transducer structures with matching layers and acoustic damping. This will include generic design guidelines and rules of thumb, where possible, for devices for underwater SONAR, non-destructive testing and the many biomedical applications that do not require imaging arrays. The software underpinning the design process will also be discussed. Susan Trolier-McKinstry will then cover the basic properties of piezoelectric materials for these applications. Emphasis will be placed on the mechanisms responsible for the piezeoelectric transduction, and the link to the observed temperature and composition dependence of the dielectric, elastic, and piezoelectric response. This will lead to a discussion of hard and soft piezoelectric materials, and to the links between the coercive field, hysteresis, and domain wall motion.

Sandy Cochran is Deputy Director and Team Leader in Medical Ultrasound in the University of Dundee's Institute for Medical Science and Technology. He received his B.Sc. degree in electronics in 1986, first working on ultrasound in 1988. He was awarded his Ph.D. for work on ultrasonic arrays in 1990, and MBA in 2001, both from the University of Strathclyde. He has held two independent Research Fellowships, one from the Royal Society of Edinburgh relating to non-destructive testing and the other from EPSRC relating to underwater sonar. His present research interests are focused on ultrasound devices for medicine and life sciences, with applications in diagnosis and therapy. He also maintains interest in relevant materials, systems design and applications issues, and in underwater sonar and industrial processing for medical and life sciences applications. He collaborates extensively with industry and university groups around the world.

Susan Trolier-McKinstry is a professor of ceramic science and engineering, director of the W. M. Keck Smart Materials Integration Laboratory and co- director of the Nanofabrication facility at the Pennsylvania State University. Her main research interests include understanding the mechanisms that control structure-processing-property relationships in dielectric and piezoelectric thin films, developing new electromechanical measurement capabilities, and utilizing thin films in microelectromechanical systems. She is a fellow of the American Ceramic Society, an academician of the World Academy of Ceramics, a fellow of IEEE, and a member of the Materials Research Society.

Title: **Plane Wave Imaging and Applications for Ultrafast Doppler, Elastography, and Contrast**

Instructors: **Mathias Fink, Mickael Tanter,** Langevin Institute, ESPCI ParisTech

Course Description

The advent of ultrafast ultrasonic scanners is paving today the way to tremendous applications in medical Ultrasound. This course will present the basic principles of Ultrafast Imaging (plane wave imaging, synthetic aperture imaging, parallel receive beamforming, plane wave compounding, ...) and their implications in terms of resolution, contrast and frame rates. It will also explain the analogy such concept with optical holography. For our purposes, theoretical aspects and experimental validations will be highlighted. The course will also emphasize technological issues and system architecture constraints. Far beyond breaking technological barriers, this concept of ultrafast imaging is currently changing the paradigm of ultrasound imaging. The course will illustrate how this concept leads to breakthrough innovations in the field by revisiting Bmode, Doppler, tissue strain and nonlinear imaging. Many examples (Shear Wave Imaging, Ultrafast Doppler, fUltrasound, Ultrafast Contrast Imaging,...) will illustrate the potential of this new concept and technology.

Mathias Fink received the M.S. degree in mathematics from Paris University, France, in 1967, and the Ph.D. degree in solid state physics in 1970. Then he moved to medical imaging and received the Doctorat es-Sciences degree in 1978 from Paris University. His Doctorat es-Sciences research was in the area of ultrasonic focusing with transducer arrays for real-time medical imaging. Mathias Fink is a professor of physics at the Ecole Superieure de Physique et de Chimie Industrielles de la Ville de Paris (ESPCI ParisTech), Paris, France. In 1990 he founded the Laboratory Ondes et Acoustique at ESPCI that became in 2009 the Langevin Institute. In 2002, he was elected at the French Academy of Engineering, in 2003 at the French Academy of Science and in 2008 at the College de France on the Chair of Technological Innovation. Mathias Fink's area of research is concerned with the propagation of waves in complex media and the development of numerous instruments based on this basic research. His current research interests include time-reversal in physics, super-resolution, metamaterials, medical ultrasonic imaging, ultrasonic therapy, multiwave imaging, acoustic smart objects, acoustic tactile screens, underwater acoustics, geophysics and telecommunications. He has developed different techniques in medical imaging (ultrafast ultrasonic imaging, transient elastography, supersonic shear imaging), wave control and focusing in complex media with time-reversal mirrors. He holds more than 55 patents, and he has published more than 350 peer reviewed papers and book chapters. 4 start-up companies have been created from his research (Echosens, Sensitive Object, Supersonic Imagine and Time Reversal Communications). In 2012, he received the Ian Donald Medal from the international Society of Ultrasound in Obstetrics and Gynecology and the Rayleigh Award from the IEEE UFFC Society

