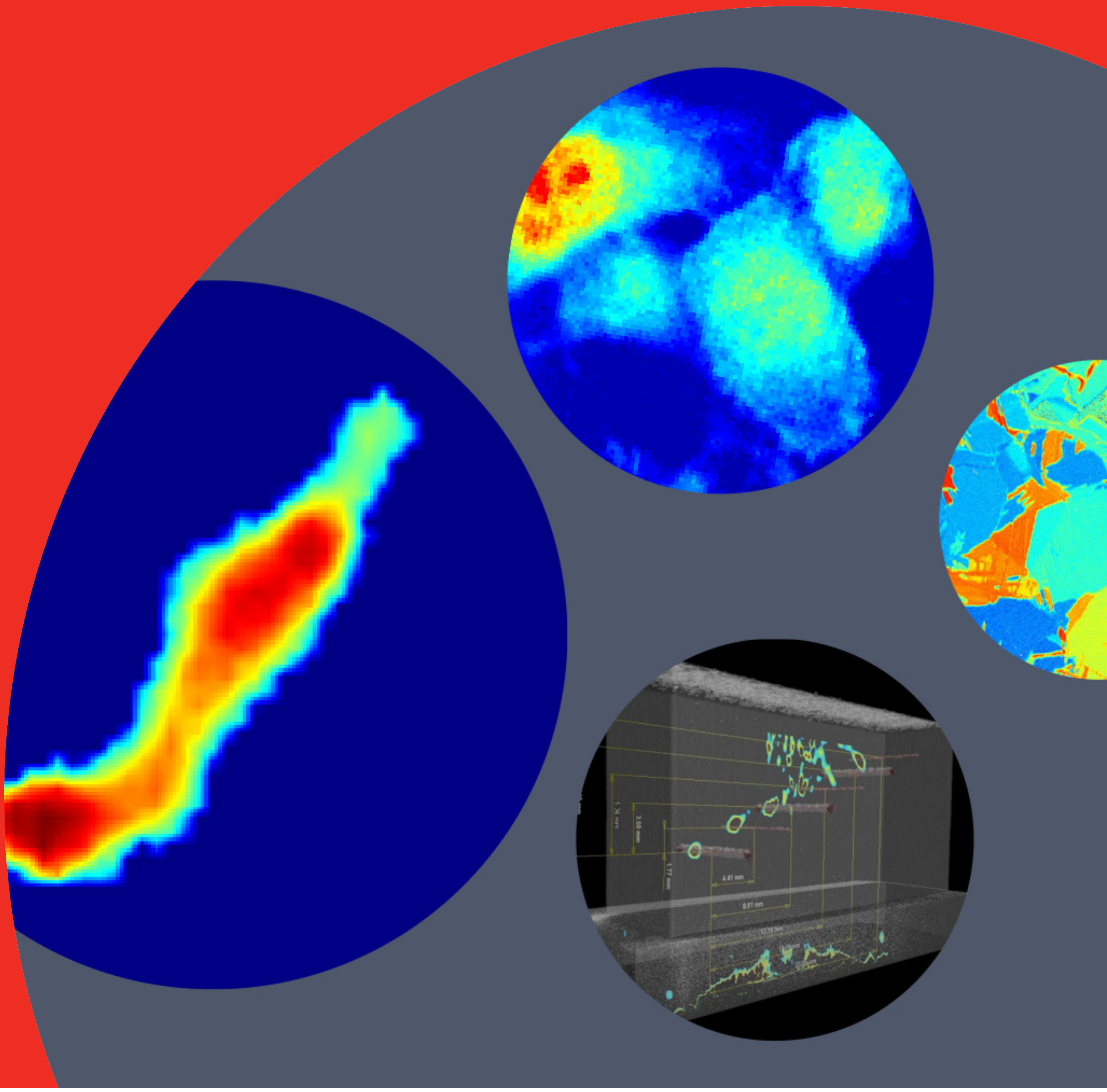
Optics + Ultrasound V

12–13 September 2022
Institute of Physics, London, UK



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Optics + Ultrasound V Programme

Monday 12 September 2022

10am - 10:30am	**Registration and Refreshments**
	Morning Session: NDE & Materials I
10:30am - 11:30am	Exploring Irradiation-Induced Property Change in Fusion Reactor Materials using Laser-Induced Transient Grating Spectroscopy **Invited Talk: Felix Hofmann**
11:30am - 11:45am	Optimization of Laser Adhesion Test of titanium/composite bonding by beam shaping **Mr Mathieu Ducousso**
11:45am - 12pm	Characterizing elasticity of NiTi epitaxial thin film by transient grating spectroscopy **Tomas Grabec**
12pm - 12:15pm	Laser-ultrasonic monitoring of elastic parameters of aluminium alloy sheets during natural aging using zero-group-velocity resonances **Georg Watzl**
12:15pm - 12:30pm	SRAS++: single-crystal elasticity measurements in polycrystalline materials **Dr Paul Dryburgh**
12:30pm - 1:30pm	**Lunch and Poster Session**
	Afternoon Session: Novel Instrumentation and Methods
1:30pm - 2:30pm	Projecting pressure images with acoustic holography **Invited Talk: Peer Fischer**
2:30pm - 2:45pm	Liquid crystal sensors for ultrasonic displacement measurements **Martha Turvey**
2:45pm - 3pm	A practical measurement procedure used for a laser induced ultrasound system **Jun Li**
3pm - 3:30pm	**Afternoon Break**
	Afternoon Session: NDE & Materials II
3:30pm - 3:45pm	Characterization of Strongly Anisotropic Materials by Transient Grating Spectroscopy **Pavla Stoklasová**
3:45pm - 4pm	Directivities and relative amplitudes of bulk waves for buried sources at different depths **Miss Xin Tu**
4pm - 4:15pm	Sizing non-sharp defects using ultrasonic array images **Dr Shivaprasad Shridhara Bhat**
4:15pm - 4:30pm	Phased array design for grating lobe suppression in Laser Induced Phased Arrays (LIPA) **Mr Peter Lukacs**
4:30pm - 4:45pm	Towards inline material microstructure imaging using spatially resolved acoustic spectroscopy (SRAS) **Dr Rikesh Patel**
4:45pm - 7pm	**Networking with Buffet and Drinks**

Tuesday 13 September 2022

9am - 9:30am	**Registration**
	Morning Session: Physical and Ultrafast acoustics
9:30am - 10:30am	Laser Ultrasound: a perfect tool to observe Zero Group Velocity and Backward Guided Elastic Waves **Invited Talk: Clare Prada**
10:30am - 10:45am	Acoustic Super oscillations: Enhancing the Resolution of Laser Ultrasonics **Prof Anthony Kent**
10:45am - 11am	Picosecond ultrasonics of two-dimensional nanolayers **Mrs Wenjing Yan**
11am - 11:15am	**Morning Break**
	Morning Session: Ultrafast and Photoacoustics
	Ultrafast
11:15am - 11:30am	Polarisation-sensitive super-resolution phononic reconstruction of nanostructures **Dr Rafael Fuentes Dominguez**
11:30am - 11:45am	Development of GHz optoacoustic lenses for sub-optical resolution imaging **Mengting Yao**
11:45am – 12pm	3D phononic endo-microscopy of biological matter **Dr Salvatore LaCavera III**
	Photoacoustics
12pm - 12:15pm	All-optical photoacoustic endomicroscopy needle probe for optical biopsy **Tianrui Zhao**
12:15pm - 12:30pm	Noise reduction in LED-based photoacoustic imaging with spatiotemporal singular value decomposition **Mengjie Shi**
12:30pm - 1:30pm	**Lunch and Poster Session**
	Afternoon Session: Biomedical I
1:30pm - 2.30pm	Optical Ultrasound (OpUS) Imaging for Guiding Minimally Invasive Procedures **Invited Talk: Adrien Desjardin**
2:30pm - 2:45pm	Characterising biomechanics of the limbal niche using vibrational optical coherence elastography (OCE) **Mr Yilong Zhang**
2:45pm - 3pm	Real-Time Ultrasonic Needle Tip Tracking with an Integrated Fibre-optic Hydrophone **Dr Christian Baker**
3pm - 3:30pm	**Afternoon Break**
	Afternoon Session: Biomedical II
3:30pm - 3:45pm	Real-time, minimally invasive optical ultrasound imaging of cardiovascular anatomy **Mr Robert Stafford-Williams**
3:45pm - 4pm	Whole-Body Small Animal Imaging System **Miss Alissa Silva**

