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CEEUS 2026

THE 1ST IEEE CENTRAL AND EASTERN EUROPEAN ULTRASONICS SYMPOSIUM

* PRELIMINARY *

IEEE CEEUS 2026

THE 1ST IEEE CENTRAL AND EASTERN EUROPEAN ULTRASONICS SYMPOSIUM

22-24 June 2026, Warsaw, Poland

CONTENTS

* PRELIMINARY *

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PROGRAMME

22 JUNE 2026, MONDAY

OPENING & PLENARY SESSION (9:00–10:40)

Chairs: Marcin Lewandowski, Beata Brzozowska

9:00-9:20 **Welcome and opening remarks**
We would like to welcome all participants to the 1st IEEE Central and Eastern European Ultrasonics Symposium (CEEUS-2026). We are excited to bring together researchers, practitioners, and industry experts from across the region to share their latest findings and innovations in the field of ultrasonics. This symposium is a unique opportunity for networking, collaboration, and knowledge exchange, and we look forward to a productive and inspiring event.

9:20-10:00 **High-Frame-Rate Ultrasound Imaging in the Deep Learning Era**
Dr. Alfred C. H. Yu *– Professor, Associate Vice-President (Partnerships, Entrepreneurship, and Commercialization) @ University of Waterloo, LITMUS, Canada*

10:00-10:40 **Wearable ultrasound technology**
Prof. Sheng Xu *@ Department of Anesthesiology, Perioperative and Pain Medicine at Stanford University, USA*

23 JUNE 2026, TUESDAY

PLENARY SESSION (9:00–11:20)

Chairs: Moritz Herzog, Christoph Leitner

9:00-9:45 **When Sound Becomes Medicine: Biomedical Ultrasound as the Interdisciplinary Science**
Dr. Peter A. Lewin *@ School of Biomedical Engineering, Drexel University, Philadelphia, USA*

9:45-10:30 **Open-source wearable ultrasound platforms: a rocky path from lab prototype to public knowledge**
Dr. Sergei Vostrikov *@ Rheonics, Switzerland*

10:30-11:15 **New Adventures in CEUS using Sub-micron Bubbles**
Prof. Agata Exner *– Henry Willson Payne Professor & Vice Chair for Basic Research, Department of Radiology Professor, Department of Biomedical Engineering Co-Director, Medical Scientist Training Program Case Western Reserve University / University Hospitals of Cleveland, Ohio, USA*

24 JUNE 2026, WEDNESDAY

PLENARY SESSION (9:00–11:20)

Chairs: Ewelina Knapska, Piotr Karwat

9:00-9:45 **Designing ultrasound systems for brain research across different spatial scales**
Mark E. Schafer, PhD, FAIUM, FASA, FAIMBE *@ Rockefeller Neuroscience Institute, West Virginia University, USA*

9:45-10:30 **Miniaturized and power-efficient focused ultrasound microsystems for wearable and implantable ultrasound neuromodulation**
Dr Tiago L. Costa *@ Delft University of Technology, Delft, Netherlands*

10:30-11:15 **New Frontiers in AI-driven Ultrasound Tissue Characterization**
Prof. Ahmed El Kaffas *@ University of California San Diego, USA*

INVITED / KEYNOTE SPEAKERS

22 June 2026, Monday

Opening & Plenary Session

9:20–10:00

HIGH-FRAME-RATE ULTRASOUND IMAGING IN THE DEEP LEARNING ERA

Dr. Alfred C. H. Yu – Professor, Associate Vice-President (Partnerships, Entrepreneurship, and Commercialization)

University of Waterloo, LITMUS, Canada

Ultrasound is undoubtedly a popular medical imaging modality and is becoming known for its high-frame-rate imaging capabilities. However, high-frame-rate ultrasound has yet to flourish in point-of-care applications due to the lack of suitable portable hardware, and its ability to offer time-resolved flow visualization is hampered by Doppler aliasing artifacts. Can we take advantage of deep learning to overcome bottlenecks in high-frame-rate system design? Can we design neural networks to resolve Doppler aliasing artifacts in real time? This seminar will introduce our laboratory's quest to learn deep and learn smart about ultrasound imaging systems to make high-frame-rate ultrasound viable for portable use and flow estimation. We will demonstrate how deep learning solutions can be devised to resolve data transfer bottlenecks in ultrasound systems and, in turn, enable robust generation of high-frame-rate ultrasound images with data acquired from few array channels. We will also show how deep learning has enabled the design of advanced Doppler flow imaging platforms with lucid flow visualization performance. Related algorithms, real-time engineering efforts, and clinical applications will be presented throughout the presentation.

10:00–10:40

WEARABLE ULTRASOUND TECHNOLOGY

Prof. Sheng Xu

Department of Anesthesiology, Perioperative and Pain Medicine at Stanford University, USA

The use of wearable electronic devices that can acquire vital signs from the human body noninvasively and continuously is a significant trend for healthcare. The combination of materials design and advanced microfabrication techniques enables the integration of various components and devices onto a wearable platform, resulting in functional systems with minimal limitations on the human body. Physiological signals from deep tissues are particularly valuable as they have a stronger and faster correlation with the internal events within the body compared to signals obtained from the surface of the skin. In this presentation, I will demonstrate a soft ultrasonic technology that can noninvasively and continuously acquire dynamic information about deep tissues and central organs. I will also showcase examples of this technology's use in recording blood pressure and flow waveforms in central vessels, monitoring cardiac chamber activities, and measuring core body temperatures. The soft ultrasonic technology presented represents a platform with vast potential for applications in consumer electronics, defense medicine, and clinical practices.

23 June 2026, Tuesday

Plenary Session

9:20–9:45

MINIATURIZED AND POWER-EFFICIENT FOCUSED ULTRASOUND MICROSYSTEMS FOR WEARABLE AND IMPLANTABLE ULTRASOUND NEUROMODULATION

Dr Tiago L. Costa
Delft University of Technology, Delft, Netherlands

Transcranial ultrasound stimulation is emerging as a promising modality for non-invasive neuromodulation, with the ability to reach deep brain targets with a spatial selectivity that is difficult to achieve with other techniques. More recently, there has been growing interest in moving this therapy beyond the hospital setting, towards wearable and, in the longer term, implantable ultrasound systems for both neuromodulation and brain computer interfaces. This transition, however, requires a substantial reduction in both power consumption and device size. Conventional ultrasound hardware typically relies on bulky driving electronics, a limited number of transducer channels, and assembly approaches that do not scale well to compact high-density arrays. In this talk, I will present our work on miniaturized phased-array technologies for wearable and implantable ultrasound neuromodulation, with particular emphasis on electronic circuit and microfabrication strategies that improve power efficiency while enabling scalable integration. Our approach brings semiconductor and advanced packaging technologies into the ultrasound domain, combining the co-design of electronic drivers, array architectures, and microfabricated acoustic interfaces. On the electronics side, I will discuss methods to improve the efficiency of integrated multi-channel stimulators. On the device side, I will describe microfabrication routes that enable dense integration of piezoelectric transducers with electronics with minimal loss in acoustic performance. Together, these developments aim to establish a technological path towards focused ultrasound neuromodulation devices suitable for future wearable and implantable systems.

9:45–10:30

OPEN-SOURCE WEARABLE ULTRASOUND PLATFORMS: A ROCKY PATH FROM LAB PROTOTYPE TO PUBLIC KNOWLEDGE

Dr. Sergei Vostrikov
Rheonics, Switzerland

The idea of fully open-source wearable hardware has sparked growing interest in the ultrasound community in recent years, promising transparency, flexibility, and full control over system design, all of which are essential for research. Yet despite this enthusiasm, turning a research prototype into a useful open-source resource remains a complex task. What practical challenges arise when developing and sharing wearable-ultrasound designs? Why should wearable ultrasound be open source in the first place? And what defines a good and sustainable open-source project? This talk is structured around these questions. It reflects on the practical realities of open-source development in wearable ultrasound, outlines the current state of the field, and discusses future directions.

10:30–11:15
NEW ADVENTURES IN CEUS USING SUB-MICRON BUBBLES

Prof. Agata Exner
Henry Willson Payne Professor & Vice Chair for Basic Research, Department of Radiology Professor, Department of Biomedical Engineering Co-Director, Medical Scientist Training Program Case Western Reserve University / University Hospitals of Cleveland, Ohio, USA

Contrast enhanced ultrasound (CEUS) imaging has been a powerful, safe, yet underutilized capability of clinical ultrasound systems for over the past three decades. Currently available microbubble contrast agents have made possible impactful applications ranging from cardiac opacification during echocardiograph to tumor perfusion for lesion detection and therapy response assessment. Yet their activity is limited in scope due to the large bubble size which primarily confines them to the vascular compartment. More recent advancements in and convergence of nanomedicine, molecular imaging, ultrasound hardware and software, and theoretical underpinnings of shelled bubble acoustic response have enabled a slew of new applications in CEUS, this time beyond the vasculature. Specifically, phospholipid-shell stabilized heavy gas-core submicron bubbles (100-600 nm in diameter, also referred to as nanobubbles or ultrafine bubbles) have gained interest as a robust contrast agent for CEUS. Nanobubbles are ~1000x smaller in volume and 3-5 orders of magnitude higher in concentration than existing clinically utilized contrast agents. Due to these unique features, nanobubbles are highly responsive to ultrasound at a broad range of clinically relevant imaging and therapeutic ultrasound frequencies and can be used in applications that may not be well suited for larger bubbles. For example, nanobubbles can be robustly internalized into cells (including cancer cells and immune cells). This provides an opportunity to visualize cells in vivo in real time with greater penetration depth than optical imaging. Nanobubbles also show unique trafficking and distribution patterns in vivo, especially in tumors and regions of inflammation and have shown strong uptake into the extravascular space. This extravascular and intracellular localization of nanobubbles provides unique advantages including background free, cell-specific imaging by molecular targeting to cancer biomarkers. This presentation will provide an overview of emerging imaging applications of lipid-shelled nanobubbles.

24 June 2026, Wednesday

Plenary Session

9:00–9:45
WHEN SOUND BECOMES MEDICINE: BIOMEDICAL ULTRASOUND AS THE INTERDISCIPLINARY SCIENCE

Dr. Peter A. Lewin
School of Biomedical Engineering, Drexel University, Philadelphia, USA

The purpose of this talk is to introduce the breadth of multidisciplinary development that enabled marvelous advances in the field of biomedical ultrasound. Over the past century this field has evolved into one of the most profoundly interdisciplinary domains in modern science and medicine. That was achieved by a close collaboration between the scholars working on the intersection of biology, chemistry, physics, engineering, and clinical practice. The talk will attempt to demonstrate how interdisciplinary background of ultrasound researchers led to the unprecedented rise of ultrasound from a primarily diagnostic modality into a versatile platform for precision imaging, targeted therapy, and neuromodulation. Selected examples will highlight the transformation of diagnostic ultrasound into a plethora of therapeutic treatments. High-frequency (15 MHz+) ultrasound, elastography, and contrast-enhanced techniques now enable real-time visualization of tissue architecture, perfusion, and mechanobiological changes with exceptional submillimeter resolution. In parallel, therapeutic ultrasound has entered a new era defined by noninvasive, cell-specific interventions. Low-intensity (<1W/cm2) focused ultrasound (LIFU) and ultrasound-mediated drug delivery are emerging as transformative tools in neuroengineering and the treatment of the neuropsychiatric disorders. By modulating neural activity without surgery, ultrasound offers promising avenues for managing Parkinson's disease, Alzheimer's pathology, chronic pain, and addiction. Presentation of the comprehensive chart of applications will deliver the audience coherent and lucid view of the opportunities to work with the ultrasound technology in academic, industrial and clinical environment.

9:45–10:30

DESIGNING ULTRASOUND SYSTEMS FOR BRAIN RESEARCH ACROSS DIFFERENT SPATIAL SCALES

Mark E. Schafer, PhD, FAIUM, FASA, FAIMBE

Rockefeller Neuroscience Institute, West Virginia University, USA

Ultrasound is being used in clinical studies to treat such neurological issues as addiction, anxiety, depression and even coma, and to facilitate the uptake of drugs for Alzheimer's. However, there are still fundamental questions regarding ultrasound interaction with neural tissues. This talk describes the design of ultrasound exposure systems applicable to a wide range of experimental situations, from fruit flies *(Drosophila melanogaster)*, through rodents, and to humans, representing six orders of magnitude in brain tissue volume. First, the design details of a sub-millimeter 100 kHz exposure source for stimulation of fruit fly neurons will be presented. Here, the primary challenge was creating a source that would fit into a 300 μm aperture. Moving up in scale, transducers in the low megahertz range were designed to expose select portions of a rodent brain, leaving nearby areas unexposed to serve as a control. Finally, systems for clinical (human) use have completely different design requirements. Clinical data show positive results for several neurological conditions, most remarkably for the treatment of addiction. In summary, ultrasound transducer technology can encompass a wide range of experimental requirements, supporting new areas of research and discovery in brain science, and new treatment options for patients.

10:30–11:15

NEW FRONTIERS IN AI-DRIVEN ULTRASOUND TISSUE CHARACTERIZATION

Prof. Ahmed El Kaffas

University of California San Diego, USA

Ultrasound-based tissue characterization (UTC) through quantitative biomarkers has received increased interest across a variety of clinical applications over the past few years. Many UTC techniques employ raw forms of ultrasound data — most notably beamformed radiofrequency (RF) signals — to measure acoustic tissue properties as quantitative biomarkers. Parameters such as attenuation coefficient, backscatter coefficient, and speed of sound have demonstrated utility in characterizing tissue composition and pathology in a reproducible, operator-independent manner. With the increasing availability of raw ultrasound data from both research and commercial platforms, new opportunities in AI-driven UTC present themselves to maximize tissue-related information content and potentially overcome the inherent statistical variability of traditional UTC methods. Deep learning approaches, in particular, offer the promise of learning complex, high-dimensional representations directly from RF data that may capture pathology-relevant features beyond the reach of classical parametric estimators. This talk aims to cover the key challenges and opportunities in AI-driven UTC, including training data requirements, model interpretability, and regulatory considerations, as well as potential future clinical applications enabled by ultra-portable handheld and wearable ultrasound hardware, which stand to bring quantitative tissue assessment to point-of-care and longitudinal monitoring settings.

TRACK WERABLES

22 June 2026, Monday

Transducers 1

CMUT ARRAY FOR DEEP VEIN THROMBOSIS

Sören Köble, Nicolas Lange, Marco Kircher, Uwe Völz, Sandro G. Koch
Fraunhofer-Institut für Photonische Mikrosysteme, Dresden, Germany

Background, Motivation and Objective

Recent advances in medical diagnostics increasingly focus on online health monitoring. Established use cases include continuous recording of vital signs such as heart rate, blood pressure, and electrocardiograms. However, to enable early detection of critical health conditions like deep vein thrombosis (DVT), additional information on blood flow is required. Ultrasound-based flow measurement is a common method for this type of diagnosis, but it is currently limited to clinical environments. For high-risk patients, such as those with thrombosis or cardiac insufficiency, there is a strong need for solutions that are easy to use in everyday life and do not impair quality of life. This calls for compact, wearable devices with integrated sensors, electronics, and intelligent AI-based signal processing and evaluation. To enable integration into such medical wearables, our work focuses on reducing the required CMUT drive voltage while maintaining operating frequency and signal-to-noise ratio.

Statement of Contribution/Methods

Capacitive Micromachined Ultrasonic Transducers (CMUTs), characterized by high receive sensitivity and broad bandwidth, are well suited for classical sonography, particularly because of their inherent acoustic matching to water. At Fraunhofer IPMS, advances in CMUT structure optimization have enabled the realization of small apertures and large arrays with operating frequencies up to 30 MHz. CMUTs produced silicon wafers allow direct integration of analogue and digital CMOS circuits, enabling highly integrated ultrasonic front ends. The required drive voltage of CMUTs scales predominantly with the electrode gap. We therefore targeted a reduction of the gap height to lower the drive voltage. This required overcoming several technological challenges, achieving a highly uniform and precisely controlled cavity height during the polishing process. Because the vibrating plate cannot move more than the cavity height, reducing the gap also limits the maximum transmitted acoustic pressure. Simultaneously this increases electro-mechanical coupling and thus higher sensitivity of the CMUT at smaller gaps, resulting in similar SNR.

Results/Discussion

We present a CMUT design optimized for wearable applications by reducing the electrode gap. The required drive voltage was decreased from more than 120 V to 45 V while preserving the target operating frequency and signal-to-noise ratio. This reduction is particularly advantageous for medical wearables, enabling the integration of CMUT-based ultrasound sensing into compact, battery-powered devices for continuous patient monitoring and ambulatory care.

HYBRID CMUT AND SINGLE CRYSTAL ULTRASONIC TRANSDUCER SENSOR STACK FOR MUSCLE MONITORING

Tönnis Trittler[1], Paul Dekan[1], Julian Kober[1], Cornelius Kühnöl[2], Merit Städler[1], Erik Kaiser[1], Erhard Landgraf[3], Richard Nauber[2], Henning Heuer[4], Moritz Herzog[1]

[1] Else Kröner Fresenius Center for Digital Health, Dresden, Germany; [2] Vodafone Chair for Mobile Communications Systems, Dresden, Germany; [3] Infineon Technologies Dresden AG & Co. KG; [4] Fraunhofer Institute for Ceramic Technologies and Systems, Dresden, Germany

Background, Motivation and Objective

Ultrasound is widely utilized for muscle monitoring in rehabilitation, sports medicine, wearable systems, and neuromuscular diagnostics due to its noninvasive nature, real-time capability, and ability to assess both muscle structure and function. Combining Capacitive Micromachined Ultrasonic Transducers (CMUTs) with Single Crystal Piezoelectrics leverages the high receive sensitivity of CMUTs and the superior transmit efficiency of Single Crystal Piezos. In this setup with separate Transmit (TX) and Receive (RX) elements, coded excitation using long chirp signals further enhances the signal-to-noise ratio (SNR). This phantom study aims to demonstrate that this approach is suitable for muscle monitoring applications.

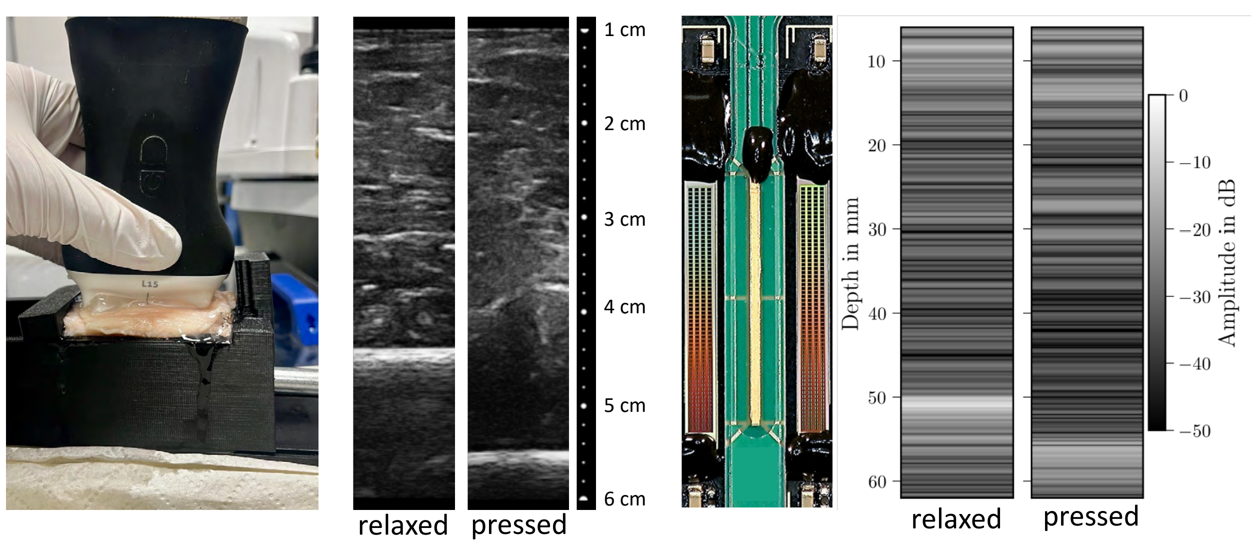
Statement of Contribution/Methods

A hybrid stack was developed, comprising a single-crystal PMN-PT TX and a CMUT RX chip, each wire-bonded to a separate printed circuit board (PCB) which were attached together, and encapsulated in PDMS (c). Excitation was performed using a Zadoff-Chu chirp (20 µs, 3.5 MHz center frequency, 5 MHz bandwidth), with mismatched filtering, time-gain compensation, and envelope detection for signal processing to obtain AScans. Signal generation employed an AMD Zynq RFSoC ZCU216 with amplification *via* a TI STHV200 chip. The hybrid stack was characterized in degassed deionized water using an aluminum reflector at a 50 mm distance. A custom muscle phantom was constructed from multiple chicken breast strips (3–5 mm thick), which are compressed by a 3D-printed press. For comparison, B-mode images were obtained with a Clarius L15 clinical scanner (a).

