Optics + Ultrasound III

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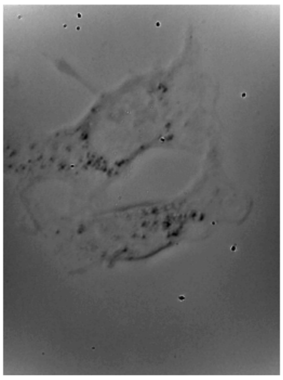

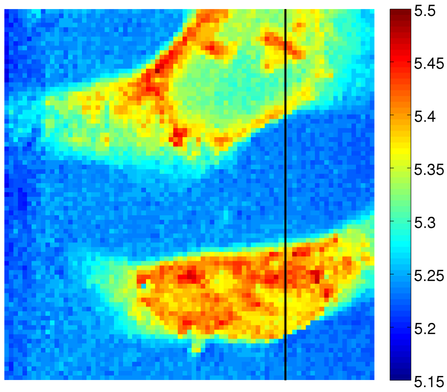

Venue: Vaughan Parry Williams Pavillion (see map at end) [1]
There is no registration fee for this meeting but please register in advance for catering purposes.
To register email Emily Judd (`emily.judd@nottingham.ac.uk`)
Enquiries to Steve Morgan[2] or Matt Clark [3]

Provisional programme 9 November 2016

1 Coffee + registration 9:30-10:00

2 Morning session

Time: 10:00
Title: Sub-acoustic resolution photoacoustic microscopy using blind structured speckle illumination
Author(s): T. Berer[1], M. Haltmeier[2], P. Burgholzer[1], E. Leiss-Holzinger[1] and T. W. Murray[3]
Address: [1] RECENDT, Research Center for Non Destructive Testing, Altenberger Strasse 69, 4040 Linz, Austria [2] Department of Mathematics, University of Innsbruck, Technikestrae 13a, 6020 Innsbruck, Austria [3] Department of Mechanical Engineering, University of Colorado at Boulder, Boulder, CO 80309, USA
Abstract: We present a method for enhancing the spatial resolution of optical absorption based photoacoustic imaging through highly scattering media. Our approach was inspired by recent work in fluorescence microscopy where super-resolution imaging was demonstrated using multiple unknown speckle illumination patterns. We extend this concept to the multiple scattering domain using photoacoustics, with the speckle pattern serving to generate ultrasound. The optical speckle pattern that emerges as light propagates through diffuse media provides structured illumination to an object placed behind a scattering wall. The photoacoustic signal produced by such illumination is detected using a focused ultrasound transducer. A novel

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reconstruction algorithm is introduced which utilises the variances in the acquired photoacoustic signals. We demonstrate through both simulation and experiment, that by acquiring multiple photoacoustic images, each produced by a different random and unknown speckle pattern, an image of an absorbing object can be reconstructed with a spatial resolution far exceeding that of the ultrasound transducer.

Time: 10:30
Title: Using spatially resolved acoustic spectroscopy in industrially relevant scenarios
Author(s): Rikesh Patel, Wenqi Li, Paul Marrow, Matthias Hirsch, Richard Smith, Steve Sharples, Matt Clark
Address: Optics and Photonics, University of Nottingham
Abstract: Spatially resolved acoustic spectroscopy (SRAS) is a method of characterising material though laser generated surface acoustic waves (SAW). It has become an established method for determining material properties through texture imaging, with the ability to obtain full quantitative grain orientation information for cubic materials. Our focus has branched out with a vision to use this technique in more engineering related fields. These includes characterising more complex structures such as hexagonal structured materials, obtaining defect and texture information from additively manufacturing parts and to make measurements on materials that are coated or are under stress. This paper will explore some of the current developments in the topics being investigated.