4pm - 4:15pm	Improving photoacoustic imaging of clinical needles using candle soot nanocomposite coatings **Mengjie Shi, Semyon Bodian**
4:15pm - 4:30pm	Highly miniaturised ultrasound transducer based on a single dual-clad optical fibre **Dr Richard Colchester**
4:30pm	**Close**

Posters sessions Monday and Tuesday lunchtime
Deep Learning Based Automated Defect Recognition for Laser Ultrasonic Imaging **Michael Gillespie, Klaudia Zymelka**
Deep Learning-Based, Laser Ultrasound Tomography of Tissue Mimicking Phantoms **Mr. Ahmed Al Fuwaires**
Detection of HIFU lesions by optical coherence tomography **Dr Jason Raymond**
Investigating Granularity for Reducing Limited Aperture Effects in Photoacoustic Imaging **Nat Redgewell**
Miniature optical-resolution photoacoustic microscopy using transparent ultrasound transducer **Kwok Ho Lam**
Apparent Anisotropic Thermal Diffusivity in Cubic Single Crystals from Transient Grating Spectroscopy **Jakub Kušnír**
A Vision Transformer and Convolution Neural Network-based Competitive Study for assessment of wound healing in Mice **Jinpeng Liao**
Quantifying dimensions of the limbal niche using optical coherence tomography (OCT) **Mr Yilong Zhang**

Oral presentations

Exploring Irradiation-Induced Property Change in Fusion Reactor Materials using Laser-Induced Transient Grating Spectroscopy

Dr Felix Hofmann[1], Abdallah Reza, Daniel Mason
[1]*University Of Oxford, UK*

Morning Session: NDE and Materials I, September 12, 2022, 10:30 AM - 12:30 PM

Fusion power promises a safe, reliable, environmentally friendly, and virtually inexhaustible energy source. Impressive milestones have been reported by international initiatives (e.g. JET and NIF) and private companies. A major hurdle for commercially viable fusion power is the availability of materials able to survive exposure to the intense irradiation conditions, ion bombardment, high temperatures and high heat flux expected in fusion reactors for tens of years. Unfortunately, the conditions anticipated in service cannot yet be re-created. While irradiation of materials with fission neutrons is perhaps most representative, it is slow, costly and produces radioactive samples. Ion-irradiation is an attractive surrogate. It allows rapid accumulation of large damage doses and enables mechanistic insight into irradiation-induced material degradation. Unfortunately, ion-irradiation only produces a few-micron-thick layer of damaged material. Approaches to probe the mechanical properties of such thin layers are well established and have been used extensively to understand irradiation-induced mechanical property evolution. However, the degradation of thermal transport properties due to irradiation, which is of key importance for fusion armour components, remains largely unexplored.

To address this challenge, we have adapted laser-induced transient grating spectroscopy (TGS) to probe the elastic and thermal transport properties of thin, ion-irradiated surface layers (1). We have developed a TGS instrument that allows rapid high accuracy measurements, as well as 2D mapping of properties (2). Using this new tool we have explored ion-irradiation-indued changes in tungsten, the leading candidate material for fusion reactor armour (3, 4). Our results show that even small damage doses can cause substantial reductions in thermal conductivity. By combining our measurements with predictions from atomistic simulations these changes can be understood in terms of the underlying defect structures (5). We can also use measured thermal diffusivity and elastic properties to infer the equivalent point defect density in the material. Remarkably our predicted defect densities are almost an order of magnitude higher than those seen in transmission electron microscopy (TEM). This observation confirms the presence of a large population of very small defects that TEM is not sufficiently sensitive to detect, in agreement with predictions from atomistic simulations. By combining TGS with insitu heating experiments of ion-irradiated samples we track the progressive removal of these small defects and can determine their nature (6). These insights are of key importance for the design of fusion reactor armour components and their operating regime. They also provide key pointers for the development of next generation, high irradiation resistance materials.

1. F. Hofmann et al., Non-Contact Measurement of Thermal Diffusivity in Ion-Implanted Nuclear Materials. Sci. Rep. 5 (2015), doi:10.1038/srep16042.
2. A. Reza et al., Non-contact, non-destructive mapping of thermal diffusivity and surface acoustic wave speed using transient grating spectroscopy. Rev. Sci. Instrum. 91, 54902 (2020).
3. A. Reza, H. Yu, K. Mizohata, F. Hofmann, Thermal diffusivity degradation and point defect density in self-ion implanted tungsten. Acta Mater. 193, 270–279 (2020).
4. A. Reza, Y. Zayachuk, H. Yu, F. Hofmann, Transient grating spectroscopy of thermal diffusivity degradation in deuterium implanted tungsten. Scr. Mater. 174, 6–10 (2020).
5. D. R. Mason, A. Reza, F. Granberg, F. Hofmann, Estimate for thermal diffusivity in highly irradiated tungsten using molecular dynamics simulation. Phys. Rev. Mater. 5, 125407 (2021).
6. A. Reza et al., Thermal diffusivity recovery and defect annealing kinetics of self-ion implanted tungsten probed by insitu transient grating spectroscopy. Acta Mater. 232, 117926 (2022).

Optimization of Laser Adhesion Test of titanium/composite bonding by beam shaping

Mr Mathieu Ducousso[1], Mr Eduardo Cuenca[1,2,3], Mr Laurent Berthe[2], Mr François Coulouvrat[3]
[1]Safran Tech, Magny Les Hameaux, France, [2]PIMM, CNRS, Arts et Métiers Paris Tech, Paris, France, [3]Sorbonne Université, Institut Jean Le Rond d'Alembert, UMR CNRS 7190, Paris, France

Morning Session: NDE and Materials I, September 12, 2022, 10:30 AM - 12:30 PM

For aeronautical applications, the actual certification rules limit the use of bonding joints for structural parts. Thus, a Non Destructive Technology able to prove that the mechanical performances of the bonding are equal to that expected is required. Laser Adhesion Test (LASAT) appears as an efficient way to achieve it. [1] It consists of generating an intense shock wave (GPa range) in the bonded structure by illuminating the surface using an intense laser pulse, in the GW/cm2 intensity range. Illumination creates a plasma expansion which generates a compressive shock wave. It is then reflected from the back face of the material into a release shock wave. This release wave is used to test the quality - or the mechanical strength - of the bond. However, method is challenging for Leap fan blade titanium bonding because of the high difference of acoustic impedance of the materials and the heterogeneity of the composite.

Based on quantitative simulations of the process [2] and considering only the metallic part of the mixed bonding, we proposed an optimization of the process by illuminating the structure using a top-hat laser profil and by accumulating the shear wave tensile contribution (radiated from edge of the illumination) with the main release one (radiated from center illumination), with time synchronization between the two waves by laser spot diameter adjusting. It allows to generate a high enough traction in the bonding to control or disbond it.

[1] M. Ducousso, S. Bardy, Y. Rouchausse, T. Bergara, F. Jenson, L. Berthe, L. Videau, N. Cuvillier, Appl. Phys. Lett., 112-11, 111904 (2018)
[2] E. Cuenca, M. Ducousso, A. Rondepierre, L. Videau, N. Cuvillier, L. Berthe et F. Coulouvrat, Propagation of laser-generated shock waves in metals: 3D axisymmetric simulations compared to experiments, J. Appl. Phys 128 (2020).

Characterizing elasticity of NiTi epitaxial thin film by transient grating spectroscopy

Tomas Grabec[1], Kristyna Zoubkova[1], Pavla Stoklasova[1], Klara Luenser[2], Sebastian Faehler[2], Petr Sedlak[1], Hanus Seiner[1]

[1]Institute Of Thermomechanics, Czech Academy Of Sciences, Czech Republic, [2]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf e.V., Germany

Morning Session: NDE and Materials I, September 12, 2022, 10:30 AM - 12:30 PM

Transient grating spectroscopy (TGS) with differential heterodyne detection setup allows to measure surface waves of micrometer wavelengths with very high sensitivity. This extraordinary sensitivity enables characterization of higher-order surface modes propagating in a slow-on-fast system of a film on a substrate. Moreover, dominantly in-plane shear modes are detectable in a measurement of a very detailed angular dispersion. Such information allows for determination of the anisotropic elasticity of a thin supported film. Specifically, we carried out TGS measurements of three-micrometer-thick epitaxial film of the Nickel-Titanium alloy at elevated and room temperatures, covering the single-crystalline austenitic state and multi-variant martensitic state, respectively. Subsequent analysis of the angular dispersion of up to five detected wave modes shows that the presumed tetragonal elasticity can be near-completely characterized using an inverse procedure based on the Ritz method. However, even with such an abundance of information, certain aspects of the anisotropic elasticity remain hidden, or more precisely, the detected modes are not sensitive to them. On the other hand, the height of the film can be determined with rather good precision.