Results/Discussion

The hybrid transducer exhibits a center frequency of 3.4 MHz, a −10 dB bandwidth of 5.1 MHz (150 %), and low crosstalk. In muscle phantom experiments, B-mode images reveal visible movement and compression of muscle fibers during pressing (b). The A-Scans from the hybrid stack (d) reflect these changes, with the visible ground reflection (at 5-6 cm) indicating deep penetration and clear extraction of fiber reflections. These results demonstrate that the hybrid approach enables effective muscle monitoring with potentially low energy consumption and minimal channel count (1 TX/RX *vs.* 196 elements in Clarius), supporting its suitability for wearable and clinical applications.

a) Muscle press with Clarius
b) B-Mode (Clarius)
c) Hybrid Stack
d) A-Scan from Hybrid Stack



TOWARDS TRANSFER FABRICATION OF ALUMINA-EPOXY ACOUSTIC MATCHING LAYERS FOR PZT ULTRASOUND TRANSDUCERS

Tomasz Zaluska[1,3], Christoph Leitner[2], Younghun Kim[4], Federico Villani[2], Butrus Khuri-Yakub[4], Luca Benini[2], Todd Coleman[1], Zhenan Bao[3]

[1] Department of Bioengineering, Stanford University, Stanford, USA; [2] Integrated Systems Laboratory, ETH Zurich, Zurich, Switzerland;
[3] Department of Chemical Engineering, Stanford University, Stanford, USA; [4] Department of Electrical Engineering, Stanford University, Stanford, USA

Background, Motivation and Objective

Efficient ultrasound transmission from high-impedance piezoelectric ceramics into water or soft tissue requires acoustic matching layers with controlled acoustic impedance, quarter-wavelength thickness, and low attenuation. For a single matching layer between PZT and a water/tissue load, the target impedance is approximately the geometric mean of the ceramic and load impedances, giving a practical design range of approximately 5-8 MRayl. Conventional transfer-based fabrication approaches can introduce acoustic discontinuities that reduce the efficiency of energy transfer from the PZT into the propagation medium. To address this limitation, we develop and characterize an alumina–epoxy composite matching layer whose acoustic impedance can be tuned through the alumina filler loading. We demonstrate the integration of this matching-layer structure with a transfer-compatible fabrication process for MHz PZT ultrasound devices, enabling scalable device fabrication and system-level integration, including implementation on silicon carrier wafers.

Statement of Contribution/Methods

Alumina–epoxy bulk coupons were fabricated by loading epoxy (Epotek 301) with alumina at the volume fractions shown in Fig. 1, casting into spacer-defined molds, curing under compression, and releasing planar samples. Acoustic characterization was performed on N=8 coupons with 0, 10, 19, and 25 vol% alumina loading. Longitudinal sound speed and normal-incidence reflection delay were extracted from front- and back-wall echo time-of-flight in a water-tank pulse-echo setup. Attenuation was estimated from the frequencydomain amplitude loss between echoes over the round-trip path. Impedance was calculated using the measured density and speed of sound ($Z=\rho\cdot c$). To implement the transfer-compatible fabrication process, the selected alumina–epoxy formulation was cast on a dextran-coated silicon carrier wafer, cured, polished to the 2 MHz quarter-wavelength target thickness, bonded to PZT with a thin adhesive layer (≈1 µm), post-cured, and released by dissolving the dextran in water.

Results/Discussion

Alumina loading increased the acoustic impedance of the epoxy composite from approximately 3.1 MRayl for unfilled epoxy to 6.0 MRayl at 25 vol% alumina, approaching the impedance range required for single-layer matching between PZT and water or soft tissue. The 19–25 vol% formulations therefore define the most relevant processing window for device integration. Importantly, these compositions remained compatible with casting into thin planar films, polishing to a quarter-wavelength thickness, bonding to PZT with a thin adhesive layer, and release from the sacrificial carrier. This links the material optimization directly to a transfer-compatible fabrication route for compact, integrated MHz ultrasound transducers.

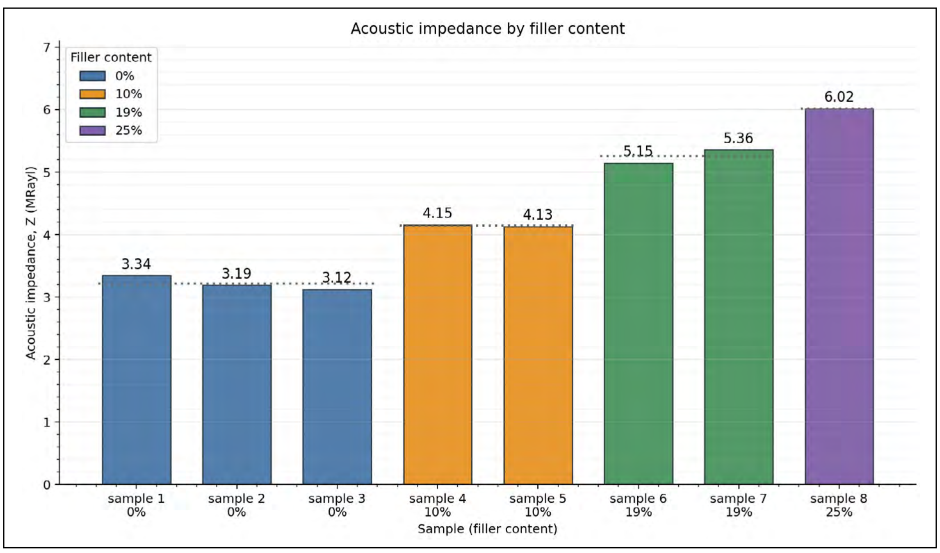


Fig. 1. Acoustic impedance of alumina-epoxy coupons as a function of alumina filler content. Values were obtained by reflection-delay analysis using measured sample thicknesses. The data show a monotonic impedance increase with filler content and support selection of the highest-loaded processable formulations for subsequent matching-layer fabrication.

TOWARDS AFFORDABLE ULTRASOUND WEARABLES WITH POLYMER-BASED CMUTS

Martin Angerer, Jinhao Lu, Jonas Welsch, Edmond Cretu and Robert Rohling

Department of Electrical and Computer Engineering, The University of British Columbia (UBC), Vancouver Canada

Background, Motivation and Objective

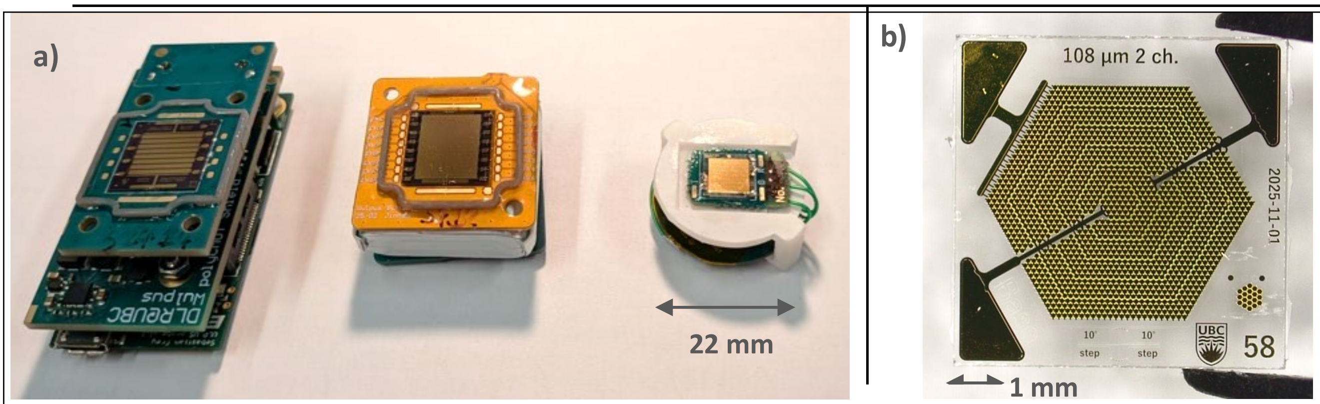
Polymer-based Capacitive Micromachined Ultrasonic Transducers (polyCMUTs) are a promising acoustic frontend technology for next-generation ultrasound systems. Their high receive sensitivity, design freedom, compatibility with rapid, low-cost fabrication and their ability to form conformal, small-scale arrays make them particularly attractive for wearables. This work presents recent progress with polyCMUTs, focusing on device performance as well as integration with ultra-low-power electronics to enable customizable, miniaturized, and affordable ultrasound wearables for varying applications.

Statement of Contribution/Methods

State-of-the-art polyCMUT devices were designed and fabricated in-house using refined and optimized surface micromachining processes to produce structural polymer layers. Transducer arrays with 2, 8, and 16 channels were developed for a range of biomedical and industrial monitoring applications. For system integration, the Wearable Ultra-Low-Power Ultrasound (WULPUS) platform was adapted to support different configurations. The resulting systems provide ±30 V DC bias, configurable excitation pulses up to 30 V, adjustable channel counts, and lightweight, battery-compatible operation.

Results/Discussion

Fig. (a) presents several recent prototypes: (left) an 8-channel pulse-echo system for industrial weld inspection and small-ROI imaging; (center) a low-cost (<USD 25) two-channel system with separate TX/RX paths enabling continuous 50 Hz monitoring for more than 40 hours on battery power; and (right) a highly miniaturized pulsed-wave Doppler system powered by a CR2032 coin cell with up to 70 hours of continuous operation. For the latter system, we further explored the geometric design flexibility of polyCMUTs to implement a ring-based, hexagonal TX-RX layout that produces quasi-isotropic and spatially co-aligned acoustic beam profiles for both channels (Fig. (b)). This architecture eliminates the need for high-voltage switching to reduce crosstalk while enabling quasi omnidirectional operation. Overall, the recent results demonstrate the potential of polyCMUTs to enable customizable, compact, low-cost, and energy-efficient ultrasound wearables for continuous monitoring applications.



Transducers 2

ACOUSTIC STACK OPTIMIZATION AND CLINICAL VALIDATION PREPARATION OF A FLEXIBLE PMN-PT ULTRASONIC TRANSDUCER ARRAY FOR WEARABLE BLOOD PRESSURE MONITORING

Syed Turab Haider Zaidi[1,2], Jinsoo Park[3], Lee Youngjin[1], Byung Chul Lee[2,3], Shin Hur[1,2]

[1] *Korea Institute of Machinery and Materials, Daejeon Metropolitan City, South Korea;* [2] *University of Science and Technology, Daejeon Metropolitan City, South Korea;* [3] *Korea Institute of Science and Technology, Seoul, South Korea*

Background, Motivation and Objective

Wearable ultrasonic transducer arrays (UTA) enable continuous, noninvasive vascular monitoring; however, acoustic inefficiencies caused by impedance mismatch and backward wave reflections impacts bandwidth, beam symmetry, and waveform fidelity. Shown in Fig. 1a is our previously developed flexible 5 × 4 PMN-PT 1–3 composite array that operates at 6 MHz and demonstrates accurate vessel tracking, yet performance remains limited without acoustic stack optimization. The objective of this work is twofold: (1) to enhance acoustic transmission and reception characteristics through matching and backing layers, and (2) to prepare the optimized system for medical validation using a programmable ultrasound research platform.

Statement of Contribution/Methods

A flexible 5 × 4 PMN-PT 1–3 composite UTA fabricated using low-temperature Sn–Bi eutectic bonding was integrated with tailored matching (ML) and backing layers (BL). The BL (0.5 mm) was characterized to evaluate acoustic delay and attenuation, while ML samples (0.1–0.4 mm) were synthesized to improve impedance transition between the piezocomposite and soft tissue. Acoustic characterization, speed, and attenuation were measured using an A309S transducer, HGL hydrophone, oscilloscope, and 3-axis scanning platform as depicted in Fig. 1b. Beam transmission, directivity, and receiving sensitivity were evaluated experimentally. For validation preparation, the optimized UTA was interfaced with the Verasonics Vantage system for RF-based vessel tracking in a vascular phantom, the setup is shown in Fig. 1c. Diameter extraction was performed via time-of-flight analysis and pressure was reconstructed using an exponential pressure–area model.

Results/Discussion

The incorporation of ML and BL improved forward acoustic transmission, reduced ringing, and increased bandwidth by approximately 1.7 MHz. Beam measurements showed a narrower and more symmetric main lobe with reduced side-lobe energy compared to the no-layer configuration, indicating behavior closer to an ideal piston source. Receiving sensitivity remained stable across angular variation. Using the Vantage 64 – Verasonics platform, phantom-based blood pressure reconstruction yielded systolic and diastolic errors of approximately ~4 mmHg and ~2 mmHg relative to a reference sensor. These findings demonstrate that acoustic stack optimization can significantly enhance signal fidelity while establishing readiness for translational and pilot on-body evaluation of wearable blood pressure monitoring systems.

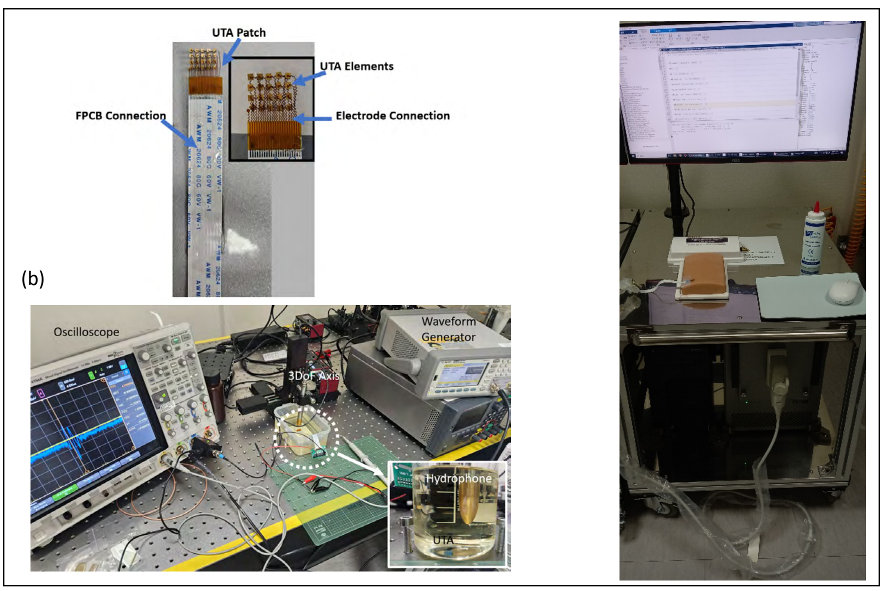


Fig. 1. (a) Fabrication of the flexible and stretchable UTA showing only the elements and connection, (b) Acoustic characterization of the UTA with matching and backing layer, (c) Setup of the Verasonics system with UTA and target phantom.

AUTOMATED FILTER DESIGN TOOL FOR IMPEDANCE MATCHING OF WEARABLE PVDF ULTRASOUND TRANSDUCERS

Stephan Thurner[1], Christoph Leitner[2], Debkalpa Goswami[1], Jörg Schröttner[11], Christian Baumgartner[1]

[1] Institute of Health Care Engineering, Graz University of Technology, Graz, Austria; [2] Integrated Systems Laboratory, ETH Zurich, Zurich, Switzerland

Background, Motivation and Objective

Flexible piezoelectrics such as polyvinylidene fluoride (PVDF) and its co-polymeres are increasingly utilized for wearable ultrasound applications due to their conformability and cost-effective manufacturing. However, transducer-transceiver impedance mismatches induce bidirectional signal reflections, degrading power transfer efficiency. Because a sensor's physical geometry inherently dictates its native impedance, dedicated matching networks are essential to minimize reflections when interfacing with standard 50 Ω acquisition systems. To bridge these highly variable, application-specific architectures with standard impedance DAQs, the objective of this work was to develop an automated MATLAB tool that rapidly synthesizes matching networks for arbitrary wearable designs.

Statement of Contribution/Methods

The proposed tool integrates the Mason equivalent circuit model with transmission line theory to simulate the acoustic transducer stack. Given the transducer's impedance at resonance, the algorithm computes 50Ω matching topologies, including series, parallel, single-L, and double-L networks. It simulates the transformed impedance profile across the frequency spectrum and determines the required discrete filter components. For experimental verification, a configurable 3D-printed test environment was developed. Calculated filter networks were physically assembled and directly evaluated with PVDF samples using a vector network analyzer (VNA).

Results/Discussion

The evaluation shows good agreement between the MATLAB simulations and the VNA measurements. The tool synthesized matching networks for transducers with real impedances above, near, and below 50Ω. For a fabricated PVDF sample operating at 35 MHz, a calculated matching network improved the return loss from approximately -2 dB (unmatched) to over -30 dB (Fig. 1). Deviations caused by tolerances of the discrete filter components were small relative to the simulated response. By eliminating manual trial-and-error procedures, the proposed tool enables rapid and systematic design of impedance matching networks for flexible ultrasound transducers.

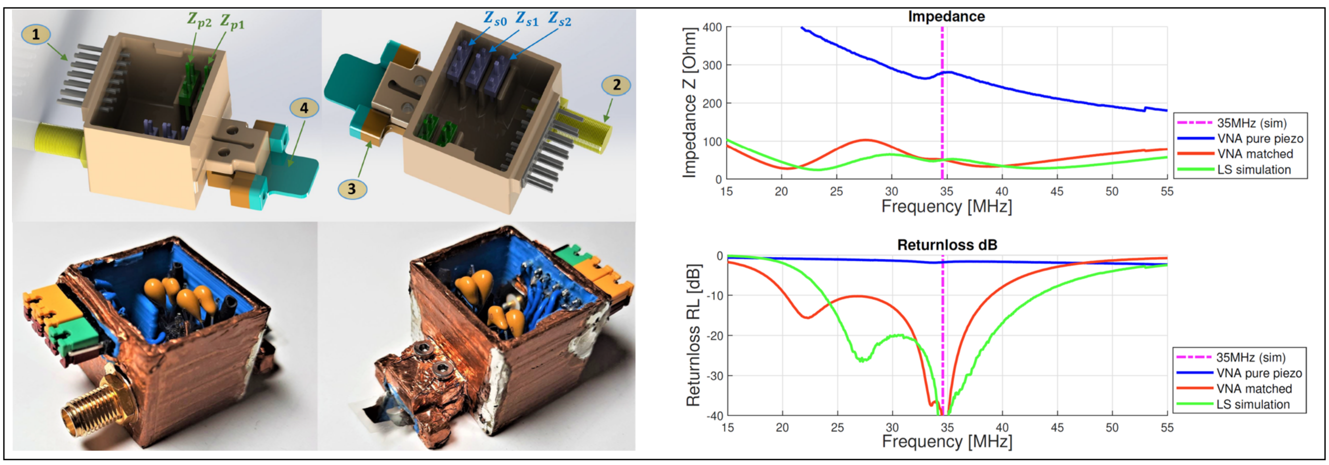


Fig. 1. Impedance matching networks for arbitrary wearable ultrasound transducer design. Left: Testbench with discrete filter components. Right: Performance comparison of unmatched (blue), simulated (green), and assembled (red) networks, detailing impedance magnitude (top) and return loss (bottom).

TOWARDS OPTIMIZED HYBRID SPARSE ARRAYS FOR WEARABLE ULTRASONIC SYSTEMS

Edgar Dorausch[1], Cornelius Kühnöl[1], Nele Kirsch[1], Tönnis Trittler[2], Gerhard Fettweis[1], Alessandro Ramalli[3], Moritz Herzog[2], Richard Nauber[1]

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Background, Motivation and Objective

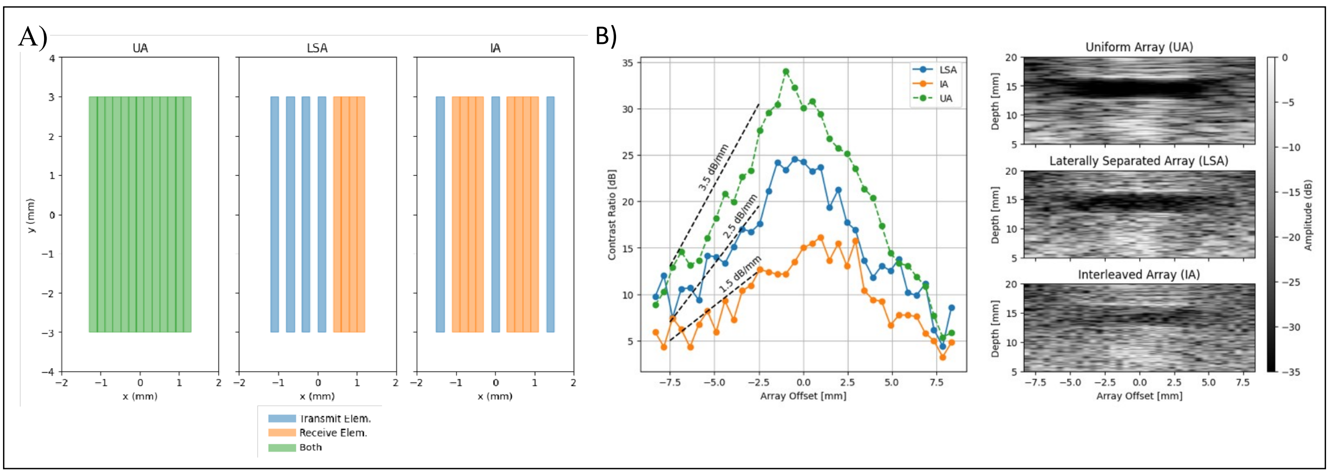
In the recent years the usage of ultrasonic systems to measure vital parameters using wearable devices (e.g. smartwatches or patches) gained increasing interest. However, achieving sufficient Signal-to-Noise-Ratio (SNR) remains challenging due the small footprint of such systems. A solution to that problem might be Hybrid Sparse Arrays (HSA). Such arrays consist of strictly separated transmit (TX) and receive (RX) paths – thus giving potential for huge SNR improvements due to optimized hardware for their usage as TX/RX respectively and the usage of long coded signals. In this study, the design of HSAs, consisting of Piezoelectric elements for TX and Capacitive micromachined ultrasonic transducer for RX (PTCR), for the wearable use case are investigated.