Time: 10:45
Title: Single Pulse Illumination of Multi-Layer Absorbers for Patterned Ultrasound Field Generation
Author(s): Michael D. Brown, Eleanor Martin, Ben T. Cox and Bradley E. Treeby
Address: Department of Medical Physics and Biomedical engineering, University College London
Abstract: In the past decade the use of optically generated ultrasound for biomedical applications has attracted increasing attention. However, at present spatially steering and focusing optically generated ultrasound fields in 3-D still poses a number of difficulties. In this work we discuss an approach for the generation of patterned optically generated acoustic fields in 3-D using a single optical pulse. This utilises multi-layer 'holograms' composed of several spatially separate absorbing layers. Each layer is individually patterned so as to focus at a set of targeted points. An optimisation approach by which a set of patterns for the generation of a desired field may be calculated is introduced. Experimental validation that the proposed absorbers are able to generate patterned acoustic fields is presented and early results of investigations into fabricating these absorbers using additive manufacturing are also discussed.

Time: 11:00
Title: Laser induced ultrasonic phased arrays using the full matrix capture and the total focusing method imaging algorithm
Author(s): Theodosia Stratoudaki[1,2], Matt Clark[2] and Paul D. Wilcox[1]
Address: [1] Department of Mechanical Engineering, University of Bristol, University Walk, Bristol, UK [2] Department of Electrical and Electronic Engineering, Faculty of Engineering, University of Nottingham.
Abstract: Ultrasonic phased arrays have changed the way that ultrasonic imaging is perceived, being at the heart of all medical ultrasonic imaging systems and sonars. During the last two decades, they have also seen a dramatic increase in their use for nondestructive testing. Conventional piezoelectric transducers are used for the vast majority of phased array ultrasonic measurements. However, it is a contact technique, requiring some kind of couplant such as adhesive bonding, or immersion in a water tank may be needed. Laser ultrasonics can address this challenge and deliver remote, couplant free acoustic imaging, extending to applications in hostile environments, places with limited access and inspection of geometrically complex components. The approach for Laser Induced Phased Arrays (LIPAs) taken in this presentation is to perform the imaging in post processing: using just one laser for ultrasonic generation and one laser interferometer for ultrasonic detection, at the non-destructive, thermoelastic regime, LIPAs of up to 160 array elements are synthesised, by using a data acquisition method known as the Full Matrix Capture and an imaging

algorithm known as the Total Focusing Method. A model is also presented and its results are compared with experimental results from aluminium samples with side drilled holes and slots at depths of 5 - 20 mm from the surface.

Time: 11:15
Title: Quantitative characterisation of functional materials by laser-ultrasonic methods
Author(s): Pavla Stoklasova, Petr Sedlak, Hanus Seiner, Michal Landa
Address: Laboratory of Ultrasonic Methods Institute of Thermomechanics, Czech Academy of Sciences web: http://LUM.it.cas.cz e-mail : ML@it.cas.cz
Abstract: The contribution deals with applications of laser-generated and optically detected ultrasonic waves (laser-ultrasonics) for determination of mechanical properties and characterisation of modern functional materials. There will be shown and discussed experimental arrangements suitable for evaluation of elastic properties of ferroelastic materials in different forms as bulk single crystals, thin wires or thin films and for determination of evolution of these properties with temperature and under mechanical stress. These material problems have initiated development of novel instrumentation and methodologies, using resonant ultrasound spectroscopy, surface acoustic waves or guided-wave approaches.

Time: 11:30
Title: Characterisation of the stress in single crystal membranes using their resonance response
Author(s): L. Zhou, M.J. Pearce, R.G. Prince, G. Colston, O. Trushkevych, M. Myronov, V.A. Shah, D.R. Leadley and R.S. Edwards.
Address: University of Warwick
Abstract: The residual stress in suspended single crystal membranes of Ge and 3C-SiC has been investigated using measurements of the membrane response to forced resonances with ultrasonic frequencies between 100 kHz and 600 kHz. Detection of the membrane response is via a scanned laser interferometer technique. This method can efficiently and easily measure the residual stress by mapping the resonant vibration patterns of the membranes and calculate their Q-factors at atmospheric or low pressure. Our study also justifies the inaccuracy in the measurements which is caused by temperature changes of the membranes due to the use of laser ultrasonics. A nonlinear elastic feature and superharmonic oscillations were observed under a strong excitation force at low pressure.