Laser-ultrasonic monitoring of elastic parameters of aluminum alloy sheets during natural aging using zero-group-velocity resonances

Georg Watzl[1], Clemens Grünsteidl[1], Jürgen Nietsch[2], Johannes Österreicher[2]
[1]RECENDT Gmbh, Linz, Austria, [2]LKR Light Metals Technologies Ranshofen, Austrian Institute of Technology, Ranshofen, Austria

Morning Session: NDE and Materials I, September 12, 2022, 10:30 AM - 12:30 PM

Forming of high-strength aluminum alloys often involves prior solution heat treatment to soften the material.
The alloy is heated to dissolve nanoscale hardening constituents, followed by rapid quenching to impede precipitation of the dissolved phases, leaving the material in a supersaturated state.
However, subsequent natural aging at room temperature partly reverses this process within a few hours [1], posing a logistical challenge to industrial operations as formability decreases and springback increases.
Here we demonstrate an in situ laser ultrasonic method based on the generation and detection of zero-group-velocity plate resonances to monitor small changes (<1%) of Young's modulus, shear modulus, and Poisson's ratio [2] during natural aging of an aluminum alloy (AA7075) sheet.
Additionally, we followed plastic mechanical properties by tensile testing and we intermittently measured electrical conductivity and performed differential scanning calorimetry to assess precipitation during natural aging.
We find strong correlation between formation of precipitation phases and an increase in elastic moduli and material strength, indicating that the presented method could be an attractive tool for process control in aluminum alloy forming.

[1] E. Becker, W. Heyroth, Phys. Status Solidi (a) 100 (1987) 485–49
[2] D. Clorennec, C. Prada, D. Royer, J. Appl. Phys. 101 (2007)

SRAS++: single-crystal elasticity measurements in polycrystalline materials

Matt Clark[1], Wenqi Li[1], Rikesh Patel[1], Richard Smith[1], **Dr Paul Dryburgh**[1]
[1]University Of Nottingham, Nottingham, United Kingdom

Morning Session: NDE and Materials I, September 12, 2022, 10:30 AM - 12:30 PM

The elastic constants (Cijkl) provide vital insights into the behaviour of a material, allowing calculation of various critical mechanical properties, along with the ultrasonic velocities often necessary for inverse problems, and facilitating simulation of microstructure evolution during materials processing. However, elasticity measurements are challenging to undertake, usually requiring a single crystal of known crystallographic orientation. Unfortunately, most engineering metals appear as polycrystalline aggregates, preventing the measurement of their elastic constants by these methods.

Spatially resolved acoustic spectroscopy (SRAS) is an acoustic microscopy technique, that can image the microstructure and measure the crystallographic orientation of grains or crystals in the material. It works by measuring the velocity of surface acoustic waves (SAWs) via the acoustic spectrum. The use of the acoustic spectrum to measure the velocity has a number of practical advantages, which makes the technique robust and fast and gives an excellent spatial resolution. This makes the measurement suitable for imaging and gives it many advantages over traditional laser UT and microstructural measurement techniques. This provides a viable method to measure the elastic constants in ‘real-world’ polycrystalline samples. The talk will review the experimental instrument, inversion procedure (for calculating both crystallographic orientation and elastic constants), and present recent experimental results.

Projecting pressure images with acoustic holography

Professor Peer Fischer[1]
[1]Heidelberg University, Germany

Afternoon Session: Novel Instrumentation and Methods, September 12, 2022, 1:30 PM - 3:00 PM

Dennis Gabor invented the hologram while working at British Thomson-Houston to refine electron microscope images. I will show that a similar concept can be used in acoustics. It simplifies an otherwise cumbersome technology and leads to the most sophisticated pressure images to date. Since sound waves can also exert forces, the acoustic hologram can be used for actuation and assembly, especially at small scales. I will describe ongoing work to realize the first fully connected 3D hologram, as well as its use to assemble matter into 3D objects in “one shot”. Taking further inspiration from optics, I will address the question whether it is possibly to realize a “beamer” for ultrasound to project high-resolution pressure patterns.

Liquid crystal sensors for ultrasonic displacement measurements

Martha Turvey[1], Dr Oksana Trushkevych[1], Dr Rachel S Edwards[1]
[1]University of Warwick, UK

Afternoon Session: Novel Instrumentation and Methods, September 12, 2022, 1:30 PM - 3:00 PM

Liquid crystal based materials could be deployed as a smart paint or removable sensor for detection of a 2D ultrasonic field. This detection method is quicker and less expensive than the standard method of laser vibrometry, which requires point scanning to map the field. Previously, polymer dispersed liquid crystals films have been shown to allow fast and cheap mapping of a displacement field [1]. Here we show that sensors made from thermochromic liquid crystals (TLCs) can be similarly used. Heat generated through local absorption of ultrasound in the sensing layer alters the material properties of the TLC, resulting in a change in wavelength of the reflected light which corresponds to temperature. This wavelength can be converted to a temperature value through comparison with a colour standard, with the temperature change depending on several factors including ultrasonic displacement. The visual nature of the sensor makes the method ideal for automation using robotic vision, and the speed and low cost allow for initial measurements over large areas, condition monitoring, and fast transducer characterisation.

[1] Edwards, R. S., Ward, J., Zhou, L. Q., & Trushkevych, O. (2020). The interaction of polymer dispersed liquid crystal sensors with ultrasound. Applied Physics Letters, 116(4), 044104.

A practical measurement procedure used for a laser induced ultrasound system

Jun Li[1]
[1] *University of Bristol, Bristol, UK*

Afternoon Session: Novel Instrumentation and Methods, September 12, 2022, 1:30 PM - 3:00 PM

In this paper, we introduced a practical measurement procedure used in the laser induced ultrasound system developed in the Bristol UNDT lab. In this system, the laser generator is a diode-pumped solid-state laser with a wavelength of 1053 nm and a power of 2 mJ while the laser detector is a built-in optical fiber Sagnac interferometer with a 1550 nm continuous wave superluminescent diode laser source. Both the laser generator and the detector head are installed on a motor-controlled stage with 3 degrees of freedom to achieve position scans for acquiring ultrasonic array datasets. The relative positions between the laser generator, the detector and the specimen are firstly calibrated and then used to design the system scan paths for a specific array inspection configuration. The number of averages used for the received signals is optimized to trade off the measurement efficiency and the signal to noise ratio. Then, the velocity of the surface wave is calculated, which is firstly used to measure system time delay and compensate signal amplitude variations due to specimen's surface roughness, and then removed using a time window to suppress the related image artefacts in the resultant ultrasound images. With considering all factors mentioned above, it is shown that the improvement of 7 dB in the signal to noise in the ultrasound images can be achieved.

Characterization of Strongly Anisotropic Materials by Transient Grating Spectroscopy

Pavla Stoklasová, Tomáš Grabec, Kristýna Zoubková, Stanislav Krátký, Hanuš Seiner
[1]Institute of Thermomechanics, Czech Academy of Sciences, Prague, Czech Republic, [2]Institute of Scientific Instruments, Czech Academy of Sciences, Brno, Czech Republic

Afternoon Session: NDE and Materials II, September 12, 2022, 3:30 PM - 4:30 PM

Transient grating spectroscopy (TGS) is a laser-ultrasonic method allowing measurement of the surface acoustic wave (SAW) velocity in an examined material for a given direction of the wave vector. We explore the capability of TGS for the determination of shear elastic coefficients of strongly anisotropic cubic materials. TGS is tested on a set of single crystals with an anisotropy factor up to A=25. Based on the obtained TGS data, we discuss the possibility of also using the TGS technique for assessing the longitudinal elastic coefficient.

We can conclude that the TGS method can be used to reliably determine the directional dependence of the SAW velocity in these materials, and the resulting experimental datasets are sufficient for inverse determination of both the soft and the hard shear elastic constants. The longitudinal coefficient can be determined with lower accuracy.