Mickaël Tanter, Ph.D., is a Research Professor of the French National Institute for Health and Medical Research (INSERM). For eight years, He is heading the team Inserm U979 “Wave Physics for Medicine” at Langevin Institute, ESPCI ParisTech, France. His main activities are centered around the development of new approaches in Wave Physics for medical imaging and therapy. His current research interests a wide range of topics: Elastography using Supersonic Shear Wave imaging, Ultrafast ultrasound imaging, Transcranial High Intensity Focused Ultrasound and more recently the concept of fUtrasound (functional ultrasonic imaging of brain activity). Mickael Tanter is the recipient of 22 patents in the field of ultrasound imaging and the author of more than 140 peer-reviewed papers and book chapters. He is Associate Editor and member of the scientific board aof IEEE Ultrasonics. In 2006, he co-founded Supersonic Imagine with M. Fink, J. Souquet, C. Cohen-Bacrie. Supersonic Imagine an innovative French company positioned in the field of medical ultrasound imaging and therapy, that launched in 2009 a revolutionary

Ultrafast Ultrasound imaging platform called Aixplorer^{TM} with a unique real time shear wave imaging modality for cancer diagnosis (>100 employees, 102 M€ venture capital, and more than 600 ultrasound systems already sold worldwide). In 2012, he received the Grand Prize of Medicine and Medical Research of Paris city.

Title: **High Frequency Transducers and Their Applications**

Instructors: **Jeffrey C. Bamber**, Institute of Cancer Research and Royal Marsden Hospital, **Timothy Button**, University of Birmingham, **Christine Demore**, University of Dundee

Course Description

Mainstream medical ultrasound imaging tends to employ frequencies up to 15-20 MHz. This course aims to acquaint attendees with the field of high-frequency ultrasound, which we define as ultrasound of frequency 15-500 MHz. It is organised into three sections. The first, which explains how high-frequency ultrasound differs from conventional ultrasound, considers the changes that occur to the ultrasonic characteristics of the system and tissues as the frequency of ultrasound is increased, and the consequences of these changes in terms of system design, construction, performance and applications. It also summarises the history of high-frequency ultrasound system development, the available commercial systems and how the information from high-frequency ultrasound relates to that from other high-resolution modalities. The second section covers device and system design, and the materials and fabrication methods that are used to create high-frequency ultrasound transducers. More specifically, the various available transducer technologies are reviewed, fabrication challenges explained and example solutions provided for single element and various array configurations. This includes the requirements and techniques for driving and controlling the transducers, beamformer systems, piezoelectric materials, single crystals, composites, capacitive methods, micromachining, micromoulding, etching, thinning the piezoelectric layer, matching and backing layers, the interconnect, and small device handling. The final section covers device and system testing, and considers how high-frequency ultrasound is used, elaborating on the first section with respect to preclinical and clinical applications, and briefly mentions advanced imaging techniques such as contrast agent imaging, elastography, photoacoustics and acoustic microscopy, and specialist applications such as ultrasound trapping/manipulation.

Jeffrey C Bamber is head of the Ultrasound and Optics Physics Team and Senior Tutor at The Institute of Cancer Research (ICR) and Royal Marsden NHS Foundation Trust, Sutton, U.K. He received a BSc in Physics from the University of Kent at Canterbury in 1972, an MSc in Biophysics and Bioengineering from the University of London in 1974, and a PhD in Biophysics in 1980, also from the University London. He became a team leader at the ICR in 1986. He has had two sabbaticals, one in 1994-1995 with the Medical Products Group, Hewlett-Packard, Andover, MA, USA, and another, briefly in 1993, at the Toyo Institute of Technology. His research interests have included: acoustic characteristics of tissues, tissue biomechanical property imaging, high frequency ultrasonic imaging and tissue characterization, ultrasound and optical methods in skin cancer, microbubble agents, photoacoustic imaging and molecular imaging. Awards for work to which he has contributed include 7 for best/selected journal papers and 2 for book publishing excellence. He is a past vice-president of the International Society for Skin Imaging.

Chrsitine Démoré is the Royal Society of Edinburgh/Caledonian Research Foundation Biomedical Research Fellow within the Ultrasound for Medicine and Life Sciences group at the Institute for Medical Science and Technology, University of Dundee, U.K. She received the BScE degree in Engineering Physics and a PhD in Physics from Queen's University, Kingston, Canada in 2000 and 2006 respectively Her research interests include: ultrasound transducer arrays for medical diagnosis, guiding intervention, and therapy; ultrasound microscopy; acoustic manipulation and tweezing of cells; design, simulation, experimental characterisation and pre-clinical testing of device performance; piezoelectric materials;

electronics instrumentation for ultrasound systems. She is an associate editor for IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control, has published extensively on high-frequency transducer design and fabrication, including two patents in the area.

Tim Button is Professor of Functional Materials and Devices at the University of Birmingham, Birmingham, U.K, and Group Leader, Advanced Electronic Materials, CEITEC, Brno, CZ. He received a BTech in materials science and technology in 1978, and a PhD in materials science and technology in 1983, both from the University of Bradford, Bradford U.K. His research interests include microstructure and property development in functional ceramics, fabrication and processing techniques for ceramic materials, influence of processing on the properties and performance of functional materials, fabrication of ceramic components to "net shape", novel piezoelectric sensor and actuator devices, and high frequency ultrasonic transducers. He is also Managing Director of Applied Functional Materials Ltd., Birmingham, U.K., a company that he co-founded in 2004 to exploit novel ceramic processing technologies which enable the manufacture of unique functional ceramic devices in complex shapes and microscale sizes. The Company develops and supplies ceramic prototype components and devices, and is currently focussing its technology on the development of ultrasonic transducers for high frequency applications.