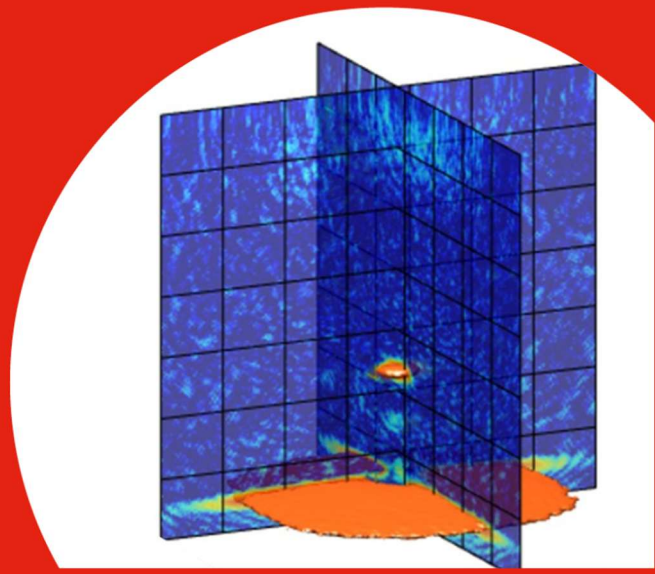


# Abstract Book

**Optics + Ultrasound VIII**

**12–13 October 2026**

Institute of Physics, London, UK



# Invited Speakers

Dr. Tomas Grabec focuses on laser-ultrasonics, wave mechanics, and connected numerical problems. Modelling of ultrasonic waves was also the topic of his doctoral thesis, defended at the Czech Technical University in Prague in 2021. Since his student years, Tomas has carried out research at the Institute of Thermomechanics of the Czech Academy of Sciences, where he is a member of Hanus Seiner's team, which develops laser-ultrasonic methods for characterisation of elastically anisotropic materials, ultimately to enhance understanding of martensitic phase transition, which gives alloys promising diverse applications. In addition, Tomas had several fruitful stays at RECENDT GmbH (Research Centre for Non-Destructive Testing based in Linz, Austria), where he collaborated on investigating ultrasonic scattering in polycrystalline materials. He will bring his expertise in waves and materials characterisation to his upcoming MSCA Fellowship in Matt Clark's team at the University of Nottingham.

### Surface Acoustics and Materials Characterisation by Transient Grating Spectroscopy

Optical generation and detection of ultrasound give a fully non-contact route to a material's elastic response. Transient grating spectroscopy (TGS) is a striking example: two interfering sub-nanosecond pump pulses create a spatially harmonic thermoelastic excitation, launching counterpropagating surface acoustic waves that are read out by a heterodyned continuous-wave probe.

Rotating the excitation direction over the sample surface builds detailed frequency-angular maps of the surface response, visualising not only surface acoustic waves, but also bulk-wave-related features with a clarity rarely achieved by conventional ultrasonic methods (Fig. 1) [1]. With the excitation pattern forcing the waves to follow the intended direction, detailed maps of phase velocities can be obtained even for strongly anisotropic materials [2]. As these velocities are set entirely by the elastic stiffness tensor, density and crystallographic orientation, such maps are a rich input for elasticity characterisation through an inverse problem [3].

We address this inverse problem with GuliweRR [4], a MATLAB package computing surface- and guided-wave velocities in anisotropic and layered media using the Ritz approach, paired with an optimisation module recovering elastic constants from measured velocities. Beyond bulk single crystals, the method has been validated on thin films measured by TGS, where the film thickness can be resolved alongside the elastic constants themselves [5].

Most recently, the procedure has been extended to solve for crystallographic orientation and elastic constants simultaneously—at least for cubic-symmetry materials—removing the need for carefully pre-oriented specimens or multiple characterisation methods. This capability has so far been explored using other methods that map acoustic velocity across a sample—most notably the SRAS method [6]—and is now shown to apply directly to TGS data of a single-crystalline sample, utilising the advantage of high sensitivity (and connected detection of bulk-wave-related features). Although still a fresh development, it points towards a general characterisation workflow taking an unoriented, unknown sample straight to its full stiffness tensor, and is offered here as a direction for discussion.

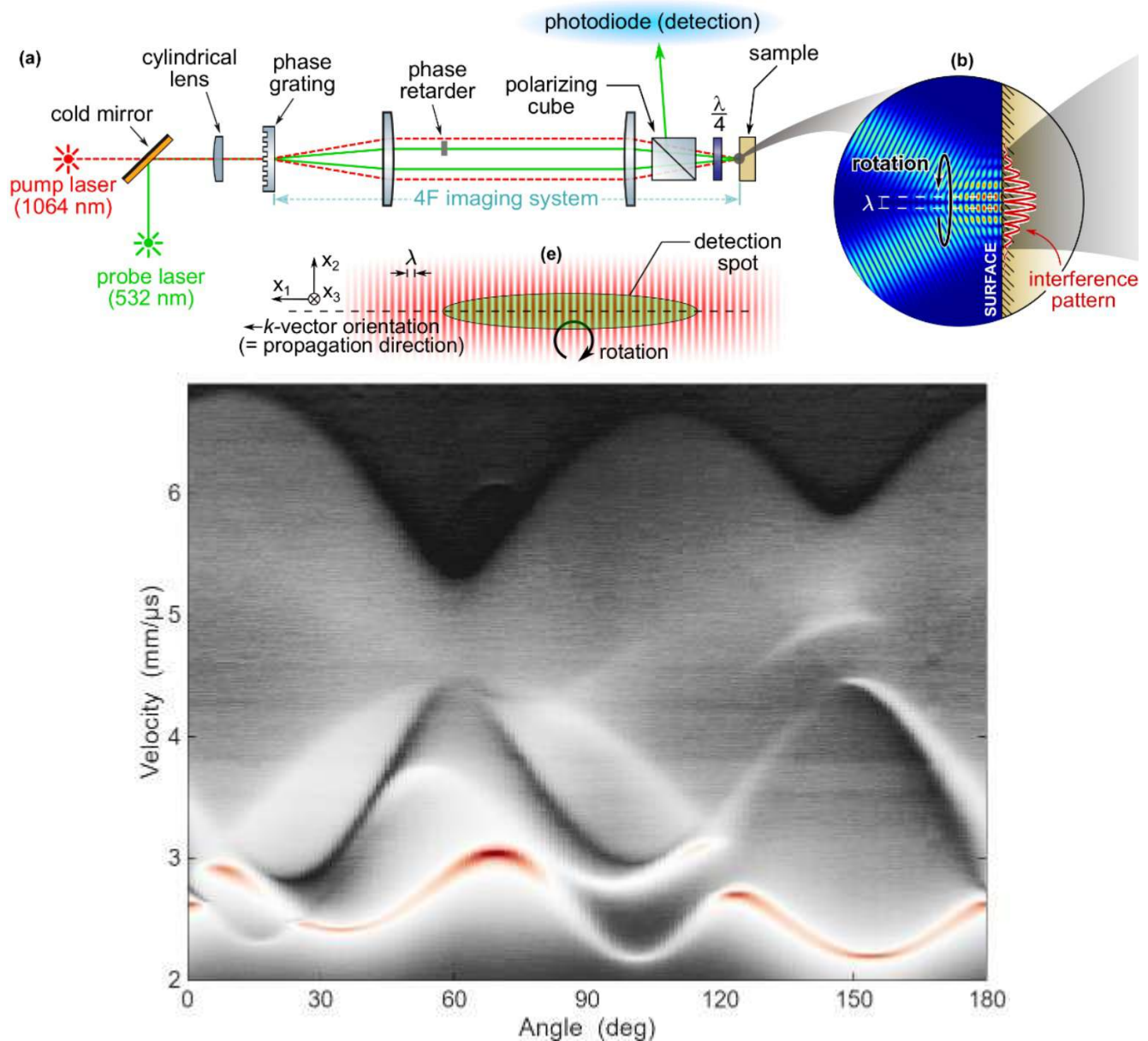


Figure 1: Transient grating spectroscopy (TGS): (a) optical setup, (b) interference of pump lasers, (c) geometry of the interference pattern forming the thermoelastic source, (d) frequency-angular dispersion map of a Fe<sub>3</sub>Al single crystal.

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Dr Robert Nuster is a senior researcher at the Institute of Physics at the University of Graz, Austria. He received his PhD in Physics from the University of Graz and has extensive expertise in photoacoustic imaging and laser ultrasound. His research focuses on optical ultrasound generation and detection, structured light/sound generation and application, metamaterials, multimodal imaging, image reconstruction, and laser-ultrasound-based materials characterization. His work combines fundamental research with technological development for applications ranging from biomedical imaging to industrial applications in the field of process monitoring and material inspection.

### Photoacoustics and Laser Ultrasound at the University of Graz: From Novel Technologies to Biomedical and Industrial Applications

Photoacoustics and laser ultrasound are highly interdisciplinary fields at the interface of optics, acoustics, thermodynamics, materials science, and biomedical research. Beyond fundamental wave propagation and interaction phenomena, advances in ultrasound generation and detection, signal processing, and image reconstruction enable applications from biomedical imaging to industrial materials characterization.

This talk provides an overview of current and future research activities at the University of Graz. In photoacoustic imaging, we develop camera-based optical ultrasound detection [1-2] and explore various structured light concepts for coded excitation to enhance image quality and imaging speed [3]. In addition, we investigate directional optical ultrasound detection concepts utilizing the properties of structured light for acoustic source localization [4], as well as multifunctional imaging technologies based on optical and acoustic metamaterials [5].

In laser ultrasound, our research spans a wide range of length scales, from the sub-micrometer to meters. Applications include residual stress analysis and the characterization of nonlinear acoustic parameters in mechanically loaded metals [6], online process monitoring in industrial steel casting, quality control of laser welding processes [7-9], and semiconductor characterization and defect detection [10-11].

A further focus is multimodal imaging that combines photoacoustic, optical, and ultrasound methods using broadband optical ultrasound generation and detection [12-13]. Future research will target the miniaturization and integration of these technologies using photonic integrated circuits (PICs), paving the way for compact, high-performance sensing and imaging systems for biomedical and industrial applications.

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## Dr. Erwin Alles (University College London)

Dr Erwin Alles received his BSc, MSc and PhD degrees in Applied Physics from Delft University of Technology, The Netherlands. After brief spells at first Michigan State University and then the Institute of Cancer Research, in 2014 he moved to UCL where he is currently an Associate Professor in the Department of Medical Physics and Biomedical Engineering and the UCL Hawkes Institute. He leads the Multimodal Interventional Sensing and Imaging (MISI) team. <https://www.ucl.ac.uk/hawkes-institute/research/research-groups/multimodal-interventional-sensing-and-imaging-misi> who use light and sound to provide image guidance in interventional and multimodal surgical settings, with applications spanning cardiovascular, pulmonary, and neurosurgery scenarios.

### Illuminating Sound: Optical Ultrasound for Biomedical Imaging

Ultrasound imaging is a mature medical imaging technology achieving real-time, video-rate imaging at depths of up to tens of cm and good soft-tissue contrast, at modest cost and without introducing ionising radiation. Conventional ultrasound imaging probes utilise electronic transducer elements that require electrical connections and driving electronics, which are difficult and costly to miniaturise to dimensions suitable for interventional applications. In addition, electronic transducers cause, or are susceptible to, interference with strong electromagnetic fields, such as encountered within MRI or CT scanners or during radiotherapy. Over the past decade, an optical ultrasound imaging modality has been developed that utilises pulsed light delivered to optically absorbing coatings to generate acoustic waves at the surface of a transducer via the photoacoustic effect, and pulse-echo signals are subsequently received by optically resonant structures. During this talk, I will provide an overview of the achievements, applications, and challenges of optical ultrasound generated by my team, in applications ranging from interventional image guidance to multimodal imaging to novel detector technologies.

# Monday 12 October

## Oral Presentations

# Rapid Crystallographic Orientation Mapping with Neural Networks: Towards Multi-Material Characterisation

Emilijia Trumpaite<sup>1</sup>, Wenqi Li<sup>1</sup>, Richard Smith<sup>1</sup>, Matt Clark<sup>1</sup>, Rikesh Patel<sup>1</sup>

<sup>1</sup>University Of Nottingham

Rapid, non-destructive characterisation of crystallographic orientation is essential for linking microstructure to the mechanical and electrical properties of polycrystalline materials. Spatially Resolved Acoustic Spectroscopy (SRAS), a laser ultrasound technique, determines orientation from surface acoustic wave (SAW) phase velocities using a brute force search algorithm (BFSA) that fits measured velocities against a database of precalculated velocity surfaces for predefined crystallographic planes. The method is effective but computationally intensive, taking multiple hours per sample. A fully connected neural network (FCNN), implemented in MATLAB and trained on calculated SAW phase velocities for cubic nickel, classified orientation into one of 441 discrete crystallographic planes with 93.6% validation accuracy, reducing processing time from 10 hours to 16 seconds on an Inconel 617 specimen, a 2250× speed-up over BFSA. The FCNN has been reproduced in Python and benchmarked against alternative model architectures. Performance on real experimental data does not yet match validation accuracy, motivating ongoing work to close the gap between precalculated training data and real SRAS measurements. Future work will extend this framework to further metals, developing material-specific models that, applied to SRAS scan data, could simultaneously determine orientation and identify the base material.

# Laser-Ultrasonic Mapping of Programmable Texture and Elastic Constants in LPBF 316L Stainless Steel by Spatially Resolved Acoustic Spectroscopy

**Peng Jin**<sup>1,2</sup>, Carolina Guerra<sup>1</sup>, Wenqi Li<sup>1</sup>, Rikesh Patel<sup>1</sup>, Marco Simonelli<sup>2,3</sup>, Richard J Smith<sup>1</sup>, Matt Clark<sup>1</sup>

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<sup>3</sup> Department of Mechanical Engineering, Politecnico di Milano, Via La Masa 1, 20156 Milan, Italy

Crystallographic texture governs elastic anisotropy in laser powder bed fused (LPBF) metals, creating both a characterisation challenge and an opportunity for property customisation [1]. Here, spatially resolved acoustic spectroscopy (SRAS) [2] and its extended framework, SRAS++ [3], are applied to LPBFed-316L stainless-steel specimens manufactured using deliberately varied scan strategies. Our texture-control experiments produced centimetre-scale quasi-single-crystalline regions and spatially programmed crystallographic orientations. SRAS, a laser-ultrasonic technique, was used to non-destructively map the resulting texture contrast over an area approaching 35 × 30 mm<sup>2</sup> by measuring surface acoustic wave velocities along multiple propagation directions.

This coverage exceeds that practically accessible with our available electron backscatter diffraction (EBSD) configuration. SRAS++ was subsequently used to recover the single-crystal elastic stiffness coefficients,  $C_{ij}$ , from additional specimens produced using different scan strategies. The recovered  $C_{ij}$  values exhibit clear strategy-dependent differences and deviate substantially from those commonly reported [4], highlighting the need for LPBF-specific elastic characterisation. Together, these measurements demonstrate SRAS/SRAS++ as a rapid, non-contact route for linking processing strategy, crystallographic texture and elastic anisotropy over component-relevant areas. The approach provides a promising framework for validating scan-path-driven microstructure control and ultimately customising local elastic response in additively manufactured components.

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# Optical ultrasound sensors for photoacoustic imaging

Bassam Jameel<sup>1</sup>, Ege Kucukkomurcu<sup>1</sup>, Thomas Chaigne<sup>1</sup>

<sup>1</sup>Institut Fresnel

Photoacoustic imaging is a promising biomedical imaging technique that provides high resolution and specific contrast at large depths ( $\gg 1$  mm) in a non-invasive and non-ionizing manner. The photoacoustic signal is generated through optical absorption and has a broadband spectrum correlated with the properties of the target objects. Conventional photoacoustic imaging systems detect acoustic signals using piezoelectric ultrasound transducers. Sensor arrays have a limited bandwidth, which in turn limits the spatial resolution ( $> 100$   $\mu\text{m}$ ). To overcome this limitation, an optical ultrasound sensor based on a Fabry–Pérot (FP) cavity can be used to achieve a broader frequency response.

An FP-based optical sensor consists of a polymer spacer layer embedded between two mirrors. Improving its overall sensitivity is crucial to maximizing image quality. Several parameters govern the detection sensitivity, including the optical reflectivity of the mirrors, the polymer thickness, and the mechanical properties of the polymer.

The functionality of the FP sensor, as well as the trade-off between optical and acoustic sensitivity to maximize the frequency response of the sensor, will be covered. Additionally, I will present the optical-ultrasound characterization platform that is used to fully characterize the fabricated sensors, from the overall sensitivity to the acoustic/mechanical properties of the polymer.

# All-Optical Colorectal Ultrasound Endoscope with Robot-Assisted Scanning: A Simulation Study

Swayam Das<sup>1</sup>, Christian Baker<sup>1</sup>, Sacha Noimark<sup>1</sup>, Bruno Siciliano<sup>2</sup>, Kaspar Althoefer<sup>3</sup>, Alberto Arezzo<sup>4</sup>, Christos Bergeles<sup>1</sup>, Sebastien Ourselin<sup>1</sup>, Wenfeng Xia<sup>1</sup>

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<sup>2</sup>PRISMA Lab, Department of Electrical Engineering and Information Technology, University of Naples Federico II, Via Claudio 21, 80125, Naples, <sup>3</sup>Centre for Advanced Robotics, School of Engineering and Materials Science, Queen Mary University of London, London, <sup>4</sup>Department of Surgical Sciences, University of Turin, Turin 10126

Current all-optical ultrasound (OpUS) endoscopes achieve high-quality imaging primarily through slow motorised raster scanning, or are limited to M-mode monitoring and single pull-back acquisitions. While recent advances have enabled 2D video-rate interventional imaging, sustained 3D volumetric imaging in endoscopic form factors remains a significant challenge.

To address this, we are developing a robot-assisted, forward-facing endoscopic OpUS probe for colorectal applications. The probe comprises a near-omnidirectional laser-ultrasound transmitter and fibre-optic ultrasound sensor to perform tomography-based acquisitions across a 1 cm<sup>3</sup> imaging volume, as the probe is swept by a robotic arm. A GPU-accelerated k-Wave acoustic simulation of this system was developed, incorporating structured inclusions mimicking colorectal polyps.

The simulation environment was validated by recovering phantom geometry using a dense raster scan and delay-and-sum (DaS) reconstruction. The validated framework is then used to evaluate robotically achievable scanning trajectories, including spiral and sparse sampling patterns, in combination with a range of reconstruction algorithms, including delay-multiply-and-sum (DMAS), time-reversal, and inverse Fourier transform methods. Performance is assessed via contrast-to-noise ratio, axial and lateral spatial resolution, structural similarity, and reconstruction time. This study aims to identify the optimal scanning and reconstruction parameters required to enable high-resolution 3D OpUS imaging for improved colorectal tumour staging and characterisation.

# The use of a spatial light modulator for increased flexibility and efficiency in laser ultrasound array imaging

**Hilde Metzger**<sup>1</sup>, Jakub Trybek<sup>1</sup>, Pete Lukacs<sup>1</sup>, Geo Davis<sup>1</sup>, Stephan Weiss<sup>1</sup>, Theodosia Stratoudaki<sup>1</sup>

<sup>1</sup>Electronic and Electrical Engineering, University of Strathclyde, Glasgow, UK

This paper explores how a spatial light modulator (SLM) can improve 3D imaging using laser induced phased arrays (LIPA), by reducing data acquisition time, increasing efficiency and adding flexibility to the existing LIPA platforms.

2D LIPAs have enabled remote, couplant-free volumetric imaging for non-destructive evaluation (NDE) [1]. Current LIPA platforms, that scan a single point-focused laser beam, easily exceed the damage threshold of the irradiated component. NDE imaging necessitates laser beam attenuation, which makes inefficient use of laser energy resources. Extensive signal averaging is used to improve low signal-to-noise ratio (SNR), at a significant cost to data acquisition time. Full Matrix Capture, where all generation–detection combinations are captured, enables a wide range of imaging angles and the detection and characterisation of diverse defect types but is time-consuming. Reducing single measurement time significantly impacts overall acquisition time.

The SLM facilitates arbitrary laser generation patterns, distributing the incident laser energy to an array of focused points, each below the damage threshold, thereby making more efficient use of a high-power laser. This multi-point excitation enables spatial encoding techniques such as Hadamard multiplexing for parallel averaging of multiple signals with a single detector, reducing data acquisition time. The results presented will be compared with those from scanning-based LIPA platform. Additionally, this SLM-based setup with multi-channel laser ultrasonic generation introduces flexibility into generating arbitrary array designs using all optical means. 2D spiral and random LIPA configurations will be presented to compare array performance and flexibility of array optimisation between platforms.

## References

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# Sub-millimeter defect detection in thin-walled flow-formed copper by laser-induced phased array imaging

To Kang<sup>1</sup>, Soonwoo Han<sup>1</sup>, Young-Ho Lee<sup>1</sup>, Jae-Deuk Kim<sup>1</sup>, Jin-Seop Kim<sup>1</sup>

<sup>1</sup>Korea Atomic Energy Research Insitute

Laser-induced phased array imaging is a non-contact nondestructive evaluation technique that employs laser-generated and laser-detected ultrasound. In this study, laser-induced ultrasonic phased array imaging combined with the total focusing method (TFM) was evaluated for microdefect detection in flow-formed copper specimens with thicknesses of 2–3 mm. The investigated defects included a single side-drilled hole (SDH), clustered SDHs, and flat-bottom holes (FBHs). The experimental results showed that the curved boundaries of the SDHs produced strong reflected and scattered signals, enabling the detection of an SDH with a diameter of 0.3 mm. Indications corresponding to the clustered SDHs were also observed. In contrast, the FBHs exhibited lower image contrast and were more difficult to detect. This difference was attributed to variations in ultrasonic reflection and scattering associated with defect geometry and orientation, which affected the amount of ultrasonic energy redirected toward the receiving aperture. These results demonstrate the feasibility of laser-induced phased array imaging for detecting microdefects in thin flow-formed copper components and highlight the strong dependence of TFM detectability on defect geometry and orientation.

# Imaging modalities of laser diffuse ultrasonic phased arrays

Jie Zhang<sup>1</sup>, Jun Li<sup>1</sup>, Paul Wilcox<sup>1</sup>

<sup>1</sup>University of Bristol

To acquire a full matrix capture (FMC) dataset using a laser-induced ultrasonic phased array, both the generation and detection lasers must be scanned independently to record signals for every possible source–receiver combination. By contrast, a laser diffuse ultrasonic phased array (LDUPA) can obtain an equivalent FMC dataset rapidly by scanning only the detection laser, while ultrasound is produced by a fixed transducer. The resulting FMC data are then recovered from the raw receive dataset through a diffuse correlation algorithm. Although the reconstructed FMC dataset is employed to generate total focusing method (TFM) images, the early, coherent raw receive data can also be used directly to produce images via a receive-only focusing (RFM) approach. This paper compares ultrasound images derived from both the raw receive datasets and the reconstructed FMC datasets under various inspection conditions, such as different transmitter locations and incident wave angles. Simulation and experimental results indicate that RFM images offer excellent detectability within the area illuminated by the incident wave, whereas TFM images provide good detectability across the entire receiver aperture. The findings further underscore the flexibility in transmitter placement and incident wave angle, enabling inspections that can be tailored to site-specific access limitations.

# Tuesday 13 October

## Oral Presentations

# Endobronchial Optical Ultrasound Imaging - Surgical Robotic Integration and Evaluation

Shaoyan Zhang<sup>1</sup>, Semyon Bodian<sup>1</sup>, Nyma Nassren<sup>1</sup>, Ashley Hooi<sup>1</sup>, Helena Lam<sup>1</sup>, Efthymios Maneas<sup>1</sup>, Edward Zhang<sup>1</sup>, Paul Beard<sup>1</sup>, Neal Navani<sup>2</sup>, Ricky Thakrar<sup>2</sup>, Richard Colchester<sup>1</sup>, Adrien Desjardins<sup>3</sup>, Erwin Alles<sup>1</sup>

<sup>1</sup>University College London, <sup>2</sup>University College Hospital, <sup>3</sup>The University of British Columbia

Accurate endobronchial biopsy guidance requires visualisation of subsurface targets and biopsy needles beyond the airway surface. Conventional endobronchial ultrasound provides real-time guidance, but probe size and imaging orientation preclude distal access and accurate needle visualisation. Optical ultrasound (OpUS) enables miniature fibre-based ultrasound probes in which optical excitation photoacoustically generates ultrasound and fibre-optic sensors detect backscattered acoustic waves. This all-optical architecture suits robotic endobronchial integration because it enables flexible and miniaturised probes while maintaining local 2D imaging over a 30 mm × 30 mm field of view with 100 µm resolution. Here we evaluated a side-viewing, linearly actuated OpUS probe for robot-navigated imaging in a lung phantom. The 1.8 mm outer-diameter probe was delivered through an Ion robotic bronchoscopy catheter without impairing navigation, platform operation, or probe delivery. Proximal actuation of the >2 m long probe produced distal linear scanning, enabling real-time imaging at 4 Hz; the probe remained functional during catheter bending down to a bend radius of 5 mm. OpUS visualised a lymph-node-mimicking inclusion from within the lung phantom. Additionally, needle-guidance experiments demonstrated clear visualisation of the needle trajectory within the OpUS imaging plane. These results support robot-compatible OpUS imaging for target localisation and guidance during endobronchial biopsy.

# Real-time 3D ultrasonic needle tracking with a photoacoustic beacon

Christian Baker<sup>1</sup>, Weidong Liang<sup>1</sup>, Richard Colchester<sup>2</sup>, Peng Lei<sup>3</sup>, Francois Joubert<sup>1</sup>, Sebastien Ourselin<sup>1</sup>, Simeon West<sup>4</sup>, Athanasios Diamantopoulos<sup>5</sup>, Wenfeng Xia<sup>1</sup>

<sup>1</sup>King's College London

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<sup>3</sup>Beijing Institute of Collaborative Innovation

<sup>4</sup>University College London Hospitals NHS Foundation Trust, <sup>5</sup>Guys and St Thomas' NHS Foundation Trust

Ultrasound-guided needle procedures such as liver biopsy are inherently three-dimensional, but guidance is provided by a 2D image in which the needle tip is often obscured by poor contrast, steep insertion angles or plane misalignment. Ultrasonic tracking, which annotates the image with the tip location, is typically limited to 2D by linear imaging probes; 3D tracking has required research-mode scanners and custom arrays [1]. We present an interventional ultrasound system providing simultaneous 2D B-mode imaging and quantitative 3D needle tip tracking with a clinical scanner. A photoacoustic beacon—an rGO/PDMS-coated optical fibre—embedded in the bevel of an 18-gauge biopsy stylet is excited by a 532 nm pulsed laser. The ultrasound is received by a sparse, 16-element, 1 MHz array around a curvilinear probe, and the tip position recovered in real time (10.5 Hz) by maximum-likelihood multilateration with dynamically weighted, non-Gaussian range uncertainties. Tracking error was  $1.96 \pm 1.24$  mm in water to 140 mm and  $2.04 \pm 0.8$  mm in an ex vivo phantom against CT. In a usability study, 12 interventional radiologists reduced biopsy failure rate by 35% [2].

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# Coherent Multi-Transducer Photoacoustic Imaging of the Internal Carotid Arteries for Guiding Endoscopic Endonasal Surgery

Qing Zhang<sup>1</sup>, Jonathan Shapey<sup>1</sup>, Wenfeng Xia<sup>1</sup>, Laura Peralta Pereira<sup>1</sup>

<sup>1</sup>King's College London

Injury to the internal carotid arteries (ICAs) is a catastrophic complication of endoscopic endonasal surgery. Photoacoustic (PA) imaging could enable vascular visualization, but its performance depends on optical wavelength, tissue penetration, and permissible laser exposure. Transcranial ultrasound reception is constrained by skull-induced aberration and limited acoustic windows.

This work investigates coherent multi-transducer PA imaging using endonasal illumination and ultrasound reception through ocular and temporal windows. The ICAs were modelled as two cylinders at different depths. Monte Carlo simulations quantified ICA absorbance across depths and wavelengths under equal-energy and maximum permissible exposure (MPE) conditions. Initial pressure distributions were propagated through a CT-derived head model using k-Wave. Signals from four phased arrays were reconstructed using aberration-corrected delay-and-sum beamforming for single-probe, incoherent, and coherent configurations.

Under equal incident energy, 760 nm shows the greatest tissue penetration depth. Under MPE-limited illumination, 980 and 1060 nm produce higher ICA absorbance than 540 and 760 nm. At 980 nm, single-probe images show artifacts and blurring, particularly through temporal windows. Multi-transducer reconstruction improves focusing and artifact suppression compared with single-probe reconstruction, while coherent compounding further enhances spatial resolution and ICA visibility. These results demonstrate the potential of coherent multi-transducer PA imaging for endonasal surgery guidance.

# Free-running ASOPS for time-resolved Brillouin scattering microscopy

Mengting Yao<sup>1</sup>, Fernando Perez-Cota<sup>1</sup>, Shai Isreal<sup>1</sup>, Salvatore La Cavera III<sup>1</sup>, Richard J. Smith<sup>1</sup>, Matt Clark<sup>1</sup>

<sup>1</sup>University of Nottingham

The mechanical properties of cells and tissues are closely linked to biological function, disease progression and extracellular-matrix remodelling. Time-resolved Brillouin scattering (TRBS), based on picosecond laser ultrasonics, provides a label-free route to probing these properties through GHz acoustic waves [1]. However, conventional TRBS systems often rely on actively stabilised asynchronous optical sampling (ASOPS), requiring precise laser-cavity control and RF synchronisation. These requirements increase cost and complexity, limiting translation beyond specialist optical laboratories.

Here, we demonstrate a simplified free-running pump–probe architecture for TRBS microscopy. Two femtosecond lasers are operated without active repetition-rate locking, and acquisition is triggered directly from the signal coincidence peak. By resolving two coincidence peaks within each acquisition window, the effective delay rate is extracted from the measured trace itself and used to recalibrate the time axis offline. We validate the approach using reference samples and compare locked and free-running acquisition during cumulative averaging. We further demonstrate fixed-cell Brillouin-frequency imaging using the free-running configuration. The corrected free-running measurements preserve the main spatial Brillouin-frequency contrast observed with locked ASOPS, establishing self-referenced free-running TRBS as a practical route towards simpler and more robust biological mechanical imaging.

# Ultrafast Pump-Probe Spectroscopy Reveals Complex Intracellular Acoustic Vibrations of Gold Nanoparticles

Rafael Fuentes-Dominguez<sup>1</sup>, Marina París-Ogáyar<sup>2</sup>, Daniel Jaque<sup>2</sup>, Richard J. Smith<sup>1</sup>, Matt Clark<sup>1</sup>, Mengting Yao<sup>1</sup>

<sup>1</sup>University of Nottingham

<sup>2</sup>Autonomous University of Madrid

The elasticity (stiffness) of a cell, and cellular tissue, is fundamental to its biological function and behaviour [1]. Consequently, diseased cells often possess unique mechanical characteristics that modulate their phenotype and influence the extracellular matrix. For instance, cancer alters protein expression in key structural sub-cellular components such as the actin cytoskeleton and the nuclear envelope, which gives rise to altered cellular elasticity [2–3]. To fully understand these processes, there is a need for sub-optical resolution imaging capable of providing elasticity information.

Here, we use ultrafast pump–probe spectroscopy to resolve the gigahertz acoustic vibrations of AuNPs [4] within cells. Measurements with particles of different diameters demonstrate that the relationship between nanoparticle size and vibrational frequency is preserved intracellularly, enabling sub-optical structural characterization after cellular uptake. Analysis of the time-domain signals also provides spatially resolved information on vibrational frequency, acoustic damping and spectral complexity. At low nanoparticle loading, the response is dominated by single-frequency oscillations with relatively narrow frequency and attenuation distributions. Increasing nanoparticle concentration produces a marked rise in multifrequency signals, together with broader frequency and damping distributions. These changes indicate increasingly complex dynamics associated with heterogeneous intracellular environments and possible mechanical interactions between neighbouring nanoparticles. Although the contributions of environmental loading, compartmental heterogeneity and interparticle coupling cannot yet be fully separated, these results establish intracellular acoustic spectroscopy as a promising approach for probing nanoparticle organization and dynamics inside cells, with potential applications in nanoscale sensing of intracellular mechanical properties.

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# Spatially Resolved Acoustic Spectroscopy: from hard to soft materials elastic characterisation

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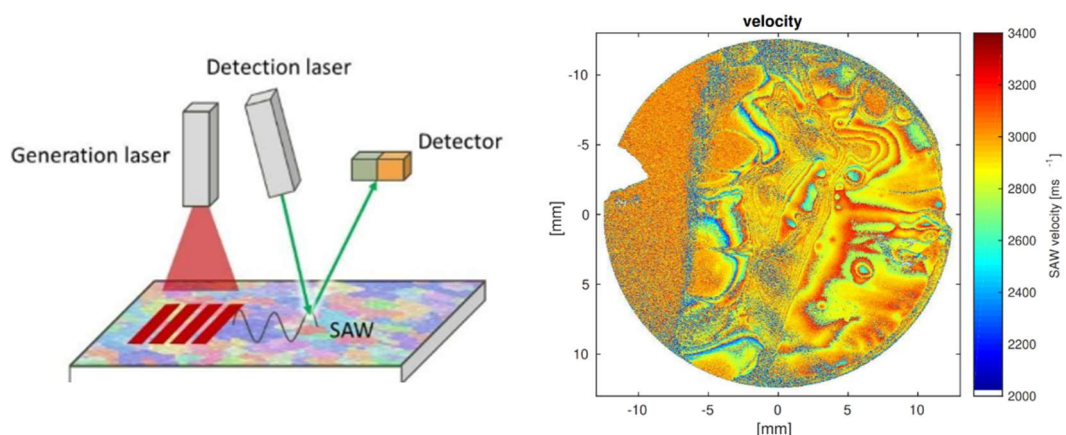
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Ultrasound is a powerful non-destructive evaluation (NDE) method used across engineering and biomedical fields. Conventional ultrasound requires physical contact and coupling media, limiting its use in harsh or confined environments. Laser ultrasonics overcomes these limitations by using light for both sound generation and detection, enabling remote, coupling-free measurements.

Spatially Resolved Acoustic Spectroscopy [1] extends laser ultrasonics to measure surface acoustic wave velocities with high precision. Mapping these velocities reveals microstructure, crystallographic orientation, and stiffness [2] in a wide range of materials.

This work expands SRAS from hard engineering alloys to multi-layer systems, coatings, and soft materials. By tuning acoustic wavelength, penetration depth can be controlled, allowing the study of elasticity and viscosity in polymers and tissue-like phantoms. SRAS thus offers a versatile platform for high-resolution, non-invasive mechanical characterisation – bridging materials science and biomedical imaging through laser-based acoustic sensing.



**Fig. 1.** (Left) Schematic of the SRAS technique – a SAW is generated and detected using separate lasers. (Right) Velocity map of 500 nm chrome layer with 10  $\mu\text{m}$  polystyrene layer. The modification of the SAW velocity can be seen between the bare metal (left side of the coverslip, 3000 m/s) and the spin-coated polystyrene layer.

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# Thermal–optical tracer visualisation of ultrasonic traps: viscous and cohesive limits on AlSi10Mg powder confinement

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Containerless handling of metal powder could enable feedstock delivery for additive manufacturing in microgravity. We combine thermal and optical tracer visualisation with confinement experiments in a 40 kHz standing wave trap.

Dry ice sublimation produces a cold CO<sub>2</sub> plume with condensed water droplets. The tracer is synchronously imaged with visible and infrared cameras. Visible imaging records condensate bands and tracer motion; infrared imaging resolves thermal contrast. Band spacing is compared qualitatively with simulated pressure, particle velocity, and Gor'kov potential fields. Relative intensities are not fitted. In separate tests, a thin, low thermal mass sheet provides complementary thermal patterns. These diagnostics reveal tracer transport and flow from acoustic forcing and buoyancy. The tracer alters gas properties, so this is qualitative visualisation rather than direct acoustic pressure measurement.

Two opposing, hexagonally arranged arrays of 30 elements each, controlled in phase and amplitude at transducer level, confined AlSi10Mg powder. Stable clusters were obtained for a 50 µm grade, a 38 to 53 µm sieve fraction, and a fraction above 53 µm. The fraction below 38 µm formed an unstable cloud.

Particles in the nominal 50 µm and 38 to 53 µm fractions have  $ka$  values of 0.014 to 0.020 and are in the Rayleigh regime. Their radii are 1.7 to 2.4 viscous boundary layer thicknesses, making viscous corrections potentially significant. Force scale estimates indicate that adhesion exceeds radiation force and favours agglomeration. For this array and powder system, particle size, viscous effects, cohesion, and streaming are key constraints on acoustic confinement.

# Investigating the response of a Colour-Changing Holographic Sensor to High Intensity Focused Ultrasound fields

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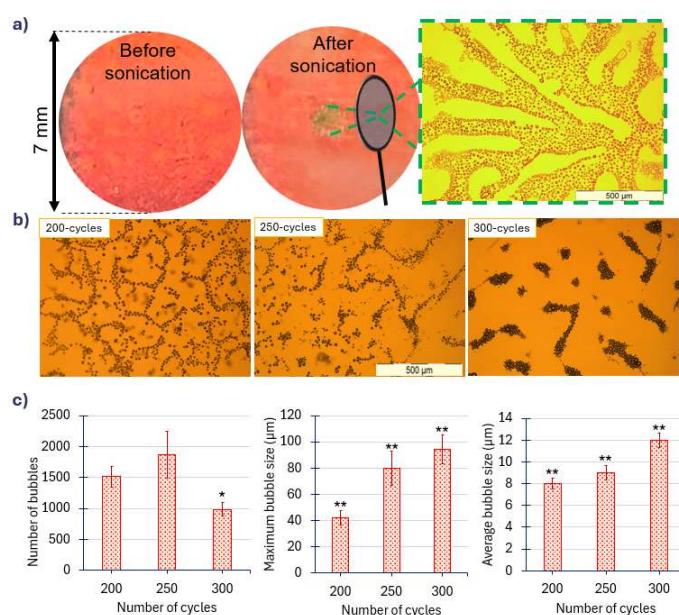
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A pressure- and temperature-sensitive colour-changing holographic sensor was investigated for its response to therapeutic high-intensity focused ultrasound (HIFU) fields, and thus its potential as a clinical quality assurance (QA) tool. The 2cm wide sensor, consisting of a Bragg reflection grating holographically inscribed in a ~160  $\mu\text{m}$  photopolymer film was previously developed and optimised for low-intensity ultrasonic pressure and temperature sensing [1]. Here, the sensors were exposed to HIFU fields generated by a Sonic Concepts H101 transducer operating at 1.1 MHz over a range of excitation amplitudes and sonication times in burst mode. A coupling cone ensured exposure at the acoustic focus. Temperature measurements were acquired using a thermocouple and compared with k-Wave simulations of the acoustic field.

The sensors begin to exhibit a visible colour change from red to green when the film surface temperature exceeds ~30°C. Microscopic imaging of the colour-change area reveals bubble formation in the photopolymer. In this work, analysis of the effect of the sonication parameters on the formation and distribution of the bubble population and colour-change area is presented. These findings support further development of the sensor as a QA tool for HIFU applications, where focal temperatures typically range between 45-65°C.

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**Figure 1.** Response of the material to HIFU fields; a) Response to a 1.1 MHz sine signal of 150 Vpp in pulsed mode with 200-cycles per burst: clear red area before sonication (left), creation of a greener area after sonication (centre) and 10x microscopic

# Joint Multi-Transducer Beamforming and Calibration Using Physics-Informed Deep Learning

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Coherent multi-transducer ultrasound (CoMTUS) combines radiofrequency (RF) data from multiple probes to enlarge the effective aperture and improve image quality. However, coherent gain depends on accurate propagation modelling: errors in relative probe pose and assumed speed of sound (SoS) cause errors in the calculated time-of-flight across transmit–receive paths. Conventional calibration requires dedicated targets and offline measurements, limiting flexible use. The discontinuous aperture also produces sparse-array artefacts, including sidelobes. Physics-informed deep learning offers an alternative by incorporating physics-based delays while preserving RF phase and amplitude information for reconstruction and calibration.

For reconstruction, a U-Net-based beamformer processes element-wise delayed RF data before receive summation, retaining physical relationships among the signals from probes. In vitro and in vivo evaluations showed that, compared with conventional beamforming using seven times more acquisition data, it increased the generalised contrast-to-noise ratio from 0.81 to 1.00 and suppressed sidelobes.

We also examined whether reconstruction features could support calibration. A lightweight network appended to the pretrained encoder estimated delay-parameter deviations. Mean element misalignment decreased from 3.74 to 0.42 mm, while SoS error fell from 80.73 to 4.64 m/s.

These findings support a unified physics-informed framework linking beamforming and calibration for future development of robust, flexible multi-probe ultrasound imaging.

# ReFOCUS-enabled Grating-lobe Suppression by Spatial-Frequency Compensation in Coherent Multi-Transducer Ultrasound imaging

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Ultrasound image quality is fundamentally governed by the available aperture. Coherent multi-transducer ultrasound (CoMTUS) synthesizes a large effective aperture from spatially separated arrays, improving resolution, contrast and field-of-view (FoV) [1]. However, gaps between arrays cause underrepresented spatial-frequency components, generating substantial grating-lobes.

Round-trip redundancy can compensate for these underrepresented contributions but conventionally requires complete element-wise transmit-receive data [2]. Here, we extend spatial-frequency compensation to ultrafast CoMTUS by computationally recovering this representation using REFOCUS beamforming [3]. Since arrays are angled, compensation is formulated in 2D with a pixel-dependent relationship between transmit-receive pairs and lateral spatial frequency.

Three angled phased arrays were operated as a CoMTUS system using diverging-wave transmissions. Compensation weights were derived relative to an idealized gap-free aperture and applied before coherent summation. In simulations, the compensation technique reduced the dominant grating-lobe by 8.5 dB, with a PSF more akin to the idealized response. Experimentally, across five point-targets distributed across the FoV, grating-lobe levels were reduced by 6.6 dB on average while preserving resolution. Measured contrast also improved across anechoic regions (gCNR increased from 0.63 to 0.66).

These results demonstrate robust spatial-frequency compensation across discontinuous coherent apertures, with ongoing work exploring reference-aperture selection and extending the framework to in vivo imaging.

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# Poster Presentations

# The impact of tissue-related factors on relative oxygen saturation and total haemoglobin mapping

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Photoacoustic imaging (PAI) is a promising add-on technique to standard ultrasound imaging since it can provide physiological information, such as the oxygen saturation levels in and around lesions. PAI can therefore be valuable in differentiating benign and malignant lesions with more certainty, potentially leading to fewer unnecessary diagnostic procedures. However, for PAI to be clinically valuable, it should be valid and reliable in different in vivo conditions.

This study aims to assess how the oxygen-mapping method of a PAI system performs under conditions that could lead to issues using physical phantom experiments. Various channel phantoms are being developed that mimic factors such as skin pigmentation level, tissue type, acoustic heterogeneity, vessel size, and vessel depth. With these phantoms, the effect of differences in skin pigmentation level, the presence of acoustic reflections, spectral colouring and fluence decay, and system sensitivity will be simulated.

The phantoms will be imaged with a PAI system after filling the channels with blood-mimicking fluid (Figure 1). Representative parameters for the oxygen-mapping performance, such as relative contrast sensitivity, are being assessed. The obtained results will provide insights into the limitations of the oxygen mapping technique and how to improve it to make it more robust and reliable.

# Optical Ultrasound image guidance in minimally invasive neurosurgery

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<sup>1</sup>UCL

Minimally invasive surgery is currently one of the safest and most effective treatment options for tumours that develop near critical structures, such as pituitary tumours that occur near the brain and optic nerves. Typically informed by endoscopy alone, critical subsurface features and resection accuracy cannot be clearly resolved, which limits treatment efficacy and risks surgical complications. Introducing an additional form of image guidance may resolve this, but due to the constrained surgical environment, the range of deployable imaging modalities are limited. Ultrasound is a non-ionising subsurface imaging modality offering handheld operation and ease of use; however, current electronic transducers are too bulky. Optical ultrasound (OpUS) imaging – where light is used to both emit and receive pulse-echo ultrasound signals – has emerged as an alternative modality offering high pressures (MPa range) and bandwidths (ca. 30 MHz) through miniature (<600 µm) fibre-optic imaging probes that achieve depth-resolved, video-rate 2D imaging using a single sensor [1]. Such probes are highly flexible and thus can be paired with surgical tools to enable field-of-view manipulation and swept 3D imaging. Here, we present an initial assessment of the applicability of OpUS imaging to interventional neurosurgery by assessing thermal safety and 2D and 3D imaging performance.

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# Optimising Acoustic Coupling and Thermal Management in Phonon Microscopy

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Phonon microscopy uses optically generated gigahertz acoustic waves to probe cellular mechanical properties, offering a label-free approach to investigating cancer cells.[1] However, acoustic impedance mismatch at the sample interface and laser induced temperature rise both limit the amplitude of the acoustic waves used in imaging. Coupled together they result in poor Signal-to-noise ratio.

This work investigates polymer layers for impedance matching and heat insulation. Poly(methyl methacrylate) (PMMA) is investigated experimentally, alongside simulations exploring poly(vinylidene fluoride) (PVDF) and polystyrene (PS) as alternative impedance matching materials and Glass, Sapphire and Diamond for different substrates.[2]

Results showed a ~2x gain in our signal's modulation depth at certain PMMA thickness, using an etched grating we were able to compare how the acoustic wave coupled into our water sample at localised points. Using Brillouin frequency analysis over PMMA gratings implies insulation to our sample from the thermal exposure caused by pump laser excitation. With a reduction in frequency of ~10s MHz positions corresponding to the PMMA gratings, pointing to the effects temperature has over Brillouin frequency.

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# Vascular and textural analysis of 3-D photoacoustic breast images in a contralateral patient study

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Photoacoustic Tomography (PAT) is a promising modality for breast cancer imaging as it provides a good description of the vascular changes surrounding a tumour [1,2]. A new pipeline dedicated to extracting quantitative metrics from PAT images vascular graph and texture (in accordance with Image Biomarker Standardization Initiative norm) was used to analyse the data from 3 patients involved in a contralateral study. Features from the vascular graph were analysed together with textural characteristics of the fibroglandular tissue through variance decomposition and a Principal Component Analysis (PCA) following the Quantitative Imaging Biomarker Alliance (QIBA) guidelines. Early results show that the total length of the vascular network is the most discriminant metric with 70 % of its variance explained by tumour status, at unchanged vascular volume fraction. Tortuosity and junction ratio decrease, describing a longer, more continuous network in breasts with a tumour. Textural features are concordant in pairs. These whole-breast effects, obtained without any tumour ROI, motivate deeper investigations with local mirrored regions towards cancer detection.

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# In Silico Proof-of-Principle of Detection and Removal of Reflection Artifacts in Photoacoustic Imaging

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Photoacoustic (PA) imaging is a relatively novel technique that combines optical illumination with acoustic detection. However, clutter due to reflection artifacts can obscure structures of interest and hamper clinical interpretation. Namely, reflections can not (directly) be separated from true signals, meaning that they will show up in the PA images as normal signals. A common cause of these artifacts is reflected skin signal.

In this research we aim to mitigate reflection artifacts. We demonstrate different detection techniques on a thyroid phantom with a proof-of-principle study. In the used phantom, signals from the skin reflect on the sternohyoid muscle fascia, and are projected on and obscure the thyroid nodule. The detection techniques we evaluate are based on 1) delay in the sagittal direction, 2) ray-tracing, where the reflection interfaces are modeled as mirrors, 3) segmentation and acoustic simulation, 4) and physical backpropagation from Singh et al. [1]. We compare these techniques, where technique 4 shows the highest accuracy, while technique 2 shows fair accuracy combined with easier potential implementation in preexisting PA setups.

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# Non-Negative Matrix Factorization for Multi-Wavelength Photoacoustic Structural Fusion of the Ex Vivo Eye

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Ex vivo photoacoustic (PA) imaging of the whole eye has previously relied on widely separated excitation wavelengths (532 nm and 1064 nm) to visualize corneal, iris, and retinal structure, leaving the closely spaced near-infrared window largely uncharacterized for structural work. We image an ex vivo goat eye at four wavelengths within this window — 700, 750, 800, and 850 nm — reconstructing each into a co-registered three-dimensional volume and normalizing for per-wavelength laser pulse energy before fusion. Rather than averaging the four volumes with fixed weights, we fuse them using non-negative matrix factorization (NMF), which restricts both the spatial and spectral factors to non-negative values. This constraint reflects the underlying physics: absorbed optical energy density, the quantity generating the PA signal, cannot be negative, so a factorization built on signed components — as in principal component analysis — can produce mathematically valid but physically meaningless negative contributions. The rank-1 NMF factorization yields a single fused structural volume together with a spectral weight vector describing how strongly each of the four wavelengths contributes to the shared structure. We compare the fused result against each individual wavelength and against uniform-weight compounding, using contrast-to-noise ratio and structural visibility across the cornea, iris, lens, sclera, and pigmented choroid as evaluation metrics. A rank-2 factorization is examined separately for evidence of a wavelength-dependent component consistent with pigmented tissue. The results indicate whether letting the fusion weights be determined by the data, rather than fixed in advance, measurably improves structural delineation of the whole eye over naive wavelength averaging.

# Predicting the ionacoustic emissions in proton beam therapy

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Rapidly producing accurate 3D maps of the radiation dose delivered during proton therapy could reduce beam delivery uncertainties and improve patient outcomes. Current dosimetry methods, such as ionisation chambers, have limited spatial resolution and long acquisition times. Ionacoustic imaging offers an alternative approach, using acoustic waves generated by thermoelastic expansion following proton energy deposition to reconstruct the dose distribution. This could enable fast, accurate and non-invasive 3D dosimetry. In the short term, ionacoustic imaging could provide beam quality assurance prior to treatment and, in the future, enable online dose monitoring during patient irradiation, helping to mitigate uncertainties arising from anatomical changes and organ motion. Although promising ionacoustic measurements have been reported, accurately predicting the signals required to optimise detection systems and enable precise 3D reconstruction remains challenging. As a first step towards experimentally measuring 3D dose distributions using ionacoustic imaging, we present recent work developing a modelling framework for clinically relevant proton beam energies and geometries. The model predicts the resulting ionacoustic signals and provides a basis for designing future experiments and establishing equipment requirements. In particular, it enables investigation of the required transducer frequency response and minimum signal-to-noise ratio for ionacoustic signal detection.