Directivities and relative amplitudes of bulk waves for buried sources at different depths

Miss Xin Tu[1], Dr Jie Zhang[1], Dr Alberto Gambaruto[1], Prof Paul Wilcox[1]
[1]University of Bristol, Bristol, UK

Afternoon Session: NDE and Materials II, September 12, 2022, 3:30 PM - 4:30 PM

Laser induced phased array (LIPA) provides a way for remote inspection in non-destructive evaluation (NDE), combining well-developed ultrasonic imaging techniques with flexible array configurations achieved by optical scanning [1]. As any other ultrasonic transducers, the directivity of the bulk waves generated by lasers needs to be determined to design the inspection, optimise the array design, and reduce scan time. The widely employed directivity patterns for laser generated ultrasound in isotropic elastic half space assumes that the laser energy is absorbed at the surface and does not suit to most non-metals. This is because the increased optical penetration depths invalidate the force dipole model for metals. Current work models the laser source as a centre of expansion below surface to account for this effect [2] and analytically calculates the far-field directivity of such a source. As optical penetration depth becomes comparable to the ultrasonic wavelength, the directivities and the relative amplitudes of the bulk waves change, and this needs to be accounted for in the design of the inspection and imaging algorithms.

[1] Stratoudaki, Clark, and Wilcox. "LIPA using FMC data acquisition and TFM." Optics express 24, no. 19 (2016)
[2] Scruby and Drain. Laser ultrasonics: techniques and applications. Routledge, 2019.

Sizing non-sharp defects using ultrasonic array images

Dr Shivaprasad Shridhara Bhat[1], Dr Jie Zhang, Dr Nicolas Larrosa
[1]*University of Bristol, Bristol, UK*

Afternoon Session: NDE and Materials II, September 12, 2022, 3:30 PM - 4:30 PM

Existing structural integrity assessment procedures typically assume flaws to be infinitely sharp when they cannot be considered as local thinning areas. The 'crack-like defect' assumption could then be over-conservative in many cases, leading to pessimistic assessments of structural components and severe underestimations of their safety margin against fracture. From an inspection point of view, one of the main challenges while adopting non-destructive evaluation (NDE) techniques is distinguishing between sharp cracks (e.g., fatigue) and non-sharp defects and identifying the more severe ones. The present work aims to investigate the performance of the ultrasonic array image-based techniques in distinguishing sharp and non-sharp defects. Parametric numerical simulations and experimental measurements are performed to generate full-matrix capture datasets, which are then processed using the total focusing method (TFM) to form an image. A TFM image-based sizing approach is then presented to quantify the measurement limitation and sizing of notch depth and width. It is demonstrated that accounting for material anisotropy (in terms of velocity vs incidence angle variation) in the imaging algorithm results in a significant reduction in notch width sizing error.

Phased array design for grating lobe suppression in Laser Induced Phased Arrays (LIPA)

Geo Davis[1], Anthony Gachagan[1], Don Pieris[1], Theodosia Stratoudaki[1], **Peter Lukacs[1]**
[1]*University Of Strathclyde, Glasgow, UK*

Afternoon Session: NDE and Materials II, September 12, 2022, 3:30 PM - 4:30 PM

Laser Induced Phased Array (LIPA) is an ultrasonic bulk-imaging technique, that synthetically produces an array by scanning a single generation and detection laser. A LIPA is a remote, couplant-free, small footprint array, thus is it can address various challenges in the field of ultrasonic imaging, including imaging in extreme environments, places of restricted access and on objects with complex geometries. Currently, the bottleneck of LIPAs is the long acquisition time due to laser scanning. Reducing the number of elements could speed up acquisition, however the resulting interelement spacing must be less than half the acoustic wavelength, in order to avoid the generation of artefacts by the grating lobes induced by under sampling.

In this work, phased array design is explored to suppress the grating lobes of LIPAs. Utilising the reconfigurability and ability over-lapping array elements that LIPA presents, novel designs are presented. The performance of the layouts is evaluated in an analytical model based on Huygens' principle. Consequently, the arrays are synthesised to experimentally demonstrate their capabilities.

By employing carefully designed arrays for LIPAs, grating lobes are surpassed to achieve artefact-free imaging with an interelement spacing larger than half the acoustic wavelength while using the same number of elements to that of a sparse periodic array.

Laser Ultrasound: a perfect tool to observe Zero Group Velocity and Backward Guided Elastic Waves

Dr Claire Prada
Institute Langevin, ESPCI, Paris, France

Morning Session: Physical and Ultrafast acoustics, September 13, 2022, 9:30 AM - 11:00 AM

In elastic waveguides, the coupling between shear and compression waves results in complex dispersion effects. Negative phase velocity modes are observed in most waveguides like plates, tubes or ribbons. These backward modes appear when two branches of neighbouring cut-off frequencies repel each other. In the absence of attenuation, the minimum frequency of a backward branch corresponds to a zero group velocity (ZGV) mode and is associated with a narrow local resonance. Since the first measurements of these resonances by laser ultrasound in 2005, several studies have demonstrated their interest in evaluating local properties of materials such as thickness, Poisson's ratio or elastic anisotropy. Through miscellaneous examples, I will give an overview of the remarkable properties of these modes and their applications to non-contact non-destructive testing of elongated structures.

Acoustic Superoscillations: Enhancing the Resolution of Laser Ultrasonics

Mr Monty Clark[1], Dr Khouloud Sellami[1], Prof Andrey Akimov[1], Dr Keith Benedict[1], **Prof Anthony Kent[1]**
[1]University Of Nottingham, Nottingham, UK

Morning Session: Physical and Ultrafast acoustics, September 13, 2022, 9:30 AM - 11:00 AM

Interference of waves in band-limited systems can give rise to the phenomenon of superoscillation, where, in local spatial and/or temporal regions, a signal is observed to oscillate faster than its highest Fourier component. Superoscillation of electromagnetic signals has been used to improve resolution of, e.g., microwave radar and optical microscopy [1].

Acoustic measurements can be subject to severe band-limiting effects, particularly in biological systems, where the attenuation of ultrasound increases strongly with frequency and limits the ultimate resolution that can be achieved in techniques such as laser ultrasonics. By analogy to the electromagnetic case, acoustic superoscillations could be exploited to improve the resolution of acoustic imaging.
In this presentation, we will describe the detection of sub-terahertz temporal acoustic superoscillations in a laser acoustics measurement [2]. Such superoscillation could be used to obtain better axial resolution in strongly scattering systems. We will also discuss the design of optical masks for laser ultrasonics to achieve 'superlensing' effects and lateral resolution exceeding the diffraction limit in the acoustic far-field.

[1] Edward T F Rogers and Nikolay I Zheludev 2013 J. Opt. 15 094008
[2] S Brehm et al. 2020 Phys. Rev. Research 2 023009

Picosecond ultrasonics of two-dimensional nanolayers

Mrs Wenjing Yan[1], Prof. Andrey V. Akimov[1], Prof. Vitalyi E. Gusev[2], Prof. Antony J. Kent[1], Prof. Amalia Patane[1]
[1]School of Physics and Astronomy, University of Nottingham, UK, [2]Laboratoire d'Acoustique de l'Université du Mans (LAUM), Le Mans Université, France, France

Morning Session: Physical and Ultrafast acoustics, September 13, 2022, 9:30 AM - 11:00 AM

Picosecond ultrasonics (PU) is a powerful non-destructive tool for probing nanomaterial properties in GHz and THz frequency ranges beyond the capability of conventional ultrasonics. PU is particularly useful for studying a new class of multifunctional materials: two-dimensional van der Waals (2D-vdW) materials that are easily exfoliated down to single atomic layers. The nanometre geometrical constrain in the third dimension not only redefines their physical properties, but also introduces important variants: interface and surfaces. Understanding of these multifunctional interfaces/surfaces and heterostructures by non-destructive PU will allow researchers to assemble new artificial nanomaterials using "LEGO-type" stacking.

We use PU to study different phonon modes in InSe, In2Se3 and MoS2 [1-4]. The experimental technique includes pump-probe setup with microscope objective for imaging ultrasonic signal with submicrometer resolution (Fig.1a). Figure 1b shows an image of elastic contact between 2D nanolayer and the Si substrate [1]. By bringing the MoS2 layer into elastic contact with the nanograting we are able to generate and detect propagating coherent phonon modes up to 40 GHz and immobile hybrid flexural phonons up to 10 GHz (Fig. 1c). We demonstrate PU probing of 2D materials and revel new type of 2D periodic phononic nanoobject, a flexural phononic crystal.