Time: 11:45
Title: Study on four transducer devices for better trapping efficiency
Author(s): Pradeep Bhasker
Address: University of Bristol
Abstract: This study is an effort to map the distribution and nature of forces over a whole device so as to get an understanding of the different regions which can prove to be useful in deciding the applications of acoustic devices. Four transducers were used to produce orthogonal waves of different frequencies for patterning micro spheres. A novel method of estimating the relative efficiency of the device based on the radial distribution function of the patterns was used. For patterning in an acoustic device it was found that anti-resonance frequency was better than resonance frequency. In an aqueous medium it was also noticed that after a certain limit, higher voltages do not provide better trapping efficiency. Optical tweezers have been used for direct measurement of the forces experienced in an acoustic trap under different voltages and frequencies.

Time: 12:00
Title: Wave control with spatially graded resonant elastic metamaterials.
Author(s): Andrea Colombi,Richard Craster and Matt Clark
Address: Imperial College London, Nottingham University
Abstract: Elastic metamaterials are an exciting and novel branch of wave physics devoted to the study of

heterogeneous and complex media able to control the propagation of mechanical waves at different scales and in various applications. Wave control is made possible by a microstructure made of subwavelength resonators, randomly arranged in the media, leading to extraordinary propagation properties. The result is that waves can be stopped, slowed down, rerouted around an obstacle or directed to a target.The potential for applications is high, involving several fields such as acoustics and elasticity and geophysics. Recently, a new type of locally resonant metamaterial made of longitudinal resonators attached to an elastic surface (membranes orhalf spaces) has shown a strong potential formanipulating flexural and Rayleigh waves. When this metamaterial is designed mixing concept derived from gradient index optics (e.g. spatially varying refractive index), the control performance are spectacular. Wewill show some numerical and laboratory example of such gradient index metamaterials and discuss some potential use in enhancedsensing and vibrationabsorption.

Time: 12:15
Title: Generation of ultrasound in solids by air shock waves caused by focused laser radiation or by electric spark discharge
Author(s): Victor V. Krylov
Address: Department of Aeronautical and Automotive Engineering, Loughborough University, Loughborough, Leicestershire, LE11 3TU, UK e-mail: V.V.Krylov@lboro.ac.uk
Abstract: This presentation gives an overview of the theoretical and experimental results obtained by the author and his co-workers in the area of generation of ultrasound in solids by strong air shock waves initiated near solid surfaces by focused laser radiation or by high-voltage electric spark discharge. Generation of Rayleigh and Lamb waves as well as longitudinal and shear bulk waves is discussed with the emphasis on possible applications to ultrasonic non-destructive testing. The advantage of generation of ultrasound in solids by incident air shock waves, in comparison with laser generation of ultrasound due to the thermo-optical generation mechanism, is that it does not depend on optical parameters of solids, i.e. it can be equally applied to metals and to light-transparent materials. The semi-analytical theory of the interaction of laser-initiated air shock waves with an elastic half-space or a plate is discussed. The obtained theoretical results are compared with the results of the experiments on air shock wave interaction with metal, plastic and wooden plates. The comparison shows that the obtained semi-analytical results are in good agreement with the experimental ones.

3 Lunch 12:30-1:30

Lunch provided!

4 Afternoon session

Time: 1:30
Title: (Invited) Spectrochemical mapping in SPM with dynamic optical excitation interplay of thermomechanical and elastic responses
Author(s): [1]Oleg Kolosov, [1]Peter Tovee, [1]Claire Tinker and [2]David Allsop.
Address: [1]Physics Department and [2]Biology and Life Sciences Department, Lancaster University, UK.
Abstract: Detecting of local optical absorption via scanning probe microscopy (SPM) opens unique possibility to study materials and biological objects with both nanoscale resolution and a chemical sensitivity. One of the most promising approached for such a system is to use a short pulsed (or, alternatively, high frequency modulated) light that can be absorbed in the dyed (for visible light) or naturally absorbing (for IR light) moieties and functional groups of the studied samples producing a local thermomechanical expansion.

Such excitation that is usually on the microsecond to ns time scale produces a vibration of the SPM probe that is proportional to the spectrally varied local absorption. In this talk we then analyse various mechanisms contributing to such a response and demonstrate that it is essential to consider a contribution of local elastic properties to the SPM data that together allows to unambiguously differentiate between pathological beta sheet peptides in amyloid fibres and benign alpha-helix peptides.