Statement of Contribution/Methods

Several manufacturing-caused constraints must be considered while designing PTCR-HSAs, including that single channel CMUT are intractable to produce - thus only four channel chip configurations are considered in this study. Furthermore, sufficient spacing is required between transducer components and an overall footprint of 3 mm × 6 mm should not be exceeded. Three array configurations are analyzed (Fig. A): *Laterally Separated Array* (LSA), *Interleaved Array* (IA) and for comparison, a *Uniform Array* (UA). The arrays designs were emulated by selecting corresponding channels from a conventional probe (Esaote L533). *Contrast Ratios* (CR) of A-scans were reconstructed at the center of an anechoic inclusion with a 4 mm radius at a depth of 15 mm, while the array center was laterally shifted to evaluate robustness to misalignment. The experiments were conducted using the ULA-OP 256 research ultrasound platform in combination with a Sun Nuclear Model 404 phantom.

Results/Discussion

The results can be seen in Fig. B. As expected, the UA achieved the highest CR (max CR: 34.1 dB) – however is not an HSA. Among the HSAs, the LSA (max CR: 24.6 dB) consistently outperformed the IA (max CR: 16.2 dB). The contrast degradation with increasing offset (UA: ~3.5 dB/mm, LSA: ~2.5 dB/mm, IA: ~1.5 dB/mm). The inferior contrast of IA could explain by the large transmit element pitch, which increases the prominence of grating lobes and degrades contrast. Overall, the results indicate that the LSA provide a more favorable compromise between hardware constraints and imaging performance for compact hybrid array designs.



PMUTS MEET WEARABLES: MINIATURIZED, BATTERY-FRIENDLY AND PERFORMANT ULTRASOUND

Chris Stöckel, Shubham Mulay, Katja Meinel, Sven Voigt, Danny Reuter
Fraunhofer Institute for Electronic Nanosystems ENAS, Chemnitz, Germany

Abstract missing.

23 June 2026, Tuesday

Signals & Systems

32CH PORTABLE SYSTEM AS FLEXIBLE PLATFORM FOR RESEARCH IN BIOMEDICAL ULTRASOUND

Marc Fournelle, Daniel Speicher, Christoph Risser, Holger Hewener, Steffen Tretbar
Fraunhofer IBMT, Sulzbach, Germany

Background, Motivation and Objective

Research in biomedical ultrasound requires access to the transmit and receive data pipeline of electronics in order to be able to investigate new approaches. In particular, unprocessed data (e.g. pre-beamformed channel data) must be made available, so that new beamforming algorithms can be optimized and investigated. A number of multichannel research platforms have been developed over the last decade by academic or industrial groups, which fulfil these requirements. However, for some applications e.g. those related to long-term data collection or for data acquisition during proband motion, portability is an additional requirement. For this reason, we developed MOUSE, a 32ch ultrasound research system with full access to the transmit signal and receive data pipeline bridging the gap between highly compact wearable systems (e.g. WULPUS, TinyProbe) and flexible high-performance research scanners (e.g. Verasonics, ULAOP).

Statement of Contribution/Methods

The system allows parametrization of signals using tri-state transmit ICs combined with PWM in a frequency range of 100 kHz to 10 MHz. Receive signals are amplified with up to 44.3 dB at a sampling rate of up to 50 MSPS and 12 bits. For data management, communication and sequence control, a ZYNQ 7 FPGA is available. The system is typically driven from a windows operating system using different UIs or an SDK, however, an iOS interface is available as well. Data transfer is realized using USB 3.0 in the cabled setup or in Wi-Fi mode with a data transmission rate of approximately 15 Mbit/s. The MOUSE can be powered using a 12V medical power supply or with a battery in the portable configuration.

Results/Discussion

The MOUSE system has been characterized and used in different medical applications. The portable system implementation (with battery and Wi-Fi mode) has been used together with a customized linear array for tracking of muscle motion during exercise as a biofeedback for physiotherapy training. The 256 element probe with integrated 8: 32 multiplexer ICs allows recording of thickness variation of the TrA (Transversus abdominis) in proband experiments. In another implementation, the MOUSE system was used for automatic estimation of the bladder volume when driving a customized (longterm attachable) 32-element linear array. The probe was driven in plane wave compounding mode and compounded B-scan images (13 angles each) were acquired and reconstructed with 23 frames/s. Finally, in a third application, the MOUSE was used for tracking of muscle motion. Customized transducer bracelets (32 elements, 1 MHz and 4 MHz) were connected to the system and features being characteristic for defined hand postures were extracted from the A-scan signals. It could be shown that hand motion in up to 3 degrees of freedom could be correctly recognized in the ultrasound data.

SIMPLIFYING ULTRASOUND ACQUISITION HARDWARE USING LOW-POWER CODED EXCITATION

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CodeAcq Ltd, GB – Imperial College London, GB

Abstract missing.

LEVERAGING A LOW-COST RISC-V MICROCONTROLLER BOARD AS WEARABLE ULTRASOUND FRONT END

A. Vignoli[1], N. Kirsch[2], E. Kaiser[2], T. Trittler[2], V. Meacci[1], A. Ramalli[1], E. Boni[1], M. Herzog[2], R. Nauber[3]

[1] Department of Information Engineering, University of Florence, Florence, Italy; [2] Else Kröner Fresenius Center for Digital Health, TU Dresden Faculty of Medicine Carl Gustav Carus, Dresden, Germany; [3] Vodafone Chair Mobile Communications Systems, Department of Electrical Engineering, TU Dresden, Dresden, Germany

Motivation and Objective

Mobile and continuous health monitoring through wearable devices is increasingly used for medical diagnostic. Ultrasound (US) is gaining interest in this context because, unlike common sensors, it enables richer physiological assessment by adding biomechanical information, e.g., blood pressure. However, wearable devices put strict constraints on weight, size, thermal behavior, and power consumption. Hence, the hardware for US transducer excitation and echo acquisition must combine low complexity, minimal form factor, and energy efficiency. This work demonstrates the feasibility of leveraging a $5.00 commercial RISCV microcontroller (μC) board as an US front-end for the excitation signals generation.

Statement of Contribution

A prototype device was implemented by interfacing a two-pole cable with a Raspberry Pi Pico 2 board (panel A). Each pole was connected to 4 general purpose input/output (GPIO) pins, short circuited together to form a single output node. The on-board RISC-V processor is programmed to configure the μC as a current-driven nine-level digital to analog converter (DAC). The output amplitude is controlled by setting the two groups of GPIOs alternatively as input or output, and by enabling a number of outputs so that activating more pins increases the source current. To enhance flexibility, the C code for the μC programming is generated by a Python class: the tool synthesizes basic waveforms, e.g., sine waves and binary codes, and arbitrary complex signals through modulation, e.g., PSK modulation and maximum length sequences. To test the prototype, the μC was connected to a setup comprising a transmitter and a receiver transducers immersed in water facing a reflective metal plate, and an oscilloscope.

Results

Preliminary tests show that the prototype can generate sine waves and arbitrary PSK-modulated signals (panel B) with a 4V peak-to-peak amplitude. When the transmitter is driven with a 5-cycle sine burst, the receiver successfully detects the reflected echoes from the target (panel C). In conclusion, the proposed DAC architecture yields nine discrete output levels, enabling the Raspberry Pi Pico 2 board to operate as a simple, low-cost excitation front-end able to synthesize arbitrary excitation. These results support its potential use in wearable US applications.

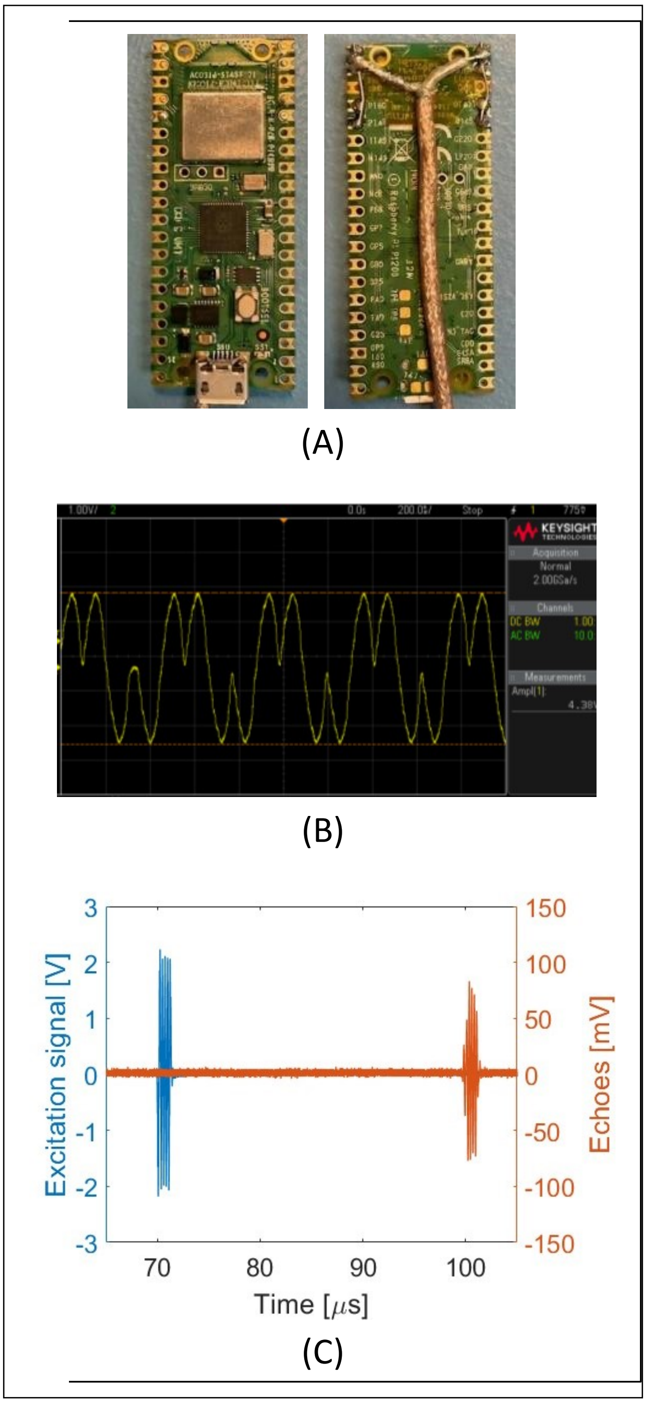


Figure. Prototype and results.

LOW-RESOURCE EMBEDDED DAS BEAMFORMER FOR MEDICAL ULTRASOUND

Federico Villani[1], Milos Hirsl[1], Luca Benini[1,2], Andrea Cossettini[1]

[1] Integrated Systems Laboratory of ETH Zurich, Zurich, Switzerland; [2] Department of Electrical, Electronie and Information Engineering (DEI), University of Bologna, Bologna, Italy

Background, Motivation and Objectives

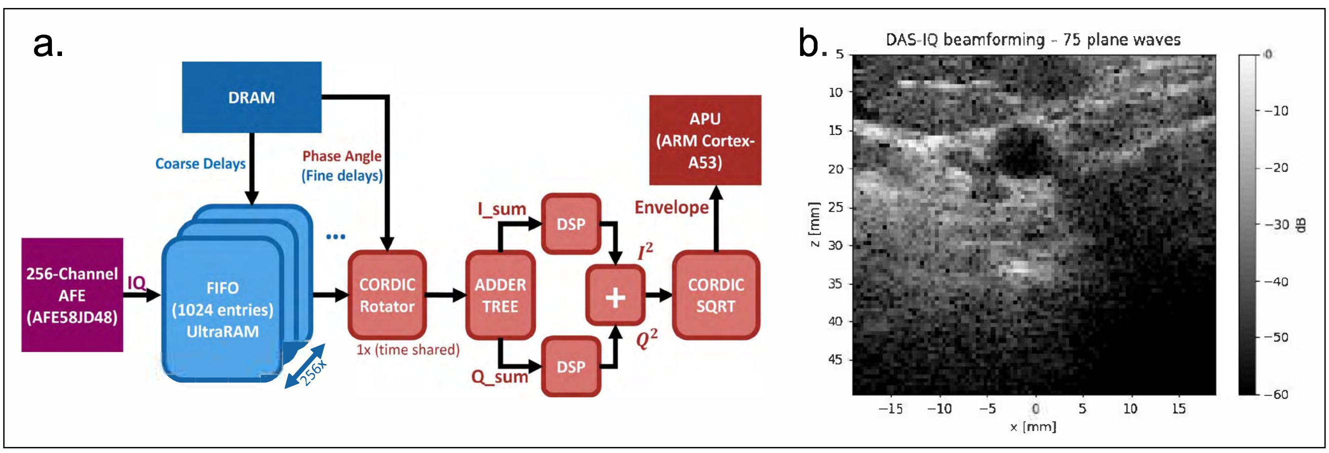
Portable US systems are increasingly integrating higher channel counts and advanced embedded acquisition capabilities. These systems require on-device image generation to enable end-users to effectively position and steer the probe during operation, after which autonomous feature extraction and downstream processing can proceed on raw data without requiring continuous image reconstruction. At the same time, embedded platforms remain constrained in computation, memory, and power, creating the need for ultra-low-resource beamforming approaches capable of low-frame-rate operation alongside the raw data acquisition pipeline, without requiring a full conventional reconstruction chain. This work presents aur ongoing development toward an ultra-low-resource, 1/Q-based embedded beamforming architecture for portable US acquisition systems, aiming at real-time image preview alongside acquisition and storage.

Statement of Contribution/Methods

We propose a low-resource beamformer architecture that leverages distributed computation across modern analog front-ends (AFEs) and a system-on-chip (SoC) featuring an Application Processing Unit (APU) to reduce FPGA fabric utilization. First, the AFEs acquire the data, downconvert them, and downsample them to baseband around the transducer's center frequency. The resulting 1/Q samples are transmitted to the FPGA via JESD204B. On the FPGA, coarse delays programmed by the APU are applied, followed by phase shifting and apodization. The channel data are then summed, and the envelope is extracted through a CORDIC unit. The envelope data are subsequently transferred to the APU, where image reconstruction, log compression, and display are performed.

Results/Discussion

We present the first synthesis-based results of this beamformer architecture. The approach reduces FPGA utilization by shifting IQ demodulation to the AFEs and finał image-processing steps to the APU. Initial synthesis results indicate operation at 300 MHz on the FPGA, supporting a l00xl00 image preview at 30 FPS from 256-channel, 16-bit, 30 Msps 1/Q-demodulated data. Utilization is below 10% for FFs and LUTs on a low-end ZUSEG SoC, and 2% LUTs / 1.6% FFs on a high-end ZU19EG, with BRAM usage of 8 Mb for a 256-channel implementation. Future work will focus on complete FPGA/APU integration and validation within the embedded acquisition system.



a. Soc reconstruction chain overview.

b. DAS beamforming of PICMUS carotid scan using the low-resource beamformer.

INVESTIGATING BINARY CODED EXCITATION SCHEMES FOR US WEARABLES WITH LOW-COMPLEXITY ELECTRONICS

Nele Kirsch[1,2], Franz Richter[1], Alessandra Vignoli[3], Edgar Dorausch [1], Cornelius Kühnöl[1], Pascal Stöver[1], Erik Kaiser[2], Merit Städler[2], Moritz Herzog[2], Gerhard Fettweiss[1], Richard Nauber[1]

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Background, Motivation and Objective

Ultrasound (US) wearables enable a multitude of novel applications in clinical, lifestyle, and rehabilitation fields by their ability to continuously monitor biomechanical properties over long periods of time. In comparison to high-end clinical US devices, such miniaturized systems are constrained by power consumption, computational resources, and hardware complexity, making it difficult to maintain high signal quality at low transmit energy. To improve the signal quality and address the trade-off between signal-tonoise ratio (SNR) and energy efficiency, we investigated binary-coded excitation combined with pulse compression (PC) on a resource-constrained microcontroller platform.

Statement of Contribution/Methods

We evaluated different binary coding strategies, specifically Barker codes, Golay codes, and Maximum Length Sequences (MLS), through numerical studies comparing acquisition methods and assessing matched-filter reconstruction with respect to axial resolution and detectability. Experimental validation was then performed using a 7 MHz piezoelectric TX/RX pair and a planar reflector in water to verify codebased gain and main lobe narrowing relative to short pulses. An implementation on a PSoC Edge microcontroller demonstrated the feasibility of coded excitation and PC under wearable-class constraints. A central feature is the hardware-oriented MLS generation scheme in which the sequence is produced entirely by an integrated feedback shift register. This removes sequence generation from the CPU and enables a timing-deterministic excitation suited to an energy-constrained wearable ultrasound operation.

Results/Discussion

While Barker codes showed limitations at higher measurement depths, both MLS and Golay codes provided robust signal reconstruction when using periodic signals. Based on these findings, MLS was selected for implementation due to its reduced complexity in hardware integration. Experimental results validate this approach, demonstrating approximately 25% narrower compression peaks and a modest SNR improvement of 5dB relative to a standard pulse-echo reference. These findings confirm that embedded binary-coded excitation is a viable strategy for enabling high-performance, energy-efficient US wearables.

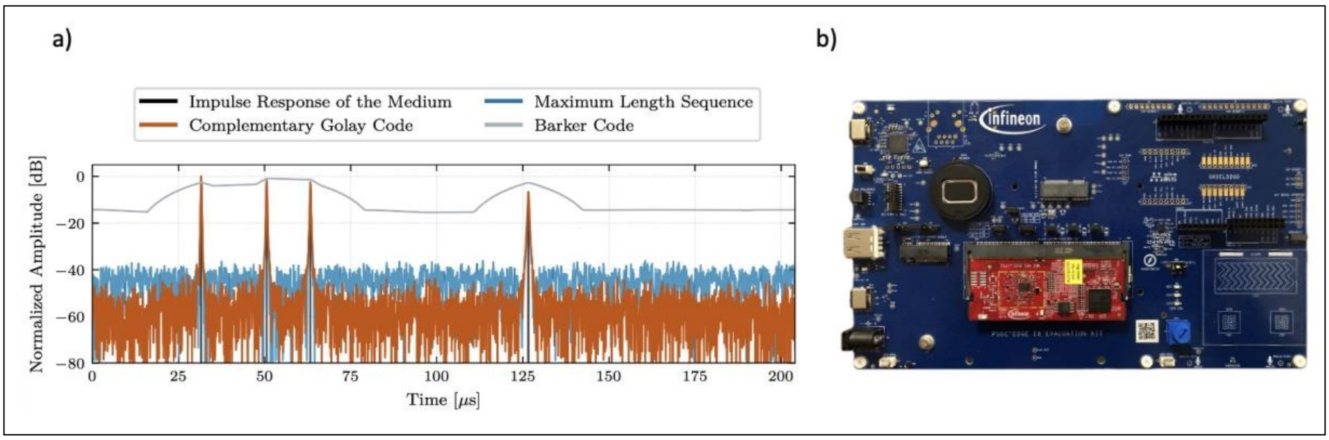


Fig. 1: a) PC results from numerical studies, b) microcontroller board used for experiments.