Polarisation-sensitive super-resolution phononic reconstruction of nanostructures

Dr Rafael Fuentes Dominguez[1]
[1]University Of Nottingham, Nottingham, UK

Morning Session: Ultrafast and Photoacoustics, September 13, 2022, 11:15 AM - 12:30 PM

Super-resolution optical microscopy has a tremendous impact in life sciences over the last two decades for its ability to reveal the insights of biological processes at nanoscale dimensions [1-2]. These methods usually rely on the optical properties of either fluorophores or nanostructures to provide super-resolution.

An alternative to light (photons) is sound (phonons) which offers sub-optical axial resolution as well as enabling the elasticity quantification on biological cells [3]. This is key to understand changes at sub-cellular level due to diseases; for instance, cancer.

In this talk, we will show a new scheme of super-resolution imaging by reconstructing nanostructures (including size, shape, position and orientation) using phonons with a precision of 3 nm enabling access to nano-elasticity measurements.

[1] Huang, Bo, Mark Bates, and Xiaowei Zhuang. "Super-resolution fluorescence microscopy." Annual review of biochemistry 78 (2009): 993-1016.
[2] Parmryd, Ingela, and Christian Eggeling. "Super-resolution optical microscopy of lipid plasma membrane dynamics." Essays in biochemistry 57 (2015): 69-80.
[3] Pérez-Cota, Fernando, et al. "Picosecond ultrasonics for elasticity-based imaging and characterization of biological cells." Journal of Applied Physics 128.16 (2020): 160902.

Development of GHz optoacoustic lenses for sub-optical resolution imaging

Mengting Yao, Dr Rafael Fuentes-Dominguez, Dr Fernando Fernando Perez-Cota, Dr Salvatore La Cavera III, Dr Richard J. Smith, Prof Matt Clark
[1]*University of Nottingham, Nottingham, UK*

Morning Session: Ultrafast and Photoacoustics, September 13, 2022, 11:15 AM - 12:30 PM

Through the use of coherent phonon beams, phonon microscopy has achieved 3D elasticity imaging of living biological cells (i.e., time-resolved Brillouin scattering). The GHz frequency range of the produced phonons provides a path to sub-optical axial resolution imaging. The optical system, however, imposes a restriction on the lateral resolution.

We provide a technique to focus coherent phonon fields using brand-new GHz optoacoustic lenses in order to obtain the "true" acoustic resolution in both the axial and lateral directions. Concave lenses and Fresnel zone-plate, for instance, can be utilised for this. The first is a flat lens that is simple to fabricate at the nanoscale, and the second is an ordinary acoustic focusing transducer design. Additionally, these lenses can also be fabricated at the tip of single-mode optical fibres and be compatible with ultrasonic endoscopic imaging systems.
In this talk, we will present the design of Fresnel zone-plate as GHz optoacoustic lenses and demonstrate its capabilities to focus coherent phonon fields for sub-optical resolution imaging.

In this presentation, we will introduce the Fresnel zone-plate design for GHz optoacoustic lenses and show how it can concentrate coherent phonon fields for imaging with sub-optical resolution.

3D phononic endo-microscopy of biological matter

Dr Salvatore La Cavera[1], Dr Fernando Perez-Cota[1], Dr Veeren Chauhan[1], William Hardiman[1], Mengting Yao[1], Dr Kerry Setchfield[1], Dr Rafael Fuentes-Dominguez[1], Prof Richard J. Smith[1], Prof Matt Clark[1]
[1]*University Of Nottingham, Nottingham, UK*

Morning Session: Ultrafast and Photoacoustics, September 13, 2022, 11:15 AM - 12:30 PM

The phenomenon of Brillouin scattering empowers powerful new technologies to visualise elastic properties of biological specimens from single cells to multi-cellular organisms. Exciting work in the field of mechanobiology is beginning to reveal a close relationship between the mechanical properties of biological tissue environments and the progression of myriad diseases. Non-destructive, label-free, and high resolution elasticity imaging techniques such as Brillouin and phonon microscopies are undergoing rapid development to meet the challenges of characterising tissue elasticity with the aim of using it as a disease biomarker for future clinical diagnostics.

In order to realise the clinical potential of Brillouin scattering-based techniques, it is critical to develop an endoscopic probe for measuring elasticity in future in-vivo environments. Engineering this technology is particularly challenging for Brillouin scattering, since the glass optical fibre that underpins endoscopy is highly photoelastic which ultimately shrouds light scattered from the microscopic region of interest. We have developed a phonon probe which actively injects high amplitude GHz strain pulses into specimens allowing us to utilise industry-standard optical fibre products and have demonstrated proof of concept this technique can be used for high resolution 3D imaging. In this talk we show that this new technology is highly applicable to the 3D elasticity imaging of biological tissue from the single-cell scale to multi-cellular organisms and provides a future pathway for the clinical application of in-vivo Brillouin spectroscopy of tissue.

All-optical photoacoustic endomicroscopy needle probe for optical biopsy

Tianrui Zhao[1], Truc Pham[1], Christian Baker[1], Michelle Ma[1], Sebastien Ourselin[1], Tom Vercauteren[1], Edward Zhang[2], Paul Beard[2], Wenfeng Xia[1]
[1]School of Biomedical Engineering and Imaging Sciences, King's College London, London, UK, [2]Department of Medical Physics and Biomedical Engineering, University College London, London, UK

Morning Session: Ultrafast and Photoacoustics, September 13, 2022, 11:15 AM - 12:30 PM

High-resolution photoacoustic endoscopy has been attractive for guiding minimally invasive procedures such as tumour biopsy by providing both molecular contrast and depth-resolved structural information of tissue in situ. In this work, we developed a photoacoustic endomicroscopy probe based on two optical fibres integrated within the cannula of a 20 gauge medical needle. A multimode fibre (MMF) was employed to deliver excitation laser via wavefront shaping. The disordered light transport through the MMF was characterised with the real-valued intensity transmission matrix, and a digital micromirror device (DMD) was used to raster-scan a tightly focused laser spot at the distal fibre tip. Optically excited ultrasound waves were received by a fibre-optic ultrasound sensor based on a plano-concave microresonator coated at the distal end of a single mode fibre. Optical sectioning was implemented by scanning the focused laser at multiple planes at varying depths. The lateral and axial resolution were measured as ~1.4 μm and ~50 μm, respectively. High-resolution photoacoustic images of mouse red blood cells and mouse ear vasculature were acquired. The developed ultrathin photoacoustic endomicroscopy probe is promising for guiding minimally invasive surgery by providing both molecular and microstructural information of tissue in real-time.

Noise reduction in LED-based photoacoustic imaging with spatiotemporal singular value decomposition

Mengjie Shi[1], Prof. Tom Vercauteren[1], Dr. Wenfeng Xia[1]
[1]School of Biomedical Engineering and Imaging Sciences, King's College London, 4th floor, Lambeth Wing St Thomas' Hospital London, London SE1 7EH, London, UK

Morning Session: Ultrafast and Photoacoustics, September 13, 2022, 11:15 AM - 12:30 PM

Photoacoustic (PA) imaging is an emerging imaging modality that offers rich spectroscopic contrast and high ultrasonic resolution. PA imaging has shown promise in various pre-clinical and clinical applications in the last two decades. Light-emitting diodes (LEDs) and laser diodes (LDs) has emerged as promising alternatives to solid-state lasers due to their low cost and compact size. However, the PA signals acquired with these light sources are easily corrupted by noise due to the low optical fluence. In this work, we proposed a spatiotemporal singular value decomposition (STSVD) based denoising method for LED-based PA imaging. Validation was performed on numerical simulations and in vivo PA data acquired from human fingers (2D) and forearm (3D). Spatiotemporal SVD efficiently improved the PA signals of blood vessels by suppressing the background noise, resulting in 1.1, 0.7, and 1.9 times SNR improvements compared to other denoising methods including single frame-based wavelet denoising, frame averaging, and single frame without denoising, respectively. It is worth noting that the processing time for STSVD was around 50 μs per frame. Thus, we conclude that STSVD is well suited to PA imaging systems with low-energy excitation light sources for real-time in vivo applications.

Optical Ultrasound (OpUS) Imaging for Guiding Minimally Invasive Procedures

Professor Adrien Desjardins[1]
[1] UCL, UK

Afternoon Session: Biomedical I, September 13, 2022, 1:30 PM - 3:00 PM

Optical ultrasound (OpUS) imaging is an emerging modality in which ultrasonic transmissions and reception are performed with light. Ultrasonic transmissions are effected with the photoacoustic effect, with nanosecond-scale light pulses delivered to engineered nanocomposite coatings. Ultrasonic reception is typically performed with high-finesse Fabry-Pérot cavities. Relative to their electronic counterparts, fibre optic ultrasound transducers can have high bandwidths and are readily miniaturised to sub-millimetre lateral dimensions, making them well suited to integration in minimally invasive devices. In this talk I will present an overview of recent developments in OpUS imaging and progress towards clinical translation.