Time: 2:00
Title: Optical transmission and reception of ultrasound for guidance of minimally invasive procedures
Author(s): Adrien Desjardins
Address: University College London
Abstract: Ultrasound imaging can be invaluable to guide a wide range of minimally invasive medical procedures. With current-generation ultrasound probes, ultrasound is generated and received electrically. The complexities involved with fabricating these electrical probes can result in high costs that limit their clinical applicability. Additionally, it can be challenging to achieve wide transmission bandwidths and adequate wideband reception sensitivity with small piezoelectric elements. Optical methods for transmitting and receiving ultrasound are emerging as alternatives to their electrical counterparts. They offer several distinguishing advantages, including the potential to generate and detect the broadband ultrasound fields (tens of MHz) required for high resolution imaging. This talk will focus on recent work involving the fabrication of optical ultrasound transducers, their integration into medical devices and tests on biological tissue. In particular, we will highlight the development of polydimethylsiloxane (PDMS) carbon nanocomposites and their application to the distal ends of optical fibres to form miniature, high-performance transmitters. When paired with fibre-optic receivers, these transmitters allow for high-resolution imaging of vascular, cardiac and placental tissue. We will also highlight how fibre-optic ultrasound receivers can be used to track medical devices within the human body with sub-mm precision. Finally, we will show recent work on imaging phantoms with tuneable optical, ultrasonic and mechanical properties.

Time: 2:15
Title: Ultra-sensitive planoconcave optical microresonator ultrasound sensors
Author(s): James A. Guggenheim, Edward Z. Zhang and Paul C. Beard
Address: [1]Department of Medical Physics and Biomedical Engineering, University College London, Gower Street, London, WC1E 6BT, UK
Abstract: Highly sensitive broadband ultrasound sensors are required to expand the capabilities of biomedical and industrial ultrasound and photoacoustic imaging techniques. Achieving high sensitivity with piezoelectric transducers requires large elements and resonant material compositions that lead to poor frequency response and directivity, ultimately compromising image quality. We present a new class of optical ultrasound sensors based on novel polymer optical microresonators with a planoconcave geometry. The strong optical confinement afforded by the design (Q¿105) leads to ultra-high sensitivity (noise-equivalent-pressure down to 1.6mPa/$\sqrt{\text{Hz}}$) in addition to broadband frequency response to tens of MHz and near-omnidirectional sensitivity.

Time: 2:30
Title: Ultrasound modulation of chemiluminescence generated inside a highly scattering medium
Author(s): Junaid Ahmad[1], Baptiste Jayet[1], Philip J Hill[2], Melissa L Mather[3], Hamid Dehghani[4], Stephen P Morgan[1] [1]
Address: Optics and Photonics Research Group, Faculty of Engineering, University of Nottingham, NG7 2RD, UK [2] School of Biosciences, University of Nottingham, LE12 5RD, UK [3] Institute of Science and Technology in Medicine, Keele University, ST4 7QB, UK [4] School of Computer Science, University of Birmingham, B15 2TT, UK
Abstract: In vivo whole animal optical imaging is a useful non-invasive tool to access the pathological information of biological tissue. But, strong optical scattering of tissue results in a loss of spatial resolution,

quantitative data and significant optical signal attenuation. This research investigates a novel hybrid optical imaging technique that combines optical imaging with ultrasound (US) to improve the spatial resolution. The system comprises of a continuously excited US transducer applied to a tissue mimicking ‘phantom’ embedded with low light radiance sources. The US transducer scans over the phantom and modulates the light sources at US frequency in the region of its beam focus. The modulated signals are recorded by a photomultiplier tube that uses a lock-in amplifier to generate a 1D profile. Initial experiments show that US enables to localise chemiluminescent sources deep (∼2mm) inside a tissue phantom with higher scattering coefficients.