 Acta Neurobiol Exp 2026, 86: I–LXIV

ENERGY EFFICIENT IMPLEMENTATIONS OF MISMATCHED FILTERING FOR WEARABLE ULTRASOUND ON THE ARM ETHOS-U55

Franz Richter[1], Nele Kirsch[1], Erik Kaiser[2], Edgar Dorausch[1], Cornelius Kühnöl[1], Pascal Stöver[1], Tönnis Trittler[2], Moritz Herzog[2], Gerhard Fettweiß[1], Richard Nauber[1]

[1] Vodafone Chair for Mobile Communications Systems, Dresden, Germany; [2] EKFZ for Digital Health, Dresden, Germany

Background, Motivation and Objective

Wearable ultrasound systems have emerged as a promising technology for continuous and non-invasive monitoring of physiological parameters such as blood pressure or heart rate. However, these devices operate under strict power and computational constraints, making efficient on-device signal processing a critical challenge. This work investigates the energy efficiency of mismatched filtering (MMF) implementations on a state-of-the-art microcontroller (MCU; Infineon PSOC-Edge) with an embedded neural processing unit (NPU). For this, MMF is implemented in time- and frequency-domain on the ARM Cortex M55 and the ARM Ethos-U55 NPU of the MCU using different numerical precisions. The implementations are analyzed for energy consumption and normalized mean-squared error (NMSE) using a pre-recorded real-world ultrasound signal with 16-bit fixed-point precision.

Statement of Contribution/Methods

Implementing MMF on the M55 is done via ARMs CMSIS library, which provides convolution- and real valued Fast Fourier Transformation (RFFT) functions for various bit-depths. For the NPU, TensorFlow-Lite (TFL) models are created. The time-domain models consist of a convolutional layer, while the frequency domain models require the manual implementation of the (R)FFT and the signal multiplication. On the MCU, runtime is measured with cycle counter events, while the NMSE is measured by comparing the MMF output of the MCU with a ground truth which is calculated on a host computer in NumPy with 64-bit precision. The power consumption is obtained by measuring the voltage drop of the MCU core voltage over a shunt resistor with the Texas Instruments INA219.

Results/Discussion

We show that performing MMF on the NPU requires more power than the M55 implementations. However, the time-domain MMF models on the NPU yield the lowest runtime overall and thus also achieve the lowest energy requirements. In contrast, the frequency-domain models on the NPU do not utilize the accelerator efficiently and thus require increased inference runtime. The NMSE of the frequency-domain methods is significantly higher than for the time-domain models, since the quantized signal is scaled in between each operation of the (R)FFT on the NPU. Overall, these findings show that utilizing the NPU for signal processing can significantly improve energy efficiency by up to 28% in wearable ultrasound systems.

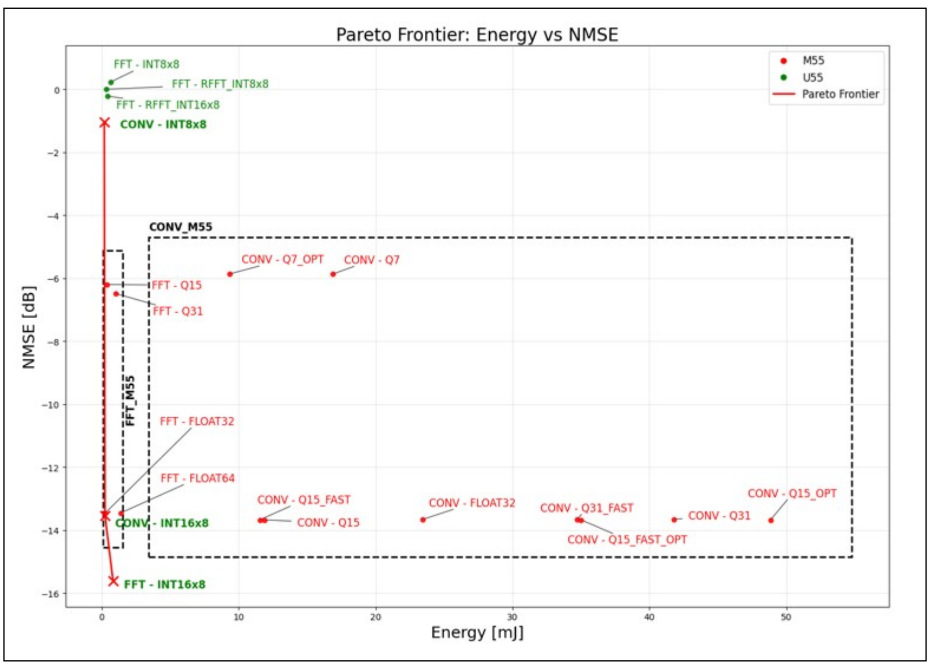


Fig. 1. A Pareto plot showing the trade-offs between energy and NMSE for the investigated MMF methods.

24 June 2026, Wednesday

Applications 1

TOWARDS ULTRASOUND-BASED BLOOD PRESSURE MONITORING: A HYBRID ARRAY ENABLING CONTINUOUS CHIRP EXCITATION FOR INCREASED AXIAL RESOLUTION

Erik Kaiser[1], Julian Kober[1], Tönnis Trittler[1], Nele Kirsch[2], Franz Richter[2], Richard Nauber[2], Gerhard Fettweis[2], Jochen Hampe[1], Moritz Herzog[1]

[1] *Else Kröner Fresenius Center for Digital Health, Dresden, Germany;* [2] *Vodafone Chair for Mobile Communications Systems, Dresden, Germany*

Background, Motivation and Objective

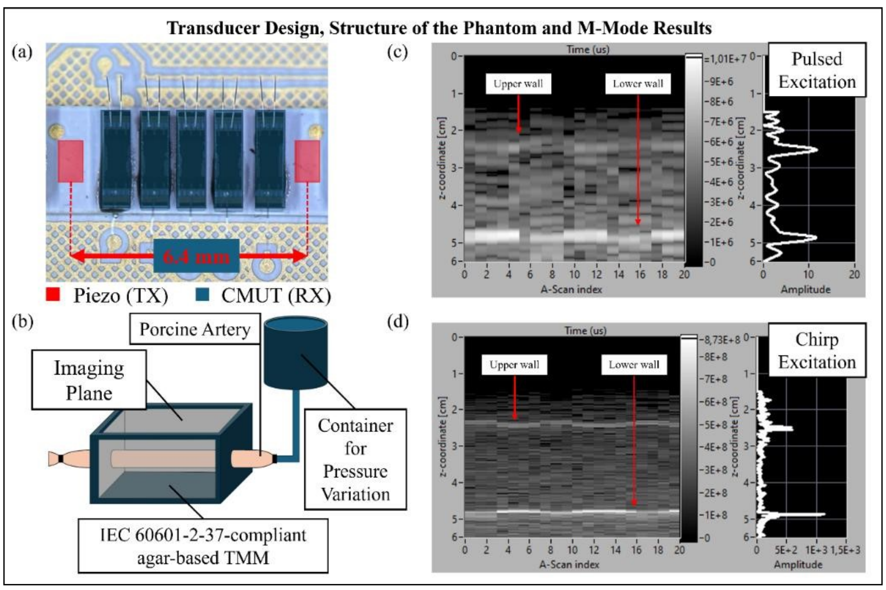
Continuous non-invasive blood pressure (BP) monitoring remains a major challenge in clinical diagnostics. Cuff-based techniques provide only intermittent measurements and limited comfort, while invasive arterial lines enable continuous BP assessment but carry a significant infection risk. Novel photoplethysmography (PPG) based approaches allow continuous non-invasive monitoring but rely on indirect estimation via light absorption, requiring frequent calibration and providing limited accuracy. In contrast, ultrasound-based BP estimation via arterial diameter tracking provides a direct alternative but requires high axial resolution in combination with sufficient signal to noise ratio. To address this, we propose a hybrid transducer array combining broadband piezoelectric transmission with capacitive micromachined ultrasound transducers (CMUTs), enabling continuous chirp excitation for high-resolution vascular monitoring.

Statement of Contribution/Methods

Our miniaturized hybrid acoustic stack integrates two lead magnesium niobate–lead titanate (PMN-PT) single crystal piezoelectric transmitters with five CMUT receiving channels (a), supported by a custom analog front end. For excitation, we used a broadband chirp signal to enhance axial resolution. To evaluate the system's ability to capture arterial wall motion, we utilized a porcine artery embedded in an IEC 60601-2-37-compliant agar-based tissue-mimicking model (b). Pressure was varied in the phantom while M-mode imaging captured wall motion. Performance comparison was conducted between short pulse excitation (c) and the proposed broadband chirp method (d).

Results/Discussion

The acoustic stack supports successfully arterial wall imaging and enables precise arterial diameter measurement. Compared with conventional short-pulse excitation, continuous chirp excitation achieved approximately 33 dB higher amplitude, and 2.75 times reduced full width at half maximum (FWHM). Continuous chirp excitation, enabled by the separate transmit and receive channels, significantly improved image quality and resolution during simultaneous operation. These results demonstrate the feasibility and advantages of the hybrid approach for vascular blood pressure monitoring.



TOWARD RELIABLE CUFFLESS BLOOD PRESSURE MONITORING USING A MULTIMODAL ULTRASOUND–ECG WEARABLE PLATFORM

Syed Turab Haider Zaidi[1,2], Lee Youngjin[1], Shin Hur[1,2]

[1] Korea Institute of Machinery and Materials, Daejeon Metropolitan City, South Korea; [2] University of Science and Technology, Daejeon Metropolitan City, South Korea

Background, Motivation and Objective

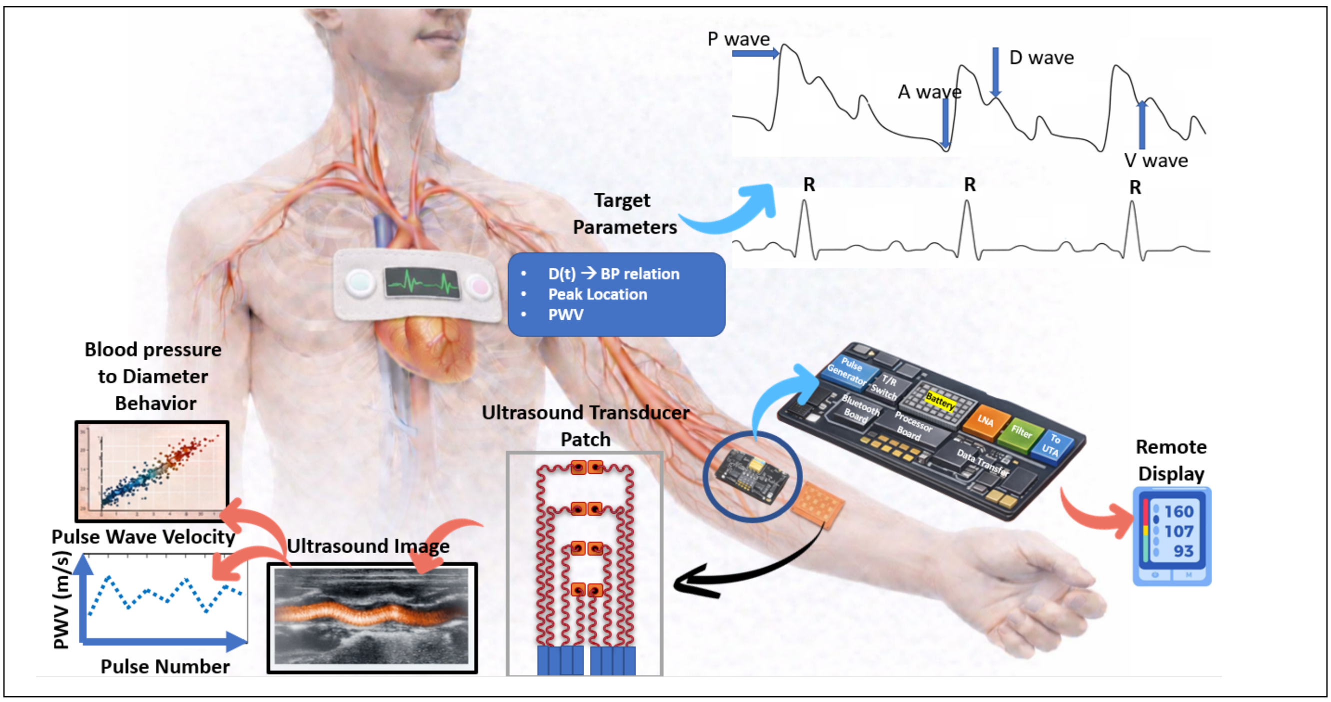
Hypertension remains a major global health challenge, affecting more than 1.3 billion people and contributing significantly to cardiovascular disease. Continuous blood pressure monitoring is essential for effective management, yet current approaches remain limited. Conventional arm cuffs provide only intermittent measurements and can disturb daily activities, while invasive arterial catheters are restricted to clinical environments. Existing cuffless wearable devices, often based on optical sensing or pulse transit time, suffer from motion artifacts and calibration drift. Recent studies suggest that improved reliability may be achieved by integrating complementary physiological signals, particularly electrical cardiac activity and mechanical vascular measurements.

Statement of Contribution/Methods

To address these limitations, we propose a flexible multimodal sensing platform integrating a PMN-PT 1-3 composite ultrasonic transducer array with a wearable ECG patch. The ultrasonic array is designed for conformal attachment over superficial arteries to monitor arterial wall motion and vessel diameter dynamics. The ECG patch simultaneously records cardiac electrical activity, providing precise timing information for synchronization with vascular mechanical signals. Combining ultrasound-based vascular measurements with ECG-derived cardiac timing enables multimodal hemodynamic analysis of arterial dynamics.

Results/Discussion

The system will be fabricated using a scalable PCB-based manufacturing method to support practical wearable implementation. In previous validation experiments using pulsatile vascular phantoms, the ultrasonic transducer array successfully tracked arterial diameter variations and reconstructed systolic and diastolic blood pressure with deviations of approximately 4 mmHg compared with reference pressure sensors. Maintaining errors within the clinically relevant ~5 mmHg range demonstrates that integrating ultrasound-derived mechanical measurements with ECG timing can improve the robustness of cuffless blood pressure estimation and supports the development of next-generation wearable cardiovascular monitoring systems.



Conceptual illustration of the multimodal cuffless blood pressure monitoring system.

MONITORING BONE FRACTURE HEALING USING GUIDED ACOUSTIC WAVES TOWARDS A WEARABLE ULTRASOUND SYSTEM

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ISAT – Institute of Sensor and Actuator Technology, Coburg University of Applied Sciences and Arts, Coburg, Germany

Background, Motivation and Objective

Bone fractures represent an increasing medical and social challenge, particularly due to falls and osteoporosis in the elderly population. Among these injuries, tibial fractures are of particular clinical importance because of their frequency and the often prolonged healing process. For effective clinical management, it is essential to determine whether biological healing progresses properly and whether sufficient stiffness and stability of the bone have been restored, for example when deciding the appropriate time to remove fixation devices. Currently, fracture healing is mainly monitored using functional assessments and X-ray imaging. However, radiographic imaging involves exposure to ionizing radiation, is relatively costly, and does not provide direct information about the mechanical stiffness of the healing bone. Therefore, alternative methods capable of assessing the mechanical state of the fracture region in a non-invasive and repeatable manner are highly desirable. In this work, we investigate an ultrasonic approach based on guided acoustic waves to monitor elasticity changes in the fracture region during the healing process.

Statement of Contribution/Methods

The proposed method analyzes the propagation characteristics of guided acoustic Lamb waves traveling through the fractured bone region. As healing progresses, the mechanical properties of the fracture zone change, which affects the propagation behavior of these waves. To study this effect, bone phantoms replicating different anatomical geometries and fracture types were developed. Initial experiments were performed using a single-element ultrasonic transmitter–receiver configuration. The received signals were evaluated with respect to wave propagation characteristics and compared with theoretical predictions for guided wave behavior.

Results/Discussion

The initial measurements show that the propagation characteristics of guided acoustic waves are sensitive to changes in the mechanical properties of the fracture region. The experimental observations demonstrate good agreement with theoretical expectations. These results indicate that the proposed method may enable monitoring of fracture healing by tracking elasticity changes in the bone and potentially allow prediction of the remaining healing time. Future work will focus on increasing the realism of the phantoms by including soft-tissue layers and on advancing both hardware and signal processing toward the development of a wearable ultrasound device for continuous fracture monitoring.

Applications 2

TOWARDS PRACTICAL ULTRASOUND-BASED HAND MOTION ANALYSIS: EFFICIENT REFERENCE ACQUISITION AND MOTION MODELING

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Measurement, Sensor and Embedded Systems Laboratory (MSE Lab), TU Bergakademie Freiberg, Freiberg, Germany

Background, Motivation and Objective

Ultrasound-based sensing at the forearm is a promising approach for hand motion analysis and future human-machine interaction systems, as it can capture internal anatomical changes related to muscle and tendon activity. However, practical adoption remains challenging due to the effort required for calibration, the complexity of suitable motion representations, and the computational demands of data-driven processing. The objective of this work is to develop methods that support a practical workflow for ultrasound-based hand motion analysis and prepare the path towards portable and embedded implementations.

Statement of Contribution/Methods

For a practical calibration, our current work demonstrates how a standard webcam can be used for an efficient generation of motion-labeled reference data. Ultrasound images are captured from the forearm muscles, whilst the webcam records the hand motion which is traced using MediaPipe to allow for automated extraction of hand landmarks from video data. For efficient modeling, hand and finger motion models are investigated to transform high-dimensional landmark information into more compact and anatomically meaningful target variables. Furthermore, embedded deployment of machine learning models in potentially wearable systems is pursued by hardware and ressource aware neural architecture search in ongoing work.

Results/Discussion

Initial results demonstrate the feasibility of deriving motion-related hand information from forearm ultrasound data using the proposed reference acquisition and modeling strategy. In particular, an efficient motion model based on relative joint angles allows the learning problem to be formulated in a more compact and physiologically plausible way. The presented approach reduces the barrier for experimental calibration and establishes a flexible methodological basis for future ultrasound wearable systems. Beyond current stationary setups, the combination of efficient reference acquisition, reduced motion modeling, and embedded machine learning opens promising perspectives for practical real-time applications.

ARRAY SELECTION FOR WEARABLE ULTRASOUND DYSPHAGIA BIOFEEDBACK MONITOR DEVICE

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[1] James Watt School of Engineering, University of Glasgow, Glasgow, UK; [2] Anatomy Facility, School of Medicine, Dentistry and Nursing, University of Glasgow, UK; [3] Imaging for Radiotherapy Adaptation, Institute of Cancer Research, Sutton, UK

Background, Motivation and Objective

Wearable ultrasound is an emerging technology in medical imaging, enabling point-of-care monitoring in real time for extended periods. In the field of speech and language therapy (SLT), a specific opportunity exists for ultrasound to monitor dysphagia (swallowing disorder) in real-time in hospital and home environments. Bulky clinical systems are presently used with intrusive attachment frames. Transitioning to a small, wearable system is attractive but requires an optimal selection of the array, in terms of flexibility and frequency range, to balance image quality and penetration depth for dysphagia biofeedback monitoring in SLT.

Statement of Contribution/Methods

This study evaluated the suitability of different ultrasound transducers. Three arrays were characterized using the Verasonics Vantage 128 research system: (i) 14 MHz rigid piezocomposite (Vermon, France); (ii) 28 MHz single-crystal (Vermon); and (iii) 25 MHz flexible thin-film (Novosound, UK) (Fig. 1). Each array, without a casing, was connected to the Verasonics system via flexible PCBs and interposers. Performance was evaluated through standard characterization methods: impedance analysis, pulse-echo tests, field scans in a scanning tank, tests on phantoms and finally on fresh frozen cadavers.

Results/Discussion

Whilst many publications suggest flexible arrays have advantages for wearable, the human body itself provides sufficient compliance. Our characterization also revealed challenges using the thin-film flexible array, especially because of element dropout and limited penetration depth, which compromised image quality for deep neck structures. The 28 MHz single-crystal array had no dropout, and its penetration depth was higher but still inadequate. In contrast, the 14 MHz rigid array demonstrated itself to be more suitable, ruling out flexible and high frequency options. Our findings suggest that, despite the flexible transducer ergonomic advantages and the resolution enhancement from a high frequency array, a high-performance rigid array, at the high end of the conventional 2 – 15 MHz frequency range, currently provides a better option for dysphagia monitoring. These results support the ongoing development of a wearable device based on the integration of an optimized rigid transducer with a bespoke case for application in SLT.

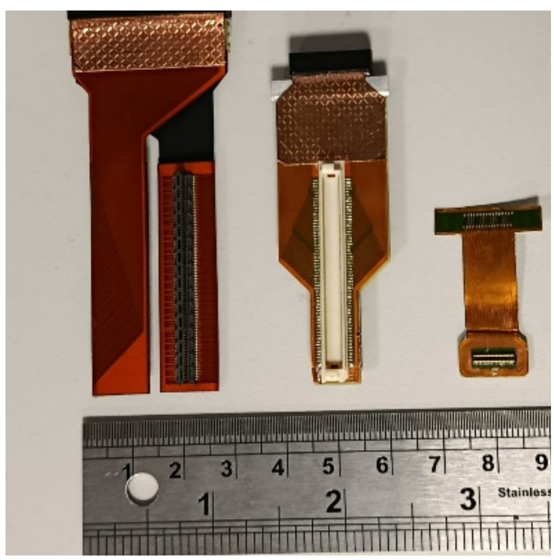

Fig. 1. Evaluated arrays (left to right): 14 MHz rigid, 28 MHz single-crystal, and 25 MHz flexible with integrated PCB. Ruler for scale.

AUTOMATED FEATURE EXTRACTION OF DISTRIBUTED WEARABLE ULTRASOUND SIGNALS DURING HIGHLY DYNAMIC PHYSICAL ACTIVITY

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[1] Department of Bioengineering, George Mason University, Fairfax VA, USA; [2] Center for MedTech Innovation, George Mason University, Fairfax VA, USA; [3] Myokinetics, Inc., Baltimore MD, USA; [4] Patriot Performance Lab, George Mason University, Fairfax VA, USA

Background, Motivation and Objective

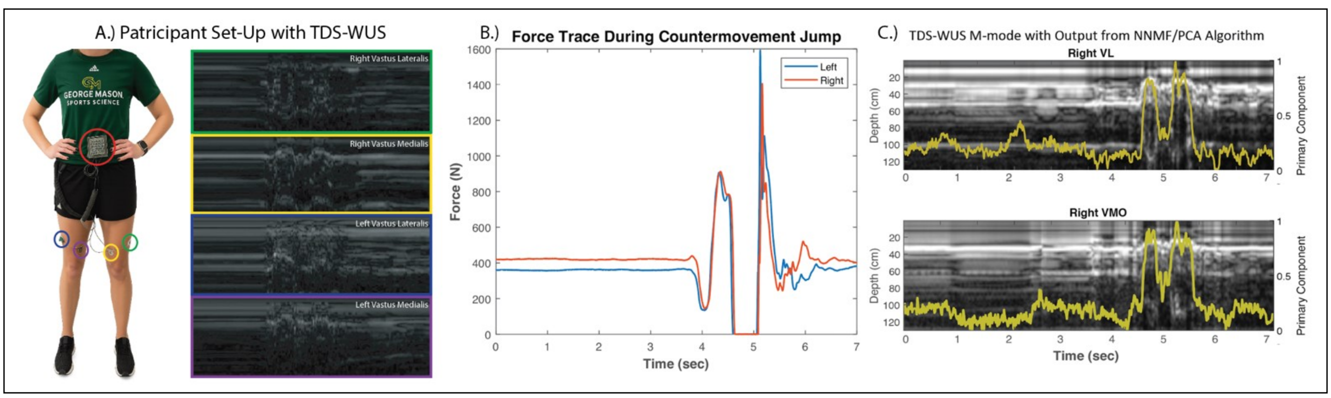
Musculoskeletal ultrasound technology is increasingly utilized for assessing muscle activation in real-time. However, bulky handheld probes and operator dependency of conventional systems hinder imaging during physical activity. We have developed a compact, distributed wearable ultrasound (D-WUS) system that employs time-delayed spectrometry (TDS), a frequency-domain technique that uses chirp transmit-receive signals for multi-site M-mode imaging. This study presents an automated processing pipeline designed specifically for D-WUS data, enabling real-time muscle-level metrics essential for monitoring rehabilitation and recovery.

Statement of Contribution/Methods

A wearable 4-channel D-WUS system was used to collect M-mode data from 20 subjects performing bilateral countermovement jumps (CMJs). The WUS system transmitted 20-ms chirps spanning 3-5 MHz and acquired echo signals from 4 transducers distributed over different muscles, left and right vastus lateralis (VL) and vastus medialis oblique (VMO) muscles (Fig. A1), at a rate of 50 lines/s. Echo signals down-mixed, low-pass filtered, and Fourier transformed in real-time to obtain M-mode data (Fig. A). M-mode data was processed using a composite factorization technique utilizing a non-negative matrix factorization (NNMF) across a range of factors (1: 50). The factors were then concatenated and processed using principal component analysis to obtain the primary time-domain component (Fig. C) that described tissue contraction during CMJ (Fig. B). Correlation analysis was performed on these time-domain signals from different muscles to examine muscle coordination healthy individuals and subjects with reported knee injury.

Results/Discussion

NNMF-based processing automatically provided a time trace that visually tracks the movement in tissue interfaces in M-mode images and correlated well with the bilateral force-time measurements (Fig. C). Participants with prior knee injuries showed decreased VL-VMO correlation (p=0.039) and increased activation time-lags (p=0.013). These findings indicate that intra-limb coordination deficits could be used as an indicator of persistent dysfunction post-injury. This D-WUS approach with automated NNMF processing can provide actionable metrics beneficial for real-time rehabilitation feedback.



TRACK TECH

22 June 2026, Monday

Oral session 1

11:00–11:20
TWO-POINT MODEL-FREE ESTIMATION OF SHEAR WAVE ATTENUATION FOR ULTRASOUND ELASTOGRAPHY

Ramin Almasi, Piotr Kijanka

AGH University of Krakow, Faculty of Mechanical Engineering and Robotics, Department of Robotics and Mechatronics, Krakow, Poland

Background, Motivation and Objective

Ultrasound shear wave elastography is widely used in clinical imaging to assess tissue mechanical properties. In addition to wave speed, shear wave attenuation provides additional diagnostic information, yet accurate estimation remains challenging due to noise and model assumptions in existing techniques. This study proposes a model-free, two-point attenuation estimation method that combines time-frequency analysis with the Kullback-Leibler (KL) divergence, enabling more robust performance under limited data conditions and low SNR.

Statement of Contribution/Methods

This work introduces a model-free two-point method for estimating the shear wave attenuation coefficient from ultrasound particle velocity measurements, where is the proportionality constant in the linear frequency-dependent model $\alpha(f) = \alpha!f$. The method requires particle velocity data $v_m(x, t)$ measured at two lateral positions x_1 and x_2. First, the peak arrival times t_{p1} and t_{p2} of the signals $v_m(x_1, t)$ and $v_m(x_2, t)$ are identified in the time domain. A continuous wavelet transform (CWT) is then applied to obtain the time-frequency representations $V_m(x_1, t, f)$ and $V_m(x_2, t, f)$. Next, the amplitude spectra at the peak times are extracted, yielding $V_m(x_1, f) = V_m(x_1, t_{p1}, f)$ and $V_m(x_2, f) = V_m(x_2, t_{p2}, f)$. The spectral difference between the two signals is quantified using the KL divergence, D_f^{KL}. The attenuation coefficient α_0 is then estimated using the derived relationship $\alpha_0 = D_f^{KL}/\zeta\,\Delta x$, which relates the KL divergence, propagation distance, and $\zeta = \int V_m(x_1, f)\, f\, df$.

Results/Discussion

Results from the noise-free analytical phantoms confirmed the validity of the proposed method, producing attenuation estimates consistent with those obtained using the 2P-FSP technique. Attenuation coefficients were reconstructed as a function of the first signal position and the inter-point distance, demonstrating stable behavior across analytical models. Under low-SNR tissue-mimicking phantom conditions, clear performance differences emerged between the two approaches. As the push/detection voltage decreased to 15-25 V, 2P-FSP became increasingly sensitive to spectral model mismatch, resulting in biased attenuation estimates and reduced spatial coverage. In contrast, the proposed method produced stable attenuation estimates across all phantoms (P_{V1}-P_{V4}). For ROI measurements at 25 V, the coefficient of variation ($CV = \sigma/\mu$) was 30.77%, 8.33%, 14.93%, and 7.14% for P_{V1}-P_{V4} when using the proposed method, compared with 1094.50%, 5.66%, 21.15%, and 279.03% for 2P-FSP. The robustness and expanded spatial coverage of the proposed method were further confirmed in *ex vivo* bovine liver experiments.

11:20–11:40
EX VIVO INVESTIGATION OF SHEAR WAVE DISPERSION ESTIMATION USING THE SUPERLET TRANSFORM

Wiktor Jachym[1], Matthew W. Urban[2], Piotr Kijanka[1]

[1] AGH University of Krakow, Faculty of Mechanical Engineering and Robotics, Department of Robotics and Mechatronics, Krakow, Poland;
[2] Mayo Clinic, Department of Radiology, Rochester, MN, USA

Background, Motivation and Objective

Ultrasound shear wave elastography (SWE) enables noninvasive assessment of the viscoelastic properties of soft tissues and is widely used in clinical practice. In acoustic radiation force (ARF)-based SWE, an ultrasound transducer generates an ARF excitation that induces shear waves propagating laterally through the tissue. Dispersion curves, which describe the relationship between shear wave phase velocity and frequency, are estimated to characterize tissue mechanical properties, particularly viscoelasticity. However, the accuracy and robustness of dispersion estimation may be affected by measurement conditions and ARF excitation parameters. The objective of this study is to experimentally evaluate a signal processing approach based on a novel time-frequency analysis method, the Superlet Transform, for robust estimation of dispersion curves in ARF-based SWE.

Statement of Contribution/Methods

The investigated approach estimates the shear wave dispersion curve by applying the Superlet Transform and computing the cross-correlation between the time-frequency representations of two signals. Its performance was evaluated experimentally using tissue-mimicking phantoms and *ex vivo* datasets acquired from pig liver and kidney tissues. Measurements were performed under a wide range of ARF excitation conditions, including variations in beam configuration (F-number of 1, 1.5, and 2), and push/detection voltages (30 V and 50 V). The results obtained with the investigated method were compared with those produced by other SWE signal processing techniques from the literature, such as the Phase Gradient (PG) and the Two-Point Continuous Wavelet Transform (2P-CWT).

Results/Discussion

The investigated method, utilizing the Superlet Transform, demonstrated improved robustness across a range of excitation conditions. The percentage error remained below 10% across the entire analyzed frequency range (0-1400 Hz) for all measurement configurations. In contrast, existing methods failed to maintain phase velocity estimates with errors below 10% for frequencies above 700 Hz (2P-CWT) and 500 Hz (PG). Furthermore, within the 0-600 Hz band, the Superlet Transform provided phase velocity estimates with percentage errors below 5%. These results suggest that the Superlet Transform enables a more reliable characterization of tissue viscoelastic properties over a wider frequency range and may represent a promising alternative for SWE signal processing.

11:40–12:00

VIBRATION SHEAR WAVE VISCOELASTOGRAPHY OF ANISOTROPIC TISSUES USING ANGLE-ADAPTIVE DIRECTIONAL FILTERS: *EX VIVO* AND *IN VIVO* STUDIES

Akash Chandra[1], Manu KS[1], Maxime Lafond[2], Karla P. Mercado-Shekhar[1]

[1] IIT Gandhinagar, Gandhinagar, India; [2] LabTAU (INSERM), Lyon, France

Background, Motivation and Objective

Viscoelastic properties are promising biomarkers for muscle pathologies. Commercial shear wave elastography systems usually rely on acoustic radiation force impulse (ARFI) for muscle imaging. Systems using external mechanical vibration (EMV) sources for shear wave generation use simpler ultrasound hardware for muscle assessment. In this study, we report shear wave viscoelastography of skeletal muscle using an EMV source with two hemispherical end-effectors. To compensate for anisotropy-induced effects due to the muscle pennation angle, an angle-adaptive directional filtering method was used. The objective was to evaluate the feasibility of this approach for characterizing skeletal muscle *ex vivo* and *in vivo*.

Statement of Contribution/Methods

Ten *ex vivo* bovine muscle samples were imaged, and ten healthy human volunteers participated with written consent. The biceps [Fig. a] and gastrocnemius (GCM) muscles [Fig. b] were imaged on the dominant limb (7 right, 3 left). The EMV sources were two 10-mm-diameter end-effectors, spaced 87 mm apart, and were driven simultaneously with a chirp signal (0-900 Hz, 50 ms pulse duration) to excite at multiple shear wave frequencies for dispersion analysis. A Verasonics Vantage 256 system with an L11-5v transducer (7.6 MHz, 10 kHz frame rate, 150 frames total) was used to track shear waves using ultrafast plane-wave imaging. Inphase/quadrature data were stored for offline processing. Fiber pennation angle (θ) was estimated from Bmode images using a Hough transform (HT). An angle-adaptive 3-D directional filter was used to isolate waves propagating along the fiber for pennation angle-independent estimates. Kelvin–Voigt model fitting was used to estimate the shear modulus and viscosity.

Results/Discussion

Pennation angles estimated using an HT [red lines overlaid in Fig. c] were 19.8 ±0.32° for *ex vivo*, 1.50 ± 0.15° for biceps, and 23.0 ± 1.06° for gastrocnemius (mean ± SEM). Directional filtering [Fig. d], aligned with fiber direction, isolated shear wave component [Fig. e]. Viscoelastic estimates were 8.67 ± 0.40 kPa and 9.47 ±0.47 Pa·s for *ex vivo* tissues, 6.60 ± 0.54 kPa and 6.95 ± 0.77 Pa·s for biceps, and 6.02 ± 0.43 kPa and 6.11 ± 0.67 Pa·s for gastrocnemius, which were within the range previously reported for these muscles using ARF-based elastography. This work demonstrated EMV-based viscoelastography as a potential tool for assessing skeletal muscle.

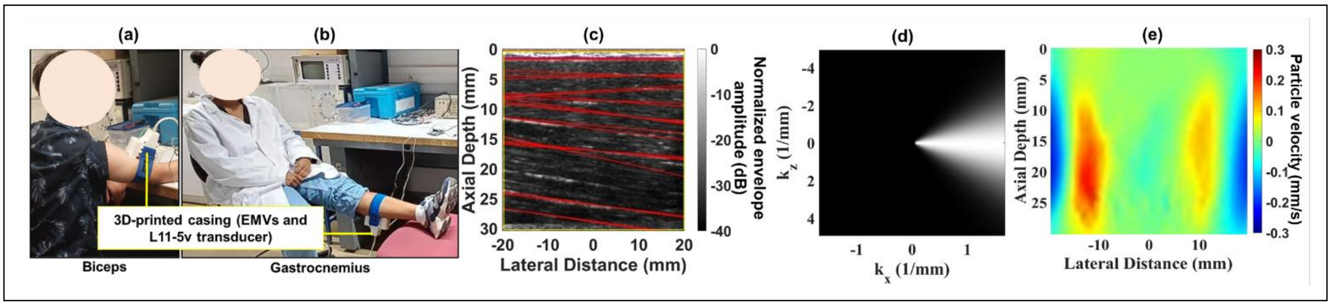


Fig. Setup for biceps (a) and gastrocnemius (b); B-mode with HT lines (c), directional filter (d), and filtered particle-velocity map along the fiber (e).

Oral session 2

13:00–13:20
SPEED OF SOUND QUANTIFICATION IN MUSCLE TISSUES: ANISOTROPIC CONSIDERATIONS

Maxime Leriche, Angéline Nemeth, Jean-Luc Gennisson
BioMaps, Université Paris-Saclay, Orsay, France

Background, Motivation and Objective

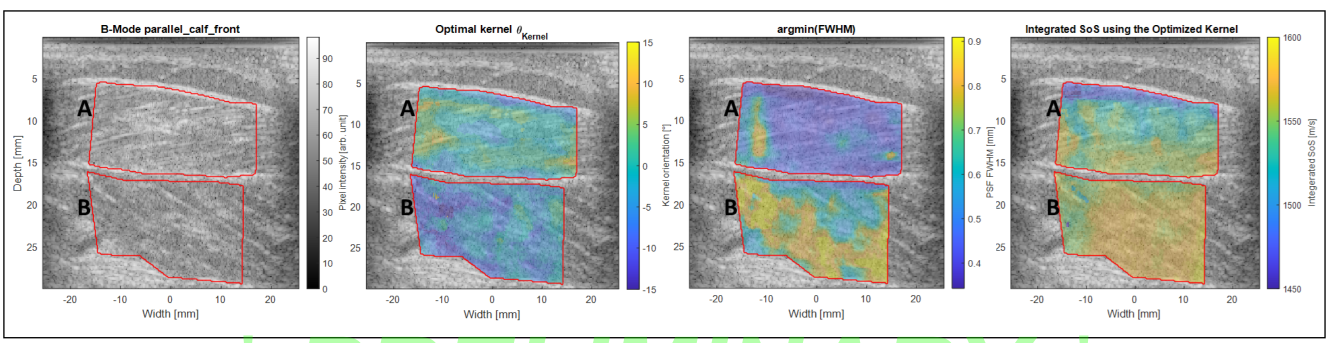
Intramuscular fat infiltration has emerged as a critical indicator of muscle quality to assess muscle health. While MRI Proton Density Fat Fraction (MRI-PDFF) is the current clinical gold standard for muscle fat quantification, high costs and low accessibility limit its routine use – particularly for frail patients with sarcopenia or neuromuscular pathologies. The current muscle function assessment methods thus rely on questionnaires which lack quantitative imaging tool. Ultrasound offers an ideal point-of-care alternative, leveraging Speed of Sound (SoS) quantification as a proxy for muscle tissue composition. However, muscle tissue presents the unique challenge of an anisotropic medium, where acoustic properties vary along and across fibers (up to +24 m/s along fibers). This study investigates how matrix imaging can highlight muscle anisotropy and derive optimized SoS quantifications.

Statement of Contribution/Methods

This work presents a novel SoS matrix imaging framework specifically tailored for the characterization of anisotropic muscle tissues. We leverage matrix imaging ability to perform a dual-stage virtual focusing (emission and reception) to derive a spatially-variant optimized kernel for the medium anisotropy, and study the Point Spread Function (PSF) that reaches maximum sharpening along the medium principal axis of anisotropy. Consequently, the OK supersede a reference kernel that considers no medium orientation to perform integrated SoS estimations. We apply the method on different medium: a homogeneous isotropic calibration phantom, ex vivo animal muscles, and in vivo healthy human calves. The ultrasound sequence consists of 121 plane-waves ranging from -30° to 30° with a linear probe L18-5 (7.5 MHz center frequency) driven by a Mach30 device (Supersonic Imagine).

Results/Discussion

Region A (gastrocnemius) present optimized kernels that matches local measure of fiber orientations, and a mean FWHM of 0.47 mm. Region B however (soleus) presents a more heterogeneous optimized kernel distribution and a mean FWHM of 0.73 mm. The estimated integrated SoS matches that of muscle tissues (A: 1535 m/s, B: 1567 m/s) but region A requires a correction for the non negligeable fat layer above. The PSF broadening in region B can be explained by the wavefront disruption after travelling through region A, but further studies are required to better explain the phenomenon.



Derived optimized kernel orientation, estimated minimal FWHM, and derived integrated SOS in a gastrocnemius and soleus of a healthy calf muscle.

13:20–13:40
PULSE-ECHO SPEED-OF-SOUND TOMOGRAPHY USING THE ADJOINT-STATE METHOD

Naiara Korta Martiartu[1], Chenyu Cui[1], Alexandre Aubry[2]

[1] *Laboratory of Signal Processing, École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland;* [2] *Institut Langevin, ESPCI Paris, PSL University, CNRS, Paris, France*

Background, Motivation and Objective

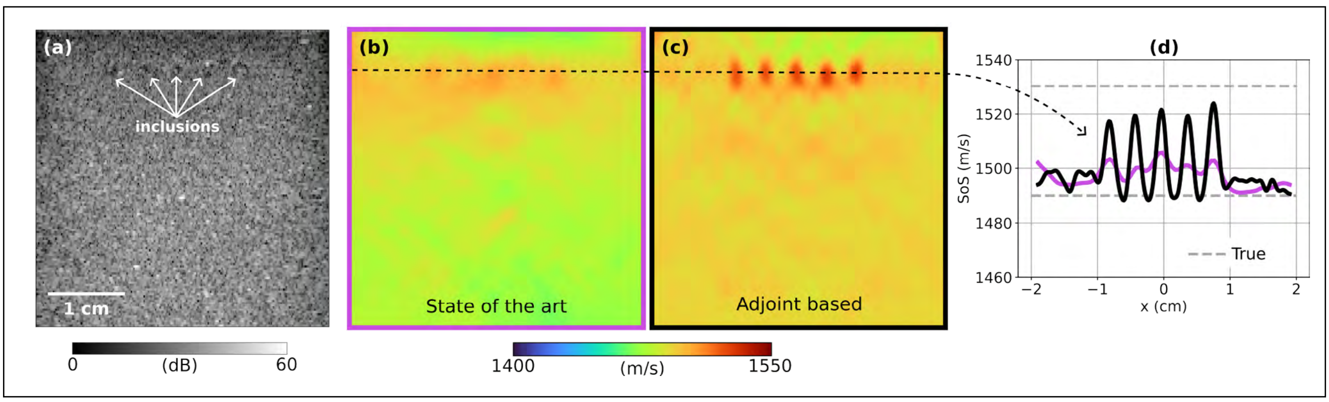
Speed-of-sound (SoS) inhomogeneities in tissue induce wavefront aberrations that degrade the quality of conventional ultrasound images. Yet these aberrations can be quantified to map the SoS, a promising biomarker for breast cancer detection. State-of-the-art pulse-echo SoS imaging techniques rely on a straight-ray approximation [1], neglecting diffraction and refraction and thereby limiting the accuracy and spatial resolution of reconstructed SoS images. Here, we move beyond ray theory and present a tomography technique that combines the paraxial wave equation and the adjoint-state method to significantly improve resolution.

Statement of Contribution/Methods

Our approach builds upon matrix imaging, which consists of decoupling the transmit and receive focal spots during numerical beamforming. The result is a matrix of impulse responses corresponding to a transducer array virtually relocated to arbitrary depths within the tissue. To account for wave propagation in heterogeneous media, we implement matrix imaging using the Fourier split-step method. At each depth, we synthesize the response of the medium to steered transmit and receive beams and isolate phase aberrations by leveraging the angular memory effect. We then estimate the SoS distribution that minimizes the L_2-norm of the observed aberrations. We show that the gradient of this misfit functional can be efficiently computed through an adjoint matrix imaging step in which aberrations are propagated upward in depth. Finally, the inverse problem is solved iteratively using a BFGS quasi-Newton algorithm.

Results/Discussion

The proposed method was validated on a tissue-mimicking gelatin phantom containing five cylindrical inclusions (2 mm diameter, +40 m/s SoS contrast) embedded in a homogeneous background (Fig. a). Compared to the state-of-the-art method [1] (Fig. b), the adjoint-based tomographic approach (Fig. c) shows substantially improved spatial resolution, allowing us to recover the shape and the SoS of the inclusions more accurately (Fig. d). By accounting for diffraction, artifacts in the background are also largely suppressed. These results highlight the potential of the proposed approach for imaging localized lesions such as breast tumors. Importantly, our iterative formulation inherently yields aberration-corrected reflectivity images in a unified framework.



[1] Stähli et al. (2020), "Improved forward model for quantitative pulse-echo speed-of-sound imaging," Ultrasonics.

13:40–14:00

ULTRASOUND IMAGING OF NONLINEAR LIVER PROPERTIES USING DUAL ACOUSTIC PRESSURE LEVELS

Andrzej Nowicki[1], Piotr Karwat[2], Jurij Tasinkiewicz[1], Norbert Żołek[1], Ihor Trots[1], Ryszard Tymkiewicz[1]

[1] Institute of Fundamental Technological Research, Polish Academy of Sciences, Warsaw, Poland; [2] us4us Ltd., Warsaw, Poland

Background, Motivation and Objective

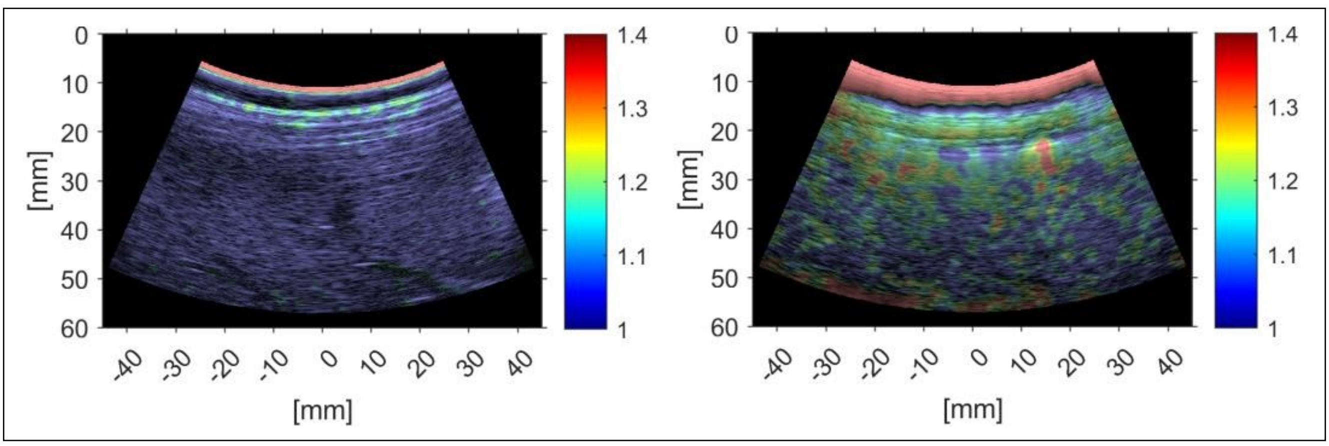
In ultrasound imaging, wave propagation is affected by tissue nonlinearity, which leads to spectral distortion. Adipose tissue is characterized by markedly higher nonlinearity compared to other tissue types, thus, estimating nonlinear acoustic properties of tissue may support the diagnosis of fatty liver disease. Typically, acoustic nonlinearity of media is quantified using the B/A parameter measured in transmission mode and requiring wide band reception systems. In this work, we focus on estimating nonlinear tissue properties in echo mode, relying exclusively on the fundamental frequency component of the signal (without harmonics), enabling more efficient utilization of the probe bandwidth.

Statement of Contribution/Methods

We propose a straightforward procedure for estimation of nonlinear properties of tissue. The method is based on acquiring two ultrasound images using beams with significantly different acoustic pressures, while recording the echoes only in the fundamental frequency band. The image obtained for lower pressure is subsequently amplitude-adjusted to account for the pressure difference between acquisitions. In the final step, the tissue nonlinearity index (NLI) is computed locally as a ratio of pixel amplitudes between the amplified low-pressure image (ALPI) and the high-pressure image (HPI). For a linear medium (B/A=0), both images are expected to be identical (apart from noise), resulting in NLI close to 1. In nonlinear media (B/A^{1}0), part of the wave energy is redistributed from the fundamental frequency to higher harmonics, which predominantly influences the HPI. After filtering out the harmonic components, the amplitude of the HPI becomes lower than that of the ALPI. Consequently, NLI exceeds 1 and increases with the nonlinearity of the investigated tissue. As an initial validation, NLI imaging was performed on healthy and fatty livers of the study authors using the us4R-lite (us4us Ltd.) and SonixTouch (Ultrasonix) systems. The acoustic pressures applied during ALPI and HPI acquisitions were 390 kPa and 1590 kPa, respectively.

Results/Discussion

Preliminary results indicate that in healthy livers NLI remained below 1.1 (left image), whereas in a liver with previously diagnosed steatosis (score 1/2) NLI locally exceeded 1.3 (right image). These findings demonstrate the potential applicability of the proposed method in the assessment and diagnosis of hepatic steatosis.



Nonlinearity index (NLI) images of: healthy liver (left), and steatotic liver (right).

14:00–14:20

DEEP LEARNING-BASED INPAINTING FOR ENHANCED MATRIX IMAGING UNDER SPARSE SAMPLING

Roser Viñals, Naiara Korta Martiartu, Jean-Philippe Thiran

Signal Processing Laboratory 5, École Polytechnique Fédérale de Lausanne, Switzerland

Background, Motivation and Objective

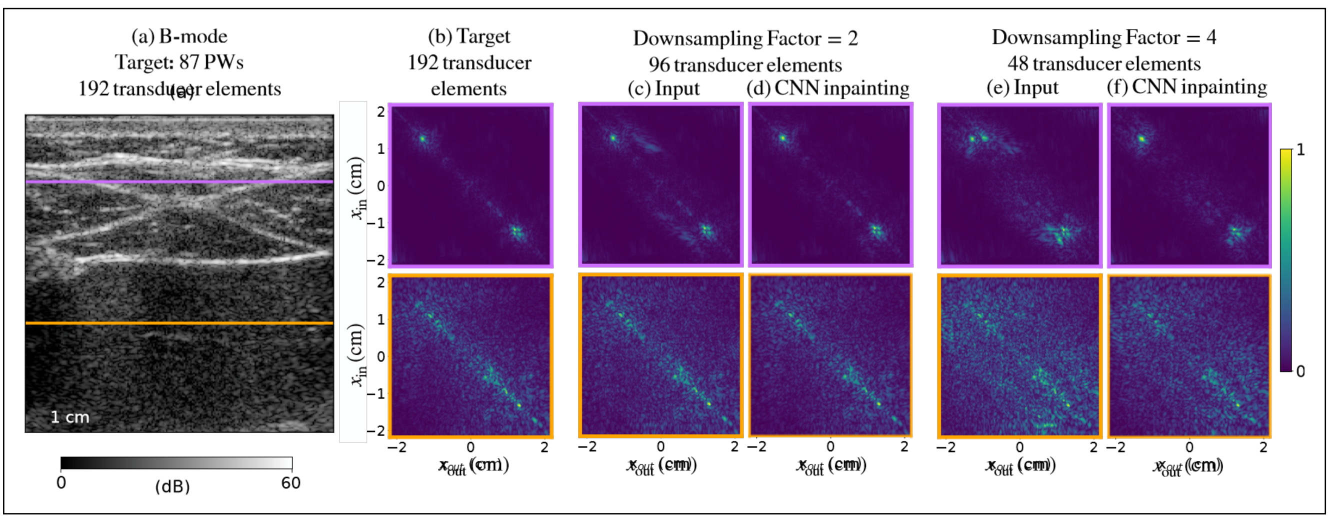
Matrix imaging is a powerful framework that decouples input and output focusing to synthesize virtual sources (x_{in}) and receivers (x_{out}) at any depth. This double-focusing operation yields a focused reflection matrix, R_{xx}, whose elements represent the impulse responses between virtual source-receiver pairs. At the ballistic time, the diagonal elements are dominated by single-scattering contributions, whereas multiple scattering events generate a diffuse background that extends over the off-diagonal elements. These terms are key to characterizing scattering media but are also highly sensitive to grating lobes (GLs). Sparse arrays–though necessary for data volume reduction under hardware or bandwidth constraints–introduce GLs due to spatial aliasing. We apply a deep learning-based inpainting method to reconstruct sparsely sampled RF data, aiming to suppress GLs and restore R_{xx}.

Statement of Contribution/Methods

We consider an *in vivo* abdominal acquisition (a), obtained with a GE 9L-D linear probe using 87 steered plane waves (PWs), to test the inpainting method trained on unsteered PWs with a dual-domain loss described in [1]. Missing RF channel data are reconstructed sequentially for each steered PW, considering uniform sparse reception arrays with downsampling factors (DF) of 2 and 4. The evaluation focuses on the R_{xx} matrices at two distinct depths (indicated in violet and orange in (a)). Specifically, we assess the method's ability to suppress aliasing artifacts and restore the diffuse background by comparing the R_{xx} matrices obtained from both the downsampled (c, e) and inpainted signals (d, f) against the fully sampled ground truths (b).

Results/Discussion

The results demonstrate that the inpainting effectively mitigates GLs across both depths analyzed. At a DF of 2, the two R_{xx} matrices obtained from the inpainted signals (d) show near-perfect qualitative and quantitative agreement with the fully sampled targets (b), successfully recovering the off-diagonal values that were previously obscured by aliasing (c). Even at a DF of 4, the inpainting enables a significant reduction of GLs (f) compared to the downsampled inputs (e), providing more faithful reconstructions of the off-diagonal values. These results demonstrate that inpainting can mitigate the traditional trade-off between data volume and signal integrity, recovering the essential off-diagonal information that is typically obscured by aliasing in sparse array systems.



[1] R. Viñals and J.-P. Thiran, "Deep Learning-Based Inpainting for Sparse Arrays in Ultrafast Ultrasound Imaging" in IEEE Transactions on Computational Imaging, 2026.

14:20–14:40
DEEPPATELLA: A TOOL FOR AUTOMATIC TRACKING OF PATELLA TENDON INSERTIONS AND TENDON ELONGATION ESTIMATION

Gerardo Romeny[1], Romina Ledergerber[1], Martin Keller[1], Daniel Behr[2], Luca Benini[3], Oliver Faude[1], Christoph Leitner[3], Paul Ritsche[1]

[1] University of Basel, Basel, Switzerland; [2] University of Applied Sciences Northwestern Switzerland, Muttenz, Switzerland; [3] ETH Zurich, Zurich, Switzerland

Background, Motivation and Objective

Patellar tendon (PT) stiffness is highly load-sensitive and can decrease by up to 29% after just 14 days of unloading, impacting force transfer and thereby rehabilitation processes and athletic performance. While automated ultrasound (US) analysis has been applied to the Achilles tendon, PT elongation—an indirect marker of stiffness—still relies on manual and time-consuming frame-by-frame annotation. We present deepPatella, a novel, automated, transformer-based tool with Kalman (KF) filtering to efficiently (and objectively) track PT elongation from US frame sequences.

Statement of Contribution/Methods

PT elongation was assessed using US (ArtUS, Telemed) with a 6 cm linear probe (LF9-5N60-A3 @7 MHz) fixed over the PT apex and tibial tuberosity during ramped isometric knee extensions. US images were recorded at 50 fps. Elongation was defined as relative displacement of proximal and distal insertions, manually labeled by two raters. The dataset included 17,475 frames from 30 participants (13 males, age=46.5 years (35–56), weight=73.7 kg (53.1–95.1), height=171.3 cm (158.0–188.0)), split into 12,221/5,254 frames (or 27/14 videos) for training/testing. A TransUNet model with sigmoid-based heatmaps, BCE-Dice loss, and ADAM optimizer predicted insertion points; predictions were smoothed using a Kalman filter. Accuracy was evaluated via Euclidean distance to reference labels within a 1 mm tolerance and by comparing predicted and Kalman filtered PT elongation against the manually labeled one.

Results/Discussion

In the 14 test videos, PT elongation was 4.8 ± 1.5 mm based on manual annotation, 4.6 ± 2.8 mm from the model prediction, and 4.6 ± 2.9 mm with KF. Mean Euclidean errors compared to manual were 0.9 ± 0.5 mm for the distal and 1.0 ± 0.4 mm for the proximal insertions, for both model and Kalman. Accordingly, total absolute elongation Euclidean errors were 1.0 ± 0.9 mm for the model and 1.0 ± 1.8 mm for Kalman. Overall, the model predicted PT insertions with high accuracy and KF smoothed but did not improve the predictions. Thus, deepPatella enables time-efficient and objective PT elongation analysis in US videos and provides the basis for automated stiffness estimation. Additionally, a user interface was developed to allow non-technical users to upload US videos, obtain elongation estimates, integrate external force-ramp data, and compute tendon stiffness.

Oral session 3

15:00–15:20
UMUD: A WEB APPLICATION FOR EASY ACCESS TO MUSCULOSKELETAL ULTRASONOGRAPHY DATASETS

Paul Ritsche[1], Fabio Sarto[2], Francesco Santini[1], Christoph Leitner[3], Martino V. Franchi[2], Oliver Faude[1], Gerardo Romeny[1], Taija Finni[4], Olivier Seynnes[5], Neil Cronin[4]

[1] University of Basel, Basel, Switzerland; [2] University of Padova, Padova, Italy; [3] ETH Zurich, Zurich, Switzerland; [4] University of Jyvaskyla, Jyvaskyla, Finland; [5] Norwegian School of Sport Sciences, Oslo, Norway

Background, Motivation and Objective

Ultrasonography is widely used to assess skeletal muscle and tendon properties, including architecture, cross-sectional area, and tissue stiffness. However, the lack of accessible and standardized public datasets limits large-scale studies and the development of automated image analysis algorithms. To address this gap, we developed the Universal Musculoskeletal Ultrasonography Database (UMUD), a platform designed to facilitate access to datasets and promote standardization in musculoskeletal ultrasonography research. UMUD is an online repository that aggregates metadata from publicly available datasets hosted on platforms such as the Open Science Framework and Zenodo. By providing detailed descriptors, including muscle group, ultrasound device, participant demographics, and publication information, the platform enables efficient dataset discovery through search and visualization tools.

Statement of Contribution/Methods

UMUD collects and structures metadata from publicly available musculoskeletal ultrasonography datasets into a searchable repository. Datasets hosted on open research infrastructures are indexed using standardized metadata descriptors, including muscle group, ultrasound device, participant characteristics, and related publications. Integrated search and visualization tools allow users to efficiently identify and explore relevant datasets for research and algorithm development.

Results/Discussion

Currently, UMUD includes 15 datasets comprising 145,464 images and/or 2,674 videos from 1,901 participants. The platform also provides benchmark datasets for training and validating algorithms. These include multi-expert analyses of muscle architecture and panoramic cross-sectional area images, a dataset with muscle geometry overlays for teaching architecture analysis and labeled datasets for deep learning models. In addition, UMUD lists state-of-the-art automated analysis algorithms to support their application. By offering a centralized and standardized repository of datasets and tools, UMUD addresses key challenges in musculoskeletal ultrasonography research, promotes transparency, and supports reproducible research and advances in automated image analysis. Future developments will expand datasets, improve platform functionalities, and introduce community-driven challenges.

15:20–15:40

PHYSICAL LEFT VENTRICLE PHANTOMS FOR VALIDATING CARDIAC DEFORMATION IMAGING: STATE OF THE ART, CHALLENGES AND FUTURE DIRECTIONS

Szymon Cygan, Jan Łusakowski-Milencki, Jakub Żmigrodzki

Warsaw University of Technology, Institute of Metrology and Biomedical Engineering, Warsaw, Poland

Background, Motivation and Objective

Quantitative imaging of myocardial deformation has become an important tool for assessing cardiac function. Techniques such as speckle-tracking echocardiography and other motion-tracking approaches enable estimation of myocardial strain and regional wall motion. However, validation of these methods remains challenging because reliable ground-truth data for myocardial deformation are rarely available *in vivo*. Physical phantoms of the left ventricle (LV) provide a controlled environment enabling repeatable measurements and quantitative evaluation of imaging algorithms. The objective of this work is to review the state of the art in the development and application of LV phantoms used for validation of cardiac deformation imaging and to identify key challenges and future research directions.

Statement of Contribution/Methods

This contribution presents a structured review of physical LV phantoms reported in the literature, including models developed for ultrasound-based strain imaging and motion analysis. Particular attention is given to engineering aspects of phantom construction, including geometry reconstruction, tissue-mimicking materials such as polyvinyl alcohol cryogel (PVA-C), and actuation mechanisms used to reproduce cyclic cardiac motion. The review also discusses experimental setups used for phantom imaging and validation of deformation estimation methods. It is complemented by the author's practical experience in the design and fabrication of several LV phantoms developed for experimental studies of cardiac deformation imaging.

Results/Discussion

Existing LV phantoms enable controlled and repeatable experiments for validation of cardiac deformation imaging algorithms and imaging systems. Materials such as PVA-C allow partial reproduction of mechanical and acoustic properties of myocardial tissue, while mechanical, hydraulic or pneumatic actuation systems can generate cyclic ventricular motion. Nevertheless, several challenges remain. One major limitation is the difficulty of controlling and reproducing realistic spatial distributions of myocardial strains. Another issue concerns ultrasound image quality, where artifacts are often introduced not by the phantom material itself but by the experimental setup, including the surrounding medium and the imaging tank in which the phantom is placed. Finally, the durability and long-term stability of phantom parameters are critical, particularly when phantoms are used to generate large datasets for machine-learning applications in cardiac image analysis. Addressing these challenges is essential for the development of more reliable experimental platforms for cardiac mechanics imaging.

15:40–16:00

DEEP CONVOLUTIONAL AUTOENCODER WITH QUANTIZED LATENT SPACE FOR EFFICIENT ULTRASOUND RF SIGNAL COMPRESSION

Marzieh Jalali, Claudio Giangrossi, Enrico Boni, Alessandro Ramalli
Department of Information Engineering, University of Florence, Florence, Italy

Background, Motivation and Objective

Modern 3-D ultrasound systems produce massive volumes of pre-beamformed radiofrequency (RF) data, creating demanding hardware requirements for storage, real-time streaming, and onboard processing. Efficient compression is therefore critical to reduce data throughput while preserving diagnostic value. This work proposes a deep convolutional autoencoder (CAE) for end-to-end compression of ultrasound RF signals, combined with latent space quantization to further reduce bitrate and emulate hardware-constrained transmission.

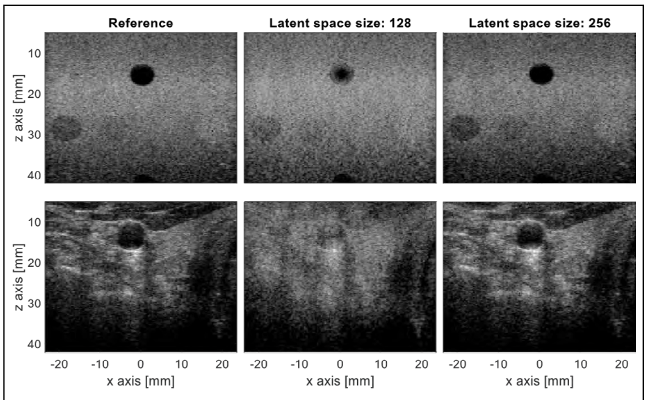
Statement of Contribution/Methods

RF data were acquired using the ULA-OP 256 scanner, performing a linear aperture scan, yielding 36,864 traces of 4096 samples each. Of these, 22,118 were used for training, with the remainder reserved for validation and testing. RF signals were reshaped and standardized using z-score normalization prior to training. A 1-D CAE was designed to learn compact latent representations of size 512, 256, and 128. The encoder applied stride-based downsampling via convolutional layers, while the decoder restored the original length using transposed convolutions. During inference, scalar quantization was applied to the latent coefficients to enable efficient storage and transmission; quantization was not included during training to avoid altering the learned model parameters. Several quantization resolutions—4, 8, and 12 bits per latent coefficient—were tested. Reconstruction quality was then assessed by mean squared error (MSE), peak signal-to-noise ratio (PSNR) on RF signals, and contrast-to-noise ratio (CNR), contrast ratio (CR), and structural similarity index (SSIM) on B-mode images.

Results/Discussion

B-mode results indicate that higher compression ratios (ComR) degrade image fidelity for both phantom (top) and *in-vivo* carotid artery (bottom) data. Latent spaces of 128 samples (center) preserve the structure of the inclusions but introduce contrast loss and border artifacts, while a 256-sample latent space (right) yields images highly consistent with the reference (left), although with lower ComR. The table shows that higher quantization resolution steadily improves reconstruction; e.g., for a latent dimension of 512, SSIM increases from 0.79 (4 bits) to 0.93 (12 bits), with CNR remaining around 7.0. The highlighted configuration provides an effective balance between ComR and quality, achieving SSIM=0.89 and PSNR=26.5 dB.

Overall, the proposed method achieves ComR values up to 24 with minimal loss of anatomical detail, demonstrating strong potential for lowering data rates in next-generation ultrasound systems.



Latent size	# Bits	ComR	CNR [a.u.]	CR [dB]	SSIM [a.u.]	MSE [a.u.]	PSNR [dB]
128	4	96	6.2	18.2	0.55	1.60	16.4
	8	48	8.8	21.6	0.78	0.48	24.6
	12	32	8.7	22.1	0.78	0.45	25.1
256	4	48	7.1	29.6	0.67	1.30	20.8
	8	24	7.3	35.6	0.89	0.20	26.5
	12	16	7.3	36.2	0.90	0.20	27.4
512	4	24	7.2	32.6	0.79	0.39	23.3
	8	12	7.0	35.3	0.92	0.07	30.4
	12	8	7.0	35.7	0.93	0.07	30.8

16:00–16:20

REAL-TIME ULTRASOUND COMPUTED TOMOGRAPHY DATA ACQUISITION AND PROCESSING USING A DEEP LEARNING APPROACH

Ziemowit Klimonda, Piotr Jarosik, Piotr Karwat, Marcin Lewandowski

us4us Ltd., Warsaw, Poland

Background, Motivation and Objective

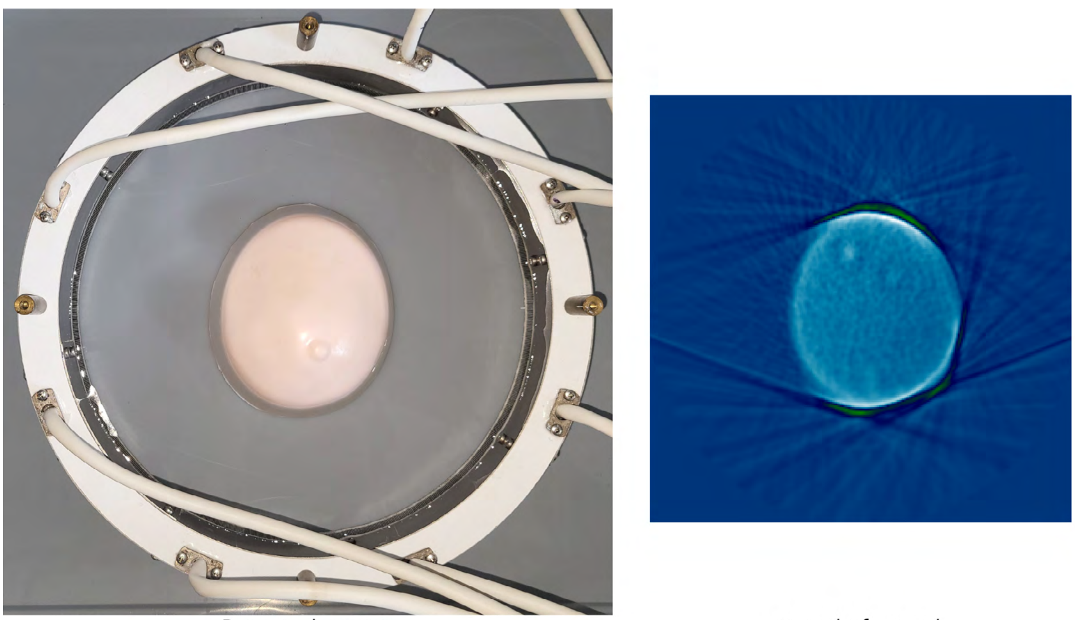
Ultrasound Computed Tomography (USCT) enables imaging of physical parameters such as the speed of sound and attenuation—properties that are diagnostically valuable, as tumors often differ from healthy tissue in these regards. Rapid acquisition and reconstruction are essential for applications such as 3D imaging, needle tracking and for reducing motion artifacts. However, the imaging frame rate in USCT is constrained by several factors, including time-of-flight, the number of transmit/receive (TX/RX) events, data transfer, and image reconstruction time. Among these, the physical propagation time of the ultrasound pulse constitutes a fundamental limitation. One practical approach to increasing the frame rate is to reduce the number of transmissions used for reconstruction. Although this compromises image quality, the resulting degradation can be mitigated through deep learning techniques. This work aims to demonstrate the feasibility of real-time USCT using neural-network-based methods.

Statement of Contribution/Methods

The acquisition setup consisted of the us4R™ ultrasound research platform (1024TX/256RX), a host PC, a ring probe containing 1024 elements, and a tissue-mimicking breast phantom. The acquisition followed a standard USCT scheme with a single element transmit and a receive aperture of 256 to 512 elements opposite the transmitter. A full scanning consisted of 1024 transmits (element-by-element) or double of this for an extended receive aperture of 512. In USCT, images are reconstructed from projection data acquired at multiple angles, typically represented as sinograms. Using a filtered backprojection algorithm, these sinograms are converted into spatial maps of physical parameters, most commonly the speed of sound. Sparse acquisition results in reduced resolution of sinograms, which adversely affects the reconstructed images. Deep learning methods were used to improve the sinograms and, consequently, the final images.

Results/Discussion

The processing of the sparse data (a reduced number of acquisitions) allows for real-time USCT imaging, and the resulted loss of image quality can be efficiently addressed using deep learning techniques.



Breast phantom speed of sound

16:20–16:40
FEASIBILITY STUDY: EXPLORING THE POTENTIAL APPLICATION OF THE US4US SYSTEM IN 3D ULTRASOUND TOMOGRAPHY

Luisa Gupta, Zewei Lu, Michael Zapf, Ian Andree, Nicole Ruiter
Institute for Data Processing and Electronics, Karlsruhe Institute of Technology, Germany

Motivation and Objective

Ultrasound computed tomography (USCT) requires high signal fidelity, bandwidth, and multi-channel scalability beyond conventional pulse-echo imaging. The US4US platform is a software-defined ultrasound system with high configurability and scalability, making it a promising candidate for USCT. This work evaluates channel-level performance focusing on transmit waveform generation and receive-chain noise and compares it to custom build USCT front-end board (FEB) from KIT's 3D USCT III system.

Statement of Contribution

First, broadband transmit modulation was investigated. Unlike the 3D USCT III system, which uses an analog power amplifier, US4US employs pulser-based excitation; pulse-width modulation was applied for the experiments. Second, reception architectures were compared. The reference system uses a FEB at the transducer array system (TAS), whereas US4US integrates an analog receive chain. To assess architectural impact, US4US was tested with direct transducer connection and with an external FEB (Fig. 1a). All measurements were performed in a controlled water-tank setup under identical conditions.

Results and Discussion

The results show that the US4US system is suitable for the USCT platform. A 4 µs linear chirp (1–4 MHz) was generated. Although shorter than the 100 µs target, the pulser provides 2× higher voltage, corresponding to 4× transmit energy. From an energy-equivalent perspective, 4 µs in US4US approximates 16 µs for USCT III.

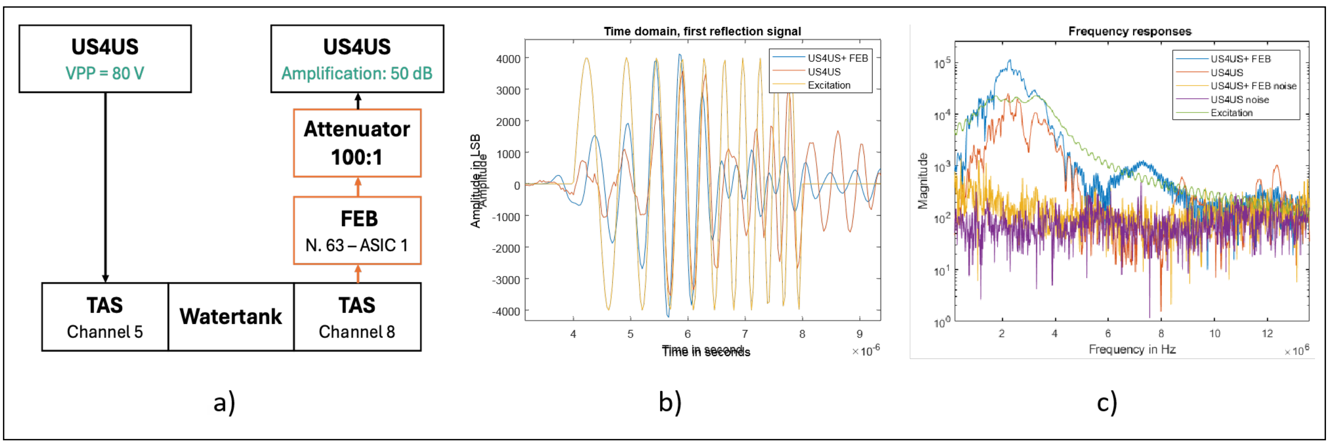


Fig. 1. (a) Measurement setup, optional inclusion of the FEB and attenuator marked in orange. (b) Time domain response with and without FEB and the excitation. (c) Frequency response with FEB (blue), without FEB (red), noise floor with FEB (yellow), without FEB (purple) and, excitation signal (green).

The receive chain was characterized by signal-to-noise ratio (SNR) and effective bandwidth (Fig. 1b and 1c). The external front-end board (FEB) increased SNR by up to 8 dB. Fig. 1c compares frequency responses with and without FEB. In both cases, dominant components appeared within 1–4 MHz. The noise floor is higher in the setup with FEB. With FEB enabled, an additional response emerged above 5 MHz, potentially due to nonlinear effects.

23 June 2026, Tuesday

Oral session 1

11:40–12:00
3D PRINTED HEMISPHERICAL UNDERWATER ULTRASOUND ABSORBERS FOR USCT APPLICATIONS

Leonard Kraus[1], Michael Zapf[1], Lukas Armbrust[2], Nicole Ruiter[1]

[1] Institute for Data Processing and Electronics, Karlsruhe Institute of Technology, Germany; [2] Technik-Haus, Karlsruhe Institute of Technology, Germany

Background, Motivation and Objective

3D Ultrasound Computed Tomography (3D USCT) is a novel method for early breast cancer detection. The hemispherical imaging aperture can induce sidewall reflections that overlap with reflections from inside the region of interest (RoI), degrading the image quality (Fig. 1). This work describes the development of ultrasound absorbers that can decrease sidewall reflectivity under incidence angles of up to 71° (Theta in Fig. 1) for frequencies 0.5 - 4.5 MHz.

Statement of Contribution/Methods

Sidewall reflections were reduced using a pyramidal acoustic absorber. Materials and production methods were evaluated to achieve suitable geometries and sufficient broadband attenuation. The material properties were characterized for a MATLAB-based k-Wave simulation, leading to an optimized absorber geometry. Prototypes were produced and validated in experiments. After successful validation, absorber mats for the current KIT 3D USCT were manufactured and tested.

Results/Discussion

Fused deposition modelling (FDM) 3D printing was chosen for the absorber mat production due to the complexity of the geometry and timely manufacturing. Thermoplastic Polyurethane (TPU) was chosen due to its flexibility and acoustic properties similar to water. According to simulations higher pyramid aspect ratios (height/width) produce higher ultrasound absorption. A simulated pyramid absorber with a height of 6.5 mm and a width of 1 mm performed best and achieved up to 37 dB dampening of the reflection (max. absorber thickness 7 mm). The pyramid absorber with the highest producible aspect ratio had a height of 4 mm and width of 4 mm and reduced the measured direct reflections by 26.11 dB ± 1.36 dB near to 29 dB reflection loss, which is considered "full" absorption for radiation force balances in IEC 61161. These absorber mats w applied to the whole imaging aperture of the KIT 3D USCT device (Fig. 1) and were able to reduce the intensity of the backwall reflection in reconstruction images (Fig. 2).

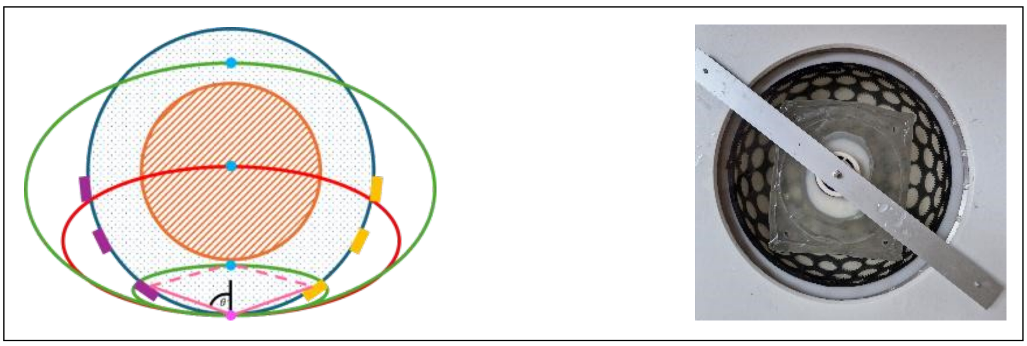


Fig. 1. Left: top-down view on waterfilled 3D USCT aperture (blue), RoI (orange circle), ultrasound emitters/receivers (violette/yellow rectangles), Ellipses represent projections from pink side wall reflections to the light blue dots, red ellipses impact RoI, green ones do not, pink lines are constructions for incident angle theta; Right: measurement setup of KIT 3D USCT.

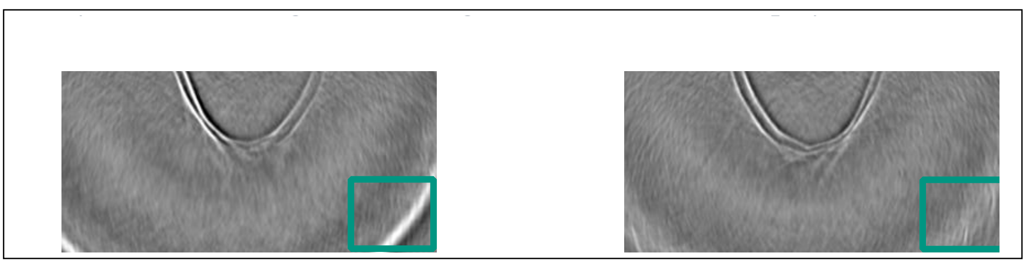


Fig. 2. Slice from reconstruction of a breast phantom, Left: without absorber mats, Right: with absorber mats. Green boxes marks sidewall reflections in both images.

12:00–12:20
DATA-DRIVEN FORWARD PREDICTION FOR ACOUSTIC METAMATERIAL TOPOLOGY OPTIMIZATION

Sourava Prasad Mishra, Paweł Kudela
Institute of Fluid-Flow Machinery, Polish Academy of Sciences, Gdańsk, Poland

Background, Motivation and Objective

Metamaterials are architected structures with exotic physical properties such as selective blocking of ultrasonic waves. Due to such property metamaterials have found significant usage in ultrasonic imaging and microbubble-based contrast-enhanced ultrasound. One example application of metamaterial is to block fundamental waves while allowing harmonic waves to pass through, aiding in artifact free imaging. Properties emerge from the geometry and arrangement of the constituents of the unit cells in metamaterials. Identifying optimal configurations for specific responses remains a computational challenge. In this work, we propose a data-driven topology optimization framework designed to predict the dispersion vector. Using machine learning techniques, our method accelerates the forward prediction process compared to traditional numerical solvers. We benchmark the proposed algorithm against established methodologies, demonstrating superior performance in terms of computational efficiency and comparable predictive accuracy for complex acoustic bandgap structures.

Statement of Contribution/Methods

We represent metamaterial topologies as binary images with solid material and void regions. The image is used as inputs to our model designed to predict the full dispersion vector. The dispersion vector is used to describe the relationship between frequency and reduced wavevector in a material. We use a Vision Transformer (ViT) architecture, leveraging self-attention mechanisms to model topology images. Unlike traditional approaches, our approach enables the capture of both local details and global geometric symmetries to achieves superior accuracy in predicting metamaterial properties.

Results/Discussion

We split a dataset of topology images and dispersion vector into train and test sets and report the results of our model on the test set. Our benchmarking results confirm the model's robustness and usability across diverse metamaterial configurations. Furthermore, the proposed method offers significant computational efficiency and enables the rapid evaluation of thousands of candidate designs in seconds.

12:20–12:40
BROADBAND ULTRASONIC FOCUSING IN WATER USING A TRAPPED-AIR PLA PARABOLIC META-MIRROR

Hafiz Muhammad Imran[1], Marco Ricci[2], Rocco Zito[1], Francesco Simonetta[1], Stefano Laureti[1]
[1] DIMES Department, University of Calabria, Italy; [2] DIET Department, Sapienza University of Rome, Italy

Background, Motivation and Objective

Efficient acoustic focusing in water is essential for ultrasonic imaging, nondestructive testing, and underwater sensing. Conventional solutions often rely on curved transducers or phased arrays, increasing system complexity and cost. Recently, trapped-air acoustic metamaterials have demonstrated strong acoustic impedance mismatch with water, enabling enhanced wave manipulation and subwavelength imaging capabilities [1]. In this work, a parabolic mirror fabricated from PLA with trapped air inclusions is investigated as a compact passive reflector for broadband ultrasonic focusing in water.

Statement of Contribution/Methods

The reflected acoustic field is modeled using the impulse-response formulation $h(r, t)$ for a plane piston source reflecting from a curved surface [2]:

$$h(r,t)=\int_S \delta(t-R/c)/(2\pi R)\,dS \qquad (1)$$

where R is the distance between the mirror element and observation point, c is the sound speed in water, and S is the reflecting surface. The mirror response is evaluated using COMSOL finite-element simulations with a planar pressure excitation. The main contribution is the introduction of trapped air cavities within a PLA reflector fabricated by additive manufacturing. The trapped air increases the acoustic impedance mismatch between the reflector and water, enabling efficient acoustic reflection. This approach overcomes the intrinsically low reflection of solid plastics in water and enables compact MRI-compatible acoustic metadevices.

Results/Discussion

Simulations show that the trapped-air PLA parabolic mirror focuses ultrasonic waves in water, producing a concentrated focal region along the mirror axis with significant pressure amplification at the focus. The trapped air significantly increases acoustic impedance mismatch, improving reflection efficiency and focusing performance. The structure operates over a broad frequency range from 100 kHz to 5 MHz, demonstrating broadband ultrasonic focusing capability. These results suggest that trapped-air PLA mirrors can provide a compact and low-cost solution for underwater ultrasonic imaging and sensing applications.

Acknowledgement

This project has received funding from the European Union's EU Framework Programme for Research and Innovation Europe Horizon (HORIZON TMA MSCA Doctoral Networks) under Grant Agreement No. 101119738 'MetacMed' (www.metacmed.eu). Views and opinions expressed are, however, those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

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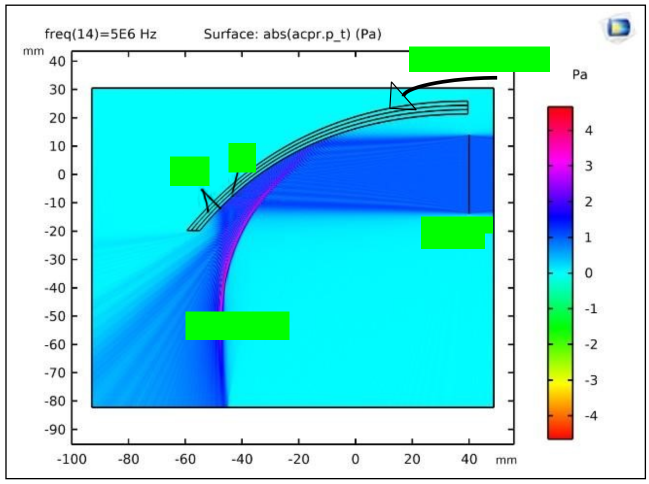


Figure: Schematic and Comsol Simulation of Trapped Air Parabolic Reflector.

Oral session 2

13:40–14:00

ADDITIVELY MANUFACTURED METAMATERIAL FILTER FOR FUNDAMENTAL AND SECOND HARMONIC SUPPRESSION IN ULTRASOUND PASSIVE CAVITATION DETECTION

Manu K. S., Ravi S. Hegde, Himanshu Shekhar

Department of Electrical Engineering, Indian Institute of Technology Gandhinagar, Gandhinagar, India

Background, Motivation and Objective

Passive monitoring of microbubble activity during cavitation-based therapy is important for treatment monitoring and to avoid undesirable tissue damage. However, bubble-specific cavitation signals in the passively received echoes can be obscured by strong tissue scattering at the fundamental frequency. Bubblespecific signals can be orders of magnitude weaker than the fundamental signals, and hence, the acquisition system's dynamic range can be compromised, leading to poor sensitivity. To overcome this challenge, this work aims to evaluate the performance of a phononic crystal (PnC) filter, a class of acoustic metamaterials, for suppressing the fundamental signal and the second harmonic to enhance the detection of subharmonic signatures.

Statement of Contribution/Methods

A stainless steel-water PnC-based metamaterial filter was designed and optimized using finite element modeling in COMSOL Multiphysics to create band gaps at 1 MHz (fundamental) and 2 MHz (second harmonic). The filters were then additively manufactured by Direct Metal Laser Sintering in eight- and tenlayer configurations (Fig. 1a). Their frequency response was characterized through immersion measurements using a broadband transducer. Cavitation signals were passively recorded during ultrasound exposure of SonoVue microbubbles (1 MHz, 50 cycles). Excitation pressure was varied from 30 to 307 kPa peak rarefactional pressure, and cavitation thresholds were determined from five fresh vials with and without the filter.

Results/Discussion

The measured transmission spectrum showed an average bandgap depth of -48 dB and -52 dB for 8- and 10layer PnCs at the fundamental (1 MHz). The corresponding depths at the second-harmonic frequency (2 MHz) were -31 dB and -35 dB (Fig. 1b). Cavitation measurements showed a significant difference ($p=0.022$) in the peak negative pressure threshold for cavitation onset between 10-layer PnC with and without the filter. Specifically, the thresholds for detecting subharmonics were 148 ± 25 kPa with the 10-layer PnC, 178 ± 30 kPa with the 8-layer PnC, and 210 ± 35 kPa without the PnC (Fig. 1c). The error bars represent calibration uncertainties. In conclusion, the metamaterial filter enhanced sensitivity to subharmonic emissions by suppressing the harmonic signals, enabling more accurate detection of cavitation thresholds.

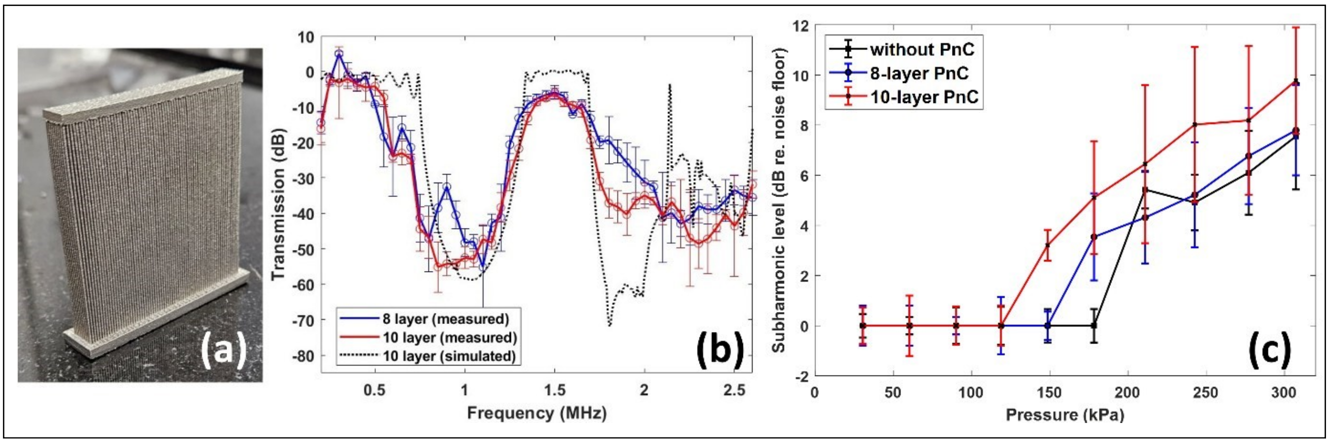


Fig. 1. (a) fabricated 10-layer PnC, (b) transmission spectra of the PnCs, (c) subharmonic level as a function of excitation pressure.

14:00–14:20
TEMPORAL STABILITY OF SONOVUE MICROBUBBLES AND THEIR EFFICIENT USE IN RESEARCH

Katarzyna Sendek, Grzegorz Molak, Łukasz Fura
Institute of Fundamental Technological Research, Polish Academy of Sciences, Warsaw, Poland

Background, Motivation and Objective

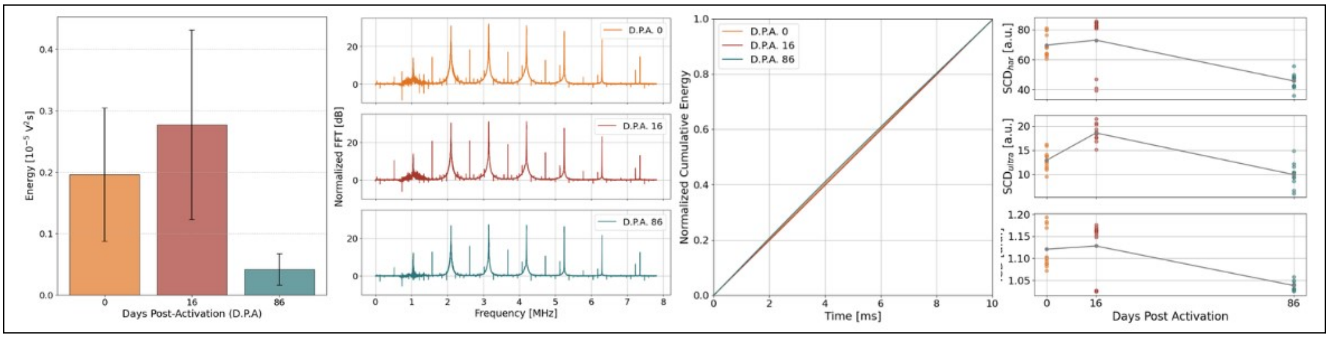
SonoVue microbubbles are widely used as an ultrasound contrast agent in contrast-enhanced ultrasound imaging. More recently, they have been incorporated into emerging transcranial focused ultrasound (tFUS) techniques as a medium of acoustic oscillations during ultrasound blood-brain barrier opening (USBBBO). This rapidly developing field has generated a growing number of preclinical and fundamental studies. However, such experiments remain costly, partly due to the use of microbubbles, whose post-activation stability is limited to approximately 6 h according to the manufacturer. In the present study, we evaluated the stability of microbubbles to support efficient experimental planning and to understand their physicochemical behavior.

Statement of Contribution/Methods

A suspension of SonoVue microbubbles (0.016% v/v) was introduced into a flow circuit aligned with the focal zone of a single-element ultrasound transducer and subjected to acoustic excitation (PNP=600 kPa, f_0=1.05 MHz, PRF=10 Hz, pulse duration=10ms). Acoustic emissions were detected using a 3 MHz matrix array probe (Vermon). Three separate SonoVue vials, activated 0, 16, and 86 days before the experiment, were investigated. For each condition, 12 independently prepared samples were examined, and each sample underwent 80 repeated sonication trials, resulting in 960 measurements per time point.

Results/Discussion

Three quantitative metrics were evaluated: total acoustic energy, normalized cumulative energy, and cavitation dose (SCD_{har}, SCD_{ultra}, ICD). The mean total acoustic energy exhibited an increase of approximately 40% at day 16, followed by a substantial decrease to about 20% of the baseline value by day 86. In contrast the normalized cumulative energy, remained largely consistent across all time points. The ultraharmonic cavitation dose, associated with stable microbubble oscillations, showed a 50% increase at day 16 and subsequently declined to 78% of the initial value at day 86, while remaining measurable. The harmonic cavitation dose also decreased over time, reaching approximately 65% of its baseline level by day 86. SonoVue microbubbles preserved their acoustic activity for at least 16 day, with a marked reduction observed at 86 days. Further investigation at intermediate time points is required to more precisely determine the onset of microbubble destabilization. These observations suggest that, in non-sterile experimental conditions, microbubbles may remain usable for up to 16 days post-activation, which could help reduce material waste associated with partially used vials.



14:20–14:40

IN VITRO CHARACTERIZATION OF ULTRASOUND STIMULATION OF SPECIFIC CELL POPULATIONS IN THE MOUSE AMYGDALA

Nastasia Mirofle[1], Łukasz Bijoch[1], Piotr KarwaT[2], Marcin Lewandowski[2], Paweł Szczypkowski[3], Piotr Wasylczyk[3], Radek Łapkiewicz[3], Anna Beroun[1], Ewelina Knapska[1]

[1]*Nencki-EMBL Center of Excellence for Neural Plasticity and Brain Disorders: BRAINCITY, Warsaw, Poland;* [2] *us4us Ltd., Warsaw, Poland;*
[3] *Faculty of Physics, University of Warsaw, Warsaw, Poland*

Background, Motivation and Objective

This project aims to validate a non-invasive ultrasound stimulation (US) method to modulate *ex vivo* activity of the amygdala in mice. Specifically, we focused on stimulating the central nucleus of the amygdala (CeA), a key brain region involved in emotional and motivational processing that is associated with neurological and psychiatric disorders. Using ultrasound stimulation to target this brain region could enable modulation of neural circuits underlying emotional and motivational impairments characteristic of depression- and addiction-related phenotypes. Even if US is an innovative and recently emerged method which opens translational opportunities, the cellular mechanisms underlying ultrasound brain stimulation are yet unknown and are a focus of much needed research. The main objective of this study was to characterize cellular effects of ultrasound stimulation and its effects in modulating central amygdala activity in mice.

Statement of Contribution/Methods

The effects of the modulation were examined at the cellular level across distinct neuronal populations (expressing Corticotropin-Releasing Factor/Hormone or Somatostatine) within the CeA in an *ex vivo* model. To achieve this, we stimulated acute brain slices that expressed a calcium indicator GCaMP in specific cell populations, and tested different stimulation parameters to identify each cell-type optimal settings.

Results/Discussion

Our preliminary data indicate that the responses to US are cell-type specific. Various parameters, regarding intensity, frequency and amplitude, either activate, inhibit or not impact these cell populations. Given the cellular heterogeneity and complex connectivity of the CeA, this step of establishing a parameter range for cell-type-specific neuromodulation appears essential for future research. Once these stimulation parameters will be identified, we will translate these protocols to *in vivo* stimulations in mice and validate spatial accuracy by using a blood-brain barrier opening approach. We will finally test the US effects observed on cells' activity by combining US to 2-photon imaging, which will allow us to observe the real time activation of these different cell types in the CeA.

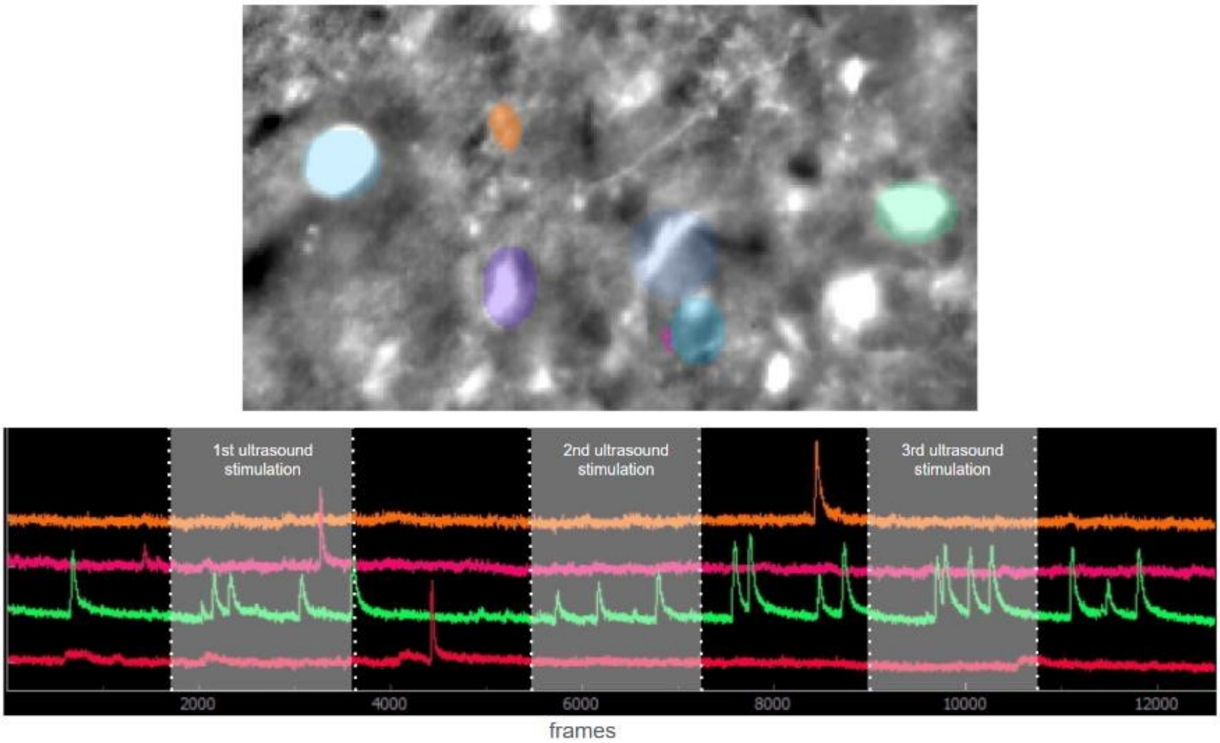


Figure. Different cells activity pattern in response to US .

14:40–15:00
SYSTEM-LEVEL EVALUATION OF HIGH-IMPEDANCE ULTRASOUND TRANSDUCERS ON A COMMERCIAL RESEARCH PLATFORM

Michael Zapf, Zewei Lu, Ian Andree, Luisa Gupta, Nicole Ruiter
Institute for Data Processing and Electronics, Karlsruhe Institute of Technology, Germany

Background, Motivation and Objective

High-impedance ultrasound transducers are employed in miniaturized and application-specific probe designs, where geometric scaling inherently reduces element capacitance and elevates electrical impedance. Conventional impedance-matching strategies are typically optimized around a single resonance frequency and are therefore difficult to extend to broadband operation. The system-level behavior of directly interfacing high-impedance transducers with commercial research platforms remains insufficiently characterized.

Statement of Contribution/Methods

A custom ultrasound transducer (minimum impedance 4 kΩ within its operational bandwidth from 0.5 to 5 MHz) was directly connected to a platform developed by US4US, without additional impedance matching. Transmit excitation and receive signal characteristics were experimentally compared across different receive-path termination resistor settings (100, 200, 400 Ω). All measurements were performed in a water-tank setup. The immersed transducers were aligned toward each other at 13 cm. Linear frequency-swept signals covering the operational bandwidth were applied, and the resulting echoes were recorded for analysis.

Results/Discussion

During transmission, the pulser output impedance remains thousands lower than the transducer impedance, leading to negligible degradation of the excitation voltage. In receive mode, the high impedance transducer behaves linearly with all termination resistor settings in frequency domain as shown in Fig. 1. Increasing the termination resistor from 100 Ω to 200 Ω results in a 54.0% increase in amplitude and SNR, followed by an additional 14.9% increase when raised from 200 Ω to 400 Ω across the frequency spectrum. Also, the phase response is well behaving over the chirp's frequencies not leading to significant visible time shifts, see Fig. 2. These results demonstrate that the US4US device can measure signals from high-impedance transducers with sufficient SNR.

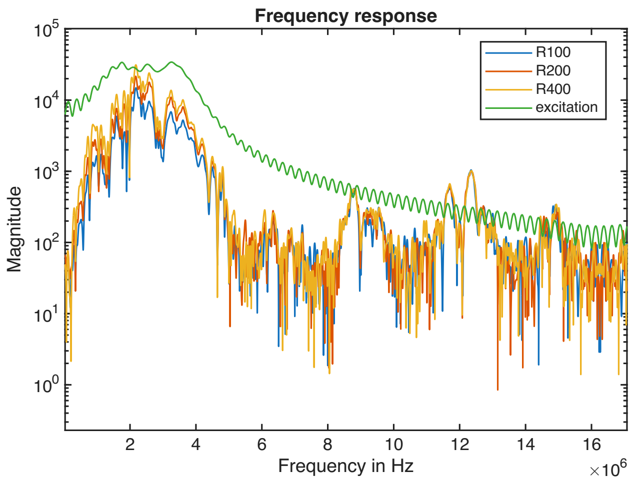


Fig. 1

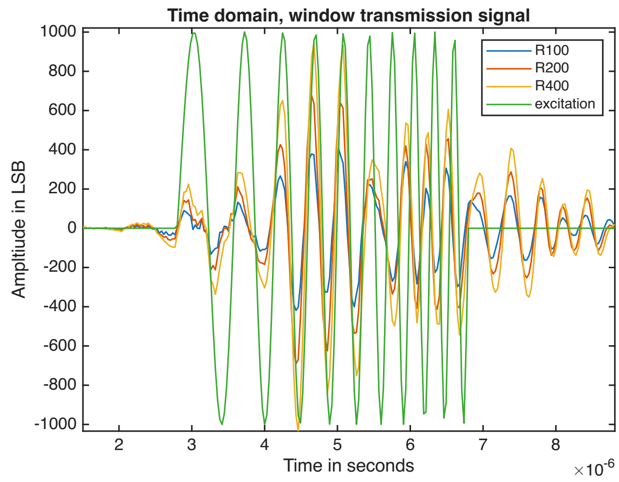


Fig. 2

15:00–15:20
SIMULATION AND CHARACTERIZATION OF A ONE-DIMENSIONAL ULTRASOUND SCANNER BASED ON ALL-SILICON ELECTROSTATIC MUTS

Jorge M. Monsalve, Marcel Jongmanns, Michael Stolz, Sergiu Langa, Sandro G. Koch
Fraunhofer IPMS, Dresden, Germany

Background, Motivation and Objective

Although sonography is a well-established application of ultrasound waves in medicine, airborne ultrasound scanners are not yet in widespread use, although they could find applications in robotics and medicine. This is partly due to the limited availability of ultrasound transducers in the low-frequency range (below 100 kHz) whose size is below half the wavelength. At Fraunhofer IPMS, we have developed an all-silicon electrostatic MUT that meets this condition and can be used to build a one- or two-dimensional array whose radiation pattern can be rotated by introducing time delays. In this work, we present the performance of a one-dimensional array and compare it against raytracing simulations.

Statement of Contribution/Methods

Our one-dimensional array consists of 8 MUTs placed side by side, each of which has a side length of 4 mm, meeting the λ/2 condition at 42 kHz. A MEMS-microphone (Knowles® SPH0141LM4H-1) is placed in the middle of the array to measure the returning echoes. We reported scanning range of ± 45° in a previous work. In this work, we perform a raytracing simulation, considering both specular reflections and scattering, to predict the echoes that would be reflected by different kinds of objects in the scanned environment. By comparing the measured echoes against these simulations, we can gain knowledge to distinguish between different kinds of reflector geometries and surfaces.

Results/Discussion

The present research is a work-in-progress. A simulation script has already been coded and is capable of computing the radiation pattern of the array and the specular reflections of an arbitrary set of objects in the proximity of the scanner. Following steps include the simulation of scattering and the comparison with experiments.

Oral session 3

15:40–16:00
HIGHLY FLEXIBLE GRAPHENE-BASED ULTRASOUND TRANSDUCER WITH ENHANCED ACOUSTIC PERFORMANCE

Shirin Movaghgharnezhad, Ehsan Ansari, Spencer Hagen, Clayton Baker, Parag Chitnis

Department of Bioengineering, George Mason University, Fairfax, VA, USA

Background, Motivation and Objective

Traditional ultrasound transducers (USTs) are designed for hand-held use and made of rigid piezoelectric ceramics, which are not suitable for wearable applications and chronic monitoring. This need for producing a new class of wearable and flexible USTs can be met by integrating piezopolymers with graphene, which has outstanding mechanical strength, flexibility, and electrical conductivity.

Statement of Contribution/Methods

We present a novel approach for fabricating UST patches using laser photothermal patterning of graphene electrodes on flexible polyimide substrates and additive manufacturing through 3D printing with Polyvinylidene fluoride-trifluoroethylene (PVDF-TrFE) ink. Fabrication steps include corona poling, gold sputter-coating of the ground electrode, and parylene-film deposition for device passivation, resulting in a UST patch with a 