Characterising biomechanics of the limbal niche using vibrational optical coherence elastography (OCE)

Mr Yilong Zhang[1], Mr Ryan Dimmock[2], Prof Ying Yang[2], Prof Zhihong Huang[1]
[1]School of Science and Engineering, University of Dundee, Dundee, UK, [2]School of Pharmacy and Bioengineering, Keele University, Stoke-on-Trent, Stoke-on-Trent, UK

Afternoon Session: Biomedical I, September 13, 2022, 1:30 PM - 3:00 PM

Introduction
The limbal niche located at the peripheral cornea is a critical structure in the regulation of epithelial stem cells. However, the biomechanics of the limbal niche is largely unknown. This study aimed to ex-vivo characterise limbal niche in corneoscleral rims with vibrational OCE. The elasticity of limbal niches and age-related change was investigated.

Methods
Ten cadaveric corneoscleral rims of donors aged 4-96 years from NHSBT tissue-bank were enrolled. A customised vibrational OCE based on OCT with a 1310nm centre-wavelength source and 20,730 Hz sampling-frequency camera was employed. Vibration amplitude of ~600nm was induced to the limbus by a mechanical shaker driven by a sinusoidal signal with 850 Hz, an amplitude of 150 mVpp from an externally-triggered-function-generator. The 2D elasticity distribution map (2mm-in-depth×1.8mm-in-lateral-distance) was obtained from strain estimation.

Results
Vibrational OCE performed the ability to identify limbal niches in donor tissues. In <65-year-group, the elasticity of the epithelium and limbal niche was 10.66±1.92kPa and 21.51±6.80kPa, which was significantly lower than those of ≥65-year-group (13.03±1.28kPa and 36.74±8.70kPa).

Conclusion
A new imaging-modality was presented for quantifying biomechanics of limbal niches and a significant influence of age on the elasticity was noticed. The findings potentially guide donor age for limbal-stem-cell-transplantation in clinical practice.

Real-Time Ultrasonic Needle Tip Tracking with an Integrated Fibre-optic Hydrophone

Dr Christian Baker[1], Dr Miguel Xochicale[1], Mr Francois Joubert[1], Dr Fang-yu Lin[1], Dr Sunish Mathews[2], Dr Dzhoshkun Shakir[1], Prof Sebastien Ourselin[1], Prof Anna David[2], Dr Brian Dromey[3], Proj Adrien Desjardins[2], Prof Tom Vercauteren[1], Dr Wenfeng Xia[1]
[1]King's College London, London, UK, [2]University College London, London, UK, [3]University College Hospital, London, UK

Afternoon Session: Biomedical I, September 13, 2022, 1:30 PM - 3:00 PM

Many minimally-invasive surgical procedures rely on ultrasound (US) guidance for accurate insertion of intraoperative needles. Clear visibility of the needle tip is essential to reach the procedure target and avoid adverse events due to erroneous needle placement. A needle-integrated US sensor enables tracking through detection of the US field. We have developed a clinically compatible, real-time US needle tracking system (UNT) that can be appended to a clinical US system, acquiring US images and superimposing a crosshair onto them at the needle tip position. The location of the needle tip is determined from the acoustic signals received by an embedded fibre-optic hydrophone comprising a high-finesse cavity at the distal end. The UNT system was developed under the ISO 13485 Medical Devices quality standard for deployment in the clinic. The tracking accuracy of the UNT was determined by translating the needle to 450 known positions in the US field of view in a tank of water (20 mm to 140 mm from the probe face, equally spaced 5 mm apart). Across the field of view, the mean distance between tracked and true positions was 0.7 ± 0.4 mm, and the mean repeatability was 0.3 ± 0.2 mm.

Real-time, minimally invasive optical ultrasound imaging of cardiovascular anatomy

Mr Robert Stafford-williams[1,3], Dr Richard J. Colchester[1,3], Dr Efthymios Maneas[1,3], Dr Edward Zhang[1], Prof Paul Beard[1], Prof Manish K. Tiwari[2,3], Prof Adrien E. Desjardins[1,3], Dr Erwin J. Alles[1,3]

[1] Department of Medical Physics and Biomedical Engineering, University College London, London, UK, [2] Nanoengineered Systems Laboratory, UCL Mechanical Engineering, University College London, London, UK, [3] Wellcome/EPSRC Centre for Interventional and Surgical Sciences, University College London, London, UK

Afternoon Session: Biomedical II, September 13, 2022, 3:30 PM - 4:30 PM

Cardiovascular disease is associated with changes in vascular geometry and usually assessed using piezoelectric ultrasound technology that can be difficult to miniaturise. This work presents a novel imaging paradigm utilising a side-emitting, fibre-based optical ultrasound (OpUS) probe to achieve high-quality, high-resolution 2D images of cardiovascular anatomy with reduced probe size.

The OpUS probe (fig. 1a) consisted of a fibre comprising a Fabry-Pérot cavity to detect ultrasound reflections, and a fibre-optic ultrasound source comprising a carbon nanotube-polymer composite coating that converts optical energy into broadband ultrasound. The probe was rapidly oscillated, perpendicular to the long axis of the vessel, to form cross-sectional, video-rate images of vessel phantoms from pulse-echo A-scans (fig. 1b-c). Delay-and-sum image reconstruction achieved high resolutions of 250 μm (axial) by 680 μm (lateral), a 40 dB dynamic range, and a real-time frame rate of up to 9 Hz, with sufficient quality to visualise surface and subsurface anatomy.

This study presents the first OpUS probe capable of high-resolution, real-time, video-rate 2D imaging of clinically relevant anatomy, with capacity to image dynamic cardiovascular events. Measuring ca. 700 μm in diameter, consisting of small-diameter off-shelf optical fibre, such probes set the stage for a new frontier in medical imaging.

Whole-Body Small Animal Imaging System

Miss Alissa Silva[1], Dr Edward Zhang, Dr Olumide Ogunlade, Dr Khoa Pham, Professor Paul Beard, Professor Ben Cox
[1]UCL, UK

Afternoon Session: Biomedical II, September 13, 2022, 3:30 PM - 4:30 PM

Photoacoustic tomography systems using Fabry-Pérot planar sensors have the potential to carry out whole-body studies of small animals [1].

While single planar Fabry-Pérot sensors suffer from an incomplete view of the acoustic fields and lead to blurring and artefacts in resulting images, this issue can be overcome by increasing the number of views with respect to the tissue sample, be it simultaneously [2] or sequentially [3].

Another contribution to the degradation of the image quality for tissue depths greater than approximately 10 mm comes from the improper account of the spatially-varying sound speeds. Such aberrations can be however corrected by carrying out ultrasound tomography to obtain 3D maps of the sound speed and acoustic absorption of a medium. By coating the planar Fabry-Pérot sensor with an optically absorbing layer and exciting this with nanosecond laser pulses, broadband ultrasound pulses can be generated and structural volumetric acoustic images can be obtained in much the same way as photoacoustic ones [4].

Designing a multiple view photoacoustic and ultrasound tomography system based on Fabry-Pérot planar sensors should provide a cost-effective, radiation-free, non-invasive means to carry out whole-body small animal studies. The content of this presentation will be the progress on this design.

[1] J. Laufer, F. Norris, J. Cleary, E. Zhang, B. Treeby, B. Cox, P. Johnson, P. Scambler, M. Lythgoe and P. Beard, In vivo photoacoustic imaging of mouse embryos. J. Biomed. Opt. 2012;17:061220.
[2] R. Ellwood, O. Ogunlade, E. Zhang, P. Beard and B. Cox, Photoacoustic tomography using orthogonal Fabry-Pérot sensors. J. Biomed. Opt. 2016;22:041009.
[3] R. Ellwood, F. Lucka, E. Zhang, P. Beard and B. Cox, Photoacoustic imaging with a multi-view Fabry-Pérot scanner. Proc. SPIE 10064, Photons Plus Ultrasound: Imaging and Sensing 2017;100641F.
[4] K. Pham, S. Noimark, N. Huynh, E. Zhang, F. Kuklis, J. Jaros, A. Desjardins, B. Cox and P. Beard, Broadband all-optical plane-wave ultrasound imaging system based on a Fabry-Pérot scanner. IEEE Trans. Ultrason. Ferroelectr. Freq. Control 2020;68:1007-1016.

Improving photoacoustic imaging of clinical needles using candle soot nanocomposite coatings

Mengjie Shi[1], Semyon Bodian[2,3], Simeon J. West[4] , Sanjayan Sathasivam[5,6], Ross J. Gordon[7], Paul Collier[7], Tom Vercauteren[1], Adrien E. Desjardins[2,3], Sacha Noimark[2,3*] and Wenfeng Xia[1]

[1]School of Biomedical Engineering and Imaging Sciences, King's College London, London, UK, [2]Department of Medical Physics and Biomedical Engineering, University College London, London, UK, [3]Wellcome/EPSRC Centre for Interventional and Surgical Sciences, University College London, London, UK, [4]Department of Anaesthesia, University College Hospital, London, UK, [5]Department of Chemistry, University College London, London, UK, [6]School of Engineering, London South Bank University, London, UK, [7]Johnson Matthey Technology Centre, Reading , UK

Afternoon Session: Biomedical II, September 13, 2022, 3:30 PM - 4:30 PM

Needle insertions are a common part of many clinical procedures such as anaethestics, fetal medicine and oncology. Ultrasound (US) imaging is often used to guide needle insertions in real time, but the visualisation of the needles, especially their tips, can be poorly resolved in US images. Photoacoustic (PA) imaging is a promising imaging modality for needle visusalition. The application of candle-soot nanoparticle-polydimethylsiloxane (CSNP-PDMS) composites onto the needle exterior and an optical fibre's distal end, inserted within the needle lumen, coupled with superficial and interstitial illumination, respectively, through an LED-based PA imaging system enhance needle visualisation at the needle shaft and tip. These composites were selected due to their high optical absorption across a broad range of visible and infrared wavelengths, simple synthesis and high photoacoustic conversion efficiency. During out-of-plane needle insertions, the proposed method differentiated between the needle shaft and tip based on the distinctive contrast-to-noise ratios derived from the generated PA signals. For in-plane insertions, the needle could be discerned at depths of up to 38 mm, owing from the enhanced signal-to-noise ratios (1.7- and 1.6-fold of the bare needle). Therefore, the enhanced visualisation of the needle with PA imaging could be helpful for US-guided minimally invasive procedures.

Highly miniaturised ultrasound transducer based on a single dual-clad optical fibre

Dr Richard Colchester[1,2], Dr Edward Zhang[1], Professor Paul Beard[1,2], Professor Adrien Desjardins[1,2]
[1]University College London, London, UK, [2]Wellcome/EPSRC Centre for Interventional and Surgical Sciences, London, UK

Afternoon Session: Biomedical II, September 13, 2022, 3:30 PM - 4:30 PM

Here we present a ultrasound transducer built onto a single optical fibre. All-optical ultrasound (OpUS) is an imaging paradigm where ultrasound is both generated and received using light. Through the use of optical fibres, highly miniaturized transducers can be fabricated, which are well-suited to minimally invasive medical imaging applications. Previous studies have utilized two optical fibre, one to transmit ultrasound and one to receive ultrasound. In our recent work we developed a device based on a single optical fibre. This device uses a dual-clad optical fibre to deliver single mode light to a plano-concave microresonator for ultrasound reception, and multimode light to an ultrasound generating composite.

The device is < 1 mm in diameter and capable of generating ultrasound pressures > 0.4 MPa, with corresponding -6 dB bandwidths > 27 MHz, as measured at 1.5 mm from the device. Combined with a high receive sensitivity, this enabled OpUS imaging with axial and lateral resolutions as low as 50 μm and 200 μm, respectively. Further, we demonstrate imaging of ex vivo porcine aorta tissue with image acquisition times of 4 s. This work represents a crucial step towards realizing the potential for OpUS to provide imaging from highly miniaturized devices

Poster presentations

Deep Learning Based Automated Defect Recognition for Laser Ultrasonic Imaging

Michael Gillespie[1]**, Klaudia Zymelka**[1]**,** Geo Davis[1], Paul Kirkland[1] , Gaetano Di Caterina[1], Theodosia Stratoudaki[1]
[1]University Of Strathclyde, Glasgow, United Kingdom

Lunch and Poster Session I, September 12, 2022, 12:30 PM - 1:30 PM

Laser Induced Phase Arrays (LIPAs) are used in non-destructive evaluation (NDE) and due to their remote and couplant-free nature, they can be performed in extreme environments and on complex geometries. LIPAs use laser ultrasonic principles to create and detect ultrasound and synthesise arrays by scanning an ultrasonic generation and a detection laser on the surface of the tested sample. Because of scanning multiple combinations of ultrasonic generation and detection positions, data acquisition is a very time-consuming process. On the other hand, the flexibility offered by LIPAs in constructing arbitrary ultrasound array designs can be used to make data acquisition faster and more efficient if the location of the region of interest (ROI) is known. The project's main objective was to develop a deep learning model able to evaluate ultrasonic images produced with LIPA for early identification and localisation of the ROI. The working model would be the first step towards automation of the NDE process, thus a decrease in the time and cost in addition to an increase in the reliability of defect detection.

Synthetic data were generated due to the time-consuming experimental ultrasonic data acquisition. The new approach merged results obtained in 2D finite element software with noise that was simulated based on experimental data. A new data capture procedure was developed implementing a deep-learning architecture to allow for in-process detection of a defect. Firstly, the system builds up confidence about a defect location. Initially transferred learned, an object detection network (YOLOv5) was utilised on all images, obtained during one LIPA scan, separately to recognise the areas resembling defects. Those results were then passed to the Kalman filter implementation to track defect proposals across subsequent images. A threshold was then placed on the estimated covariance of the bounding box locations, whereby multiple detections in close proximity are taken to be representative of a defect.

Obtained results from the AI model indicate that real-time, automated defect recognition is possible due to the comparison between the new method and the previously used thresholding procedure.

Deep Learning-Based, Laser Ultrasound Tomography of Tissue Mimicking Phantoms

Mr. Ahmed Al Fuwaires[1], Dr. Theodosia Stratoudaki
[1]University Of Strathclyde, Glasgow, UK

Lunch and Poster Session I, September 12, 2022, 12:30 PM - 1:30 PM

Using lasers for ultrasound allows for a noncontact and noninvasive method for imaging soft tissues. Using an all-optical setup means that our system could be used for biomedical situations such us brain imaging or on regions of the skin with burns, areas of the body where contact with a transducer would not be permitted. In order to accomplish the goal of imaging on these surfaces we created a setup which utilized a generation laser on one side of a tissue-mimicking phantom and a detection laser on the opposite side. This study proposes a deep learning method trained on physics-based models for time-of-flight, ultrasound tomography in phantoms. The tomography method uses data acquired by laser ultrasonic arrays, synthesised in post processing.

The time-of-flight (TOF) of the ultrasonic wave was then measured from individual A-scans for each combination of the laser generation and detection points creating a TOF matrix. Deep neural networks (DNN) are trained with models produced on pairs of TOF matrices and corresponding material speed of sound maps. After training, the DNNs learn to relate unseen TOF with speed of sound maps. As a result, the estimation of sound maps by the DNN takes place in under a second, without the need for reconstructing time consuming and computationally intensive models. The velocity variations in the speed of sound maps can be related to locations of different types of tissue. This method will allow for a faster way of creating tomographic images of tissues that would be able to detect cancers and tumors in patient with a system that is free from radiation, has a moderate cost, and produces images in real time. We present results from a phantom submerged in water within a glass vessel. Data was acquired using laser ultrasound generation and detection on opposite sides of the vessel.

Detection of HIFU lesions by optical coherence tomography

Dr Jason Raymond[1]
[1]University Of Oxford, Oxford, UK

Lunch and Poster Session I, September 12, 2022, 12:30 PM - 1:30 PM

The use of high-intensity focused ultrasound (HIFU) to induce irreversible changes in tissue due to heating is well established. We have shown that changes in tissue optical properties (scattering and absorption coefficients) could be used as a proxy to improve sensing and imaging of HIFU lesion formation, as an alternative to conventional methods such as thermometry. Optical coherence tomography (OCT) is a non-invasive optical imaging method which relies on low-coherence interferometry to determine the depth of individual scattering centres within the tissue. Previous studies have demonstrated that OCT signals are sensitive to morphological changes in heated tissue, likely due to denaturation of proteins concomitant with formation of crosslinked structures. The goal of this study was to assess the use of OCT for sensing and imaging HIFU lesions. We demonstrate the feasibility of imaging near-surface lesions in ex vivo chicken breast tissue exposed to HIFU. This technique has potential for detecting changes in optical properties corresponding to the progression of surface lesion formation which are antecedents of skin burn during HIFU exposures, thereby increasing safety and reducing treatment times.

Investigating Granularity for Reducing Limited Aperture Effects in Photoacoustic Imaging

Nat Redgewell[1], Dr James Guggenheim[1,2,3], Dr Eleanor Martin[1], Dr Michael Brown[1], Dr Paul Beard[1]
[1]Department of Medical Physics and Biomedical Engineering, University College London, London, UK, [2]Institute of Cardiovascular Sciences, University of Birmingham, Birmingham, UK, [3]School of Computer Science, University of Birmingham, Birmingham, UK

Lunch and Poster Session I, September 12, 2022, 12:30 PM - 1:30 PM

A common challenge in photoacoustic imaging (PAI) are limited aperture effects (LAEs). These arise when ultrasound (US) waves propagate perpendicular to the sensor. The creates invisible structures and artefacts within the reconstruction. We aim to address this using speckle – particularly ultrasonic heating speckle.
Granularity can be introduced via excitation laser speckle, or ultrasonic heating spots. Through simulations, we investigated both methods. Parametric studies were performed such as varying the speckle/heating spot size, varying the structure size, and altering the density of heating spots. The effects of these were examined to obtain limits of the effectiveness of these methods.

We found that to allow for reconstruction, the speckle size must not exceed the structure size. Furthermore, there is a trade-off between resolution (smaller speckle) and image contrast (larger speckle). With US heating spots, small structures reconstructions were ineffective, owing to the larger spot size.

With these findings, we aim to further develop the optical speckle method to apply it to a scattering medium. For example, we are investigating optimal obtainable speckle contrast. We are also focussing on creating a method of applying US heating speckle patterns to PAI, with our initial stages examining the effect of temperature rise in reconstructions.

Miniature optical-resolution photoacoustic microscopy using transparent ultrasound transducer

Riqiang LIN[2,3], Jiaming ZHANG[2], Xiatian WANG[3], Xiaojing GONG[3], **Kwok Ho Lam**[1,2]
[1]University Of Glasgow, UK, [2]The Hong Kong Polytechnic University, Hong Kong, [3]Shenzhen Institute of Advanced Technology, Chinese Academy of Sciences, China

Lunch and Poster Session I, September 12, 2022, 12:30 PM - 1:30 PM

Optical-resolution photoacoustic microscopy is capable of imaging the network of blood vessels, blood oxygen concentration and even tumor cells in sub-micro resolution without any contrast agent. However, traditional setups used complicated optical prism to combine the laser beam and acoustic detection coaxially, due to the opaque ultrasound transducer. To solve the issue, here we developed a novel miniature optical-resolution photoacoustic microscopy using transparent ultrasound transducer (TUT).

A miniature TUT was successfully fabricated using the lithium niobate wafer with the dimensions of 2 mm× 2 mm × 0.1 mm. A gradient-index (GRIN) lens was used as the backing layer of the transducer. A single-mode (SM) fiber with pigtailed ferrule was applied to match the GRIN lens and deliver laser. The acoustic performance of the TUT, such as the pulse-echo response and frequency spectrum, was analyzed. The phantoms, black tape, and a carbon fiber with a diameter of ~5 μm, were imaged by the miniature probe to evaluate the resolution and signal-to-noise ratio performance of the TUT. A mice ear was also employed for in vivo imaging, showing the potential of the compact probe for the biomedical research.

Apparent Anisotropic Thermal Diffusivity in Cubic Single Crystals from Transient Grating Spectroscopy

Jakub Kušnír[1], Petr Sedlák[1], Kristýna Zoubková[1], Pavla Stoklasová[1], Tomáš Grabec[1], Hanuš Seiner[1]
[1]*Institute of Thermomechanics, Czech Academy of Sciences, Prague, Czech Republic*

Lunch and Poster Session I, September 12, 2022, 12:30 PM - 1:30 PM

Transient grating spectroscopy (TGS) has been used to measure the elastic and thermal properties of solid materials. The time signal from this TGS configuration is created by the oscillating acoustic part and the slowly decreasing non-acoustic part. The acoustic part contains information about elastic properties of the material and the non-acoustic part contains information about thermal properties of the material.

Our measurements on pure metals and intermetallic cubic single crystals with elastic anisotropy ranging from isotropic to very strong anisotropy show anisotropy of thermal diffusivity, which should be isotropic, and the magnitude of this anisotropy scales with the elastic anisotropy. A numerical finite element method (FEM) model was created to simulate TGS measurements in COMSOL Multiphysics software. The anisotropic thermal diffusivity was found to be present in the simulations with isotropic thermal diffusivity and elastic anisotropy. The agreement of our measurements and simulations show that the measured anisotropy of thermal diffusivity is thus only apparent and resulting from the elastic anisotropy. It is necessary to consider this effect when determining the thermal diffusivity of elastically anisotropic materials using the “phase grating” detection mode of the TGS.

A Vision Transformer and Convolution Neural Network-based Competitive Study for assessment of wound healing in Mice

JINPENG LIAO[1], Tianyu Zhang[1], Dr. Kanheng Zhou[1], Rocliffe Holly[2], Dr. Pellicoro Antonella[2], Dr. Cash Jenna[2], Dr. Chunhui Li[1], Professor Zhihong Huang[1]
[1]School of Science and Engineering, University of Dundee, DUNDEE, UK, [2]MRC Centre for Inflammation Research, The University of Edinburgh, Edinburgh, UK

Lunch and Poster Session I, September 12, 2022, 12:30 PM - 1:30 PM

Different wound dressings should be applied depending on the stages of healing reached by a wound. Therefore, a method to assess wound healing progress would be useful when treating a wound. In this study, acute wounds were introduced to mice, and were imaged on Day 3, 5, 7, 10, and 14 using Optical Coherence Tomography Angiography (OCTA). OCTA is a useful imaging technique that can extract blood flow signals from static tissue, which was used to monitor the progress of wound healing in this study. We present a competitive study between a series of deep-learning networks, based on the vision transformer (ViT) backbone (attention mechanism-based) and convolution neural network. These networks were applied to classify the different wound healing stages. Specifically, these two networks were trained to assess the progress of wound healing, and were evaluated on the accuracy of the assessment. The ResNet-50 can achieve high accuracy in wound healing stage classification in the preliminary experiment. In future work, based on the mice wound OCTA images, the performance of the different networks (e.g., Shift-window ViT and DenseNet121) will be evaluated and discussed.

Quantifying dimensions of the limbal niche using optical coherence tomography (OCT)

Mr Yilong Zhang[1], Mr Ryan Dimmock[2], Prof Ying Yang[2], Prof Zhihong Huang[1]
[1]School of Science and Engineering, University of Dundee, Dundee, UK, [2]School of Pharmacy and Bioengineering, Keele University, Stoke-on-Trent, Stoke-on-Trent, UK

Lunch and Poster Session I, September 12, 2022, 12:30 PM - 1:30 PM

Introduction
The limbal niche in the corneoscleral rim is a highly organised three-dimensional structure providing habitat for limbal epithelial stem cells. Understanding niche dimensions potentially aid in the early diagnosis of abnormal conditions. This study aims to ex-vivo visualise and quantify the limbal niche in corneoscleral rims with spectral-domain OCT.

Methods
Ten cadaveric rims of donors aged 4-77 years from NHSBT tissue-bank were enrolled. A customised OCT system with a 1310 nm centre-wavelength source and a 91,912 Hz sampling-frequency camera was used. En-face OCT image (3.6mmx3.6mm) was generated by maximum-intensity-projection from the image stack. The mean width of the palisade-ridge (PR) and epithelial-rete-peg (ERP) of the apparent niche area was extracted from the distance between midpoints in the mean-intensity sinusoidal pattern.

Results
Niche features performed less organised with progression with age. The width of the PR in <65-year-group was smaller than that in ≥65-years-group (47.01±7.88μm vs 52.96±9.23μm). The width of the ERP had a reversed trend, with 65.18±18.52μm vs 55.06±9.67μm. A significant influence of age on dimensional parameters of the limbal niche was observed (Independent-sample-T-test, $p<0.005$).

Conclusion
This study quantified the niche dimensions in donor limbal tissues by En-face OCT image. Also, age-related change in the dimensions was investigated.

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