Time: 2:45
Title: Coupling short burst ultrasound and bioluminescent imaging.
Author(s): Baptiste Jayet[1], Junaid Ahmad[1], Hamid Dehghani[1], Steve Morgan[1]
Address: [1]Optics and Photonics, The University of Nottingham, University Park, NG72RD, Nottingham, UK [2]School of Computer Science, The University of Birmingham, B152TT, Birmingham, UK
Abstract: This research aims at coupling ultrasound (US) with bioluminescence imaging (BLI) to improve the resolution and accuracy of BLI. The influence of the passage of a short US burst on a bioluminescent source is studied using phantoms. The bioluminescence emission is modelled using a chemiluminescent solution (extracted from commercial red glow sticks) embedded inside an optically scattering gel made of agar that mimics a biological medium. The chemiluminescent light is recorded by a photomultiplier while short focused US burst, emitted by a programmable US scanner, are travelling through the medium. A change in the optical signal has been observed when the US burst travels through the source. The exact mechanisms of this interaction are still investigated. However these preliminary results are encouraging since they show that it is possible to accurately localise the luminescent source inside our optically scattering phantom.

Time: 3:00
Title: Nanoscale FRET based liposome contrast agents for ultrasound mediated fluorescence tomography
Author(s): Qimei Zhang[1], Stephen P. Morgan[1], Melissa L. Mather[2]
Address: [1] Optics and Photonics Group, Faculty of Engineering, University of Nottingham, Nottingham, NG7 2RD, United Kingdom [2] Institute for Science and Technology in Medicine, Keele University, Stoke-on-Trent, ST4 7QB, United Kingdom
Abstract: Ultrasound mediated fluorescence tomography has been investigated in the past decade to obtain fluorescence images with optical contrast and US resolution. However, the very low modulation depth due to the intrinsic incoherent properties of fluorescence leads to low signal-to-noise ratio. In this work, a new approach to fluorescence imaging in optically turbid media based on nanoscale ultrasound-switchable liposome contrast agents is reported. Liposomes containing FRET pairs with emission wavelengths located in the near-infrared window were prepared. Exposure of the liposomes to ultrasound resulted in changes in the fluorescent signal. Line scanning of a tube containing the contrast agents buried at a depth of 1 cm in a heavily scattering tissue phantom demonstrated an improvement in spatial resolution by a factor of 6.3 as compared with images obtained in the absence of ultrasound. The results obtained provide evidence of the potential the FRET based liposomes have for in vivo fluorescence imaging.

Time: 3:45
Title: Optically and acoustically triggerable sub-micron phase-change contrast agents for enhanced photoacoustic and ultrasound imaging
Author(s): Shengtao Lin[1], Anant Shah[2], Javier Hernndez-Gil[3], Bethany I. Harriss[3], Terry O. Matsunaga[4], Nicholas Long[3], Jeffrey Bamber[2], Meng-Xing Tang[1]* [1]
Address: Department of Bioengineering, Imperial College London, London, UK [2] Joint Department of Physics, Institute of Cancer Research, Surrey, England, UK [3] Department of Chemistry, Imperial College London, London, UK [4] Department of Medical Imaging, University of Arizona, Tucson, Arizona, USA *mengxing.tang@imperial.ac.uk
Abstract: We demonstrated a versatile phase-change sub-micron contrast agent that can provide three

modes of contrast enhancement: 1) photoacoustic imaging contrast, 2) ultrasound contrast with optical activation and 3) ultrasound contrast with acoustic activation. Such a contrast agent, which we call a 'Cy-droplet', comprises a highly volatile perfluorocarbon and a near infrared optically absorbing dye. It is manufactured via a 'microbubble condensation' method. The phase transition of Cydroplets can be optically triggered by a pulsed laser illumination, inducing a photoacoustic signal and forming a stable gas bubble that is visible with echoultrasound in situ, potentially in an extravascular location because of the sub-micron initial size. Alternatively, Cy-droplets can convert to microbubble contrast agent upon external acoustic energy deposition with clinically acceptable ultrasound exposure parameters, which offers potentially extravascular ultrasound contrast enhancement. Such versatility of acoustic and optical 'triggerability' can potentially improve multimodality imaging, molecularly targeted imaging and controlled drug release in the diagnosis and treatment of cancer and other diseases.

Time: 4:00
Title: A review of reporter genes used for photoacoustic imaging
Author(s): Joanna Brunker[1], Junjie Yao[2], Jan Laufer[3] and Sarah E. Bohndiek[1]
Address: [1] Department of Physics and Cancer Research UK Cambridge Institute, University of Cambridge, UK, [2] Photoacoustic Imaging Lab, Duke University, Durham, North Carolina, USA [3] Institut fr Optik und Atomare Physik, Technische Universitt Berlin, Germany
Abstract: A reporter gene is an exogenous segment of DNA encoding for a protein that can be visualised using imaging or chemical analysis. Here, we provide an overview of the various genetic reporters that have been studied using photoacoustic imaging, broadly categorising them into two groups: enzymatic reporters; as well as fluorescent proteins and chromoproteins. We review the photoacoustic imaging technologies that have been used for reporter gene imaging, including representative examples of studies that have been successfully demonstrated in living subjects. We also highlight the importance of selecting appropriate image reconstruction and spectral unmixing approaches, including the difficulties associated with estimating and correcting for the unknown light distribution within the tissue. An outlook is given of the key challenges remaining in the field and the prospects for photoacoustic reporter gene imaging, with a particular focus on cancer diagnosis, staging and treatment.

Time: 4:15
Title: Needle sized laser ultrasonic diagnostic device
Author(s): Mitra Soorani, Richard J Smith, Fernando Perez Cota, Matt Clark
Address: Optics and Photonics Group, Faculty of Engineering, University of Nottingham, University Park, Nottingham, NG72RD, UK
Abstract: Designing extremely small sized transducers can be very important both in medical and industrial applications to extract information that is hard to access externally. Optical transducers are considered as an alternative to piezoelectric transducers due to their small size and high sensitivity. Re-engineered transducers for the detection of Brillouin scattering in transmission technique [1] provided a possibility of designing such small transducers. The aim of the current work is to develop tunable transducers at the tip of single mode optical fibres that can be used to generate and detect ultrasound. The small size of the fibres allows the transducers to be deployed via needles or catheters for biomedical applications.

The transducer presented in this study is comprised of a multilayer structure of partially reflecting layers around an optically transparent filling, similar to a Fabry-Pérot interferometer [2]. Different techniques are used to deposit the layers: direct sputter coater, dip coating and spin coating. The fabricated transducers are characterised using optical spectroscopy. A pump-probe fibre based laser ultrasound instrument is used for generation and detection of ultrasound. The layer structure, layer thickness, materials and the two wavelengths determine the optimum design of the transducers.

We are presenting preliminary results of generation and detection of ultrasound in both transmission and reflection modes. The ultrasound waves are produced in different frequency regions from hundreds of MHz to tens of GHz. We will also discuss the and potential solutions for the future development of these novel

fibre optic ultrasonics transducers that we model the effect of them.

[1] F. Perez-Cota, R. Smith, E. Moradi, Kevin F. Webb and M. Clark, , J. Phys.: Conf. Ser. 684(1), January 2016. [2] Cox. B.T and Beard. P,, IEEE. 54(2), FEBRUARY 2007.

Time: 4:30
Title: Three dimensional phononic imaging of biological cells.
Author(s): Fernando Perez-Cota, Richard J. Smith, Emilia Moradi, Leonel Marques, Kevin F. Webb and Matt Clark.
Address: Optics and Photonics group, Faculty of Engineering, University of Nottingham, Nottingham, UK
Abstract: Imaging of cells using high frequency phonons (∼5GHz) offers great potential for label-free mechanical imaging and characterisation of biological cells. A carefully engineering transducer, designed to generate acoustic waves and manage the thermal and light exposure to the cells, allows us to measure the Brillouin frequency in three dimensions. The Brillouin frequency, which is a measure of the refractive index and speed of sound, gives a mechanical mechanism for contrast. While the lateral resolution of these measurements is limited by optical diffraction, the axial resolution depends on the acoustic wavelength which is typically sub-optical ($\lambda_{\mathrm{acoustic}} = \lambda_{\mathrm{optical}}/2n$). Analysis of the achievable axial resolution is presented as well as experimental results on phantom, fixed and living cells.

5 Closing remarks

6 Map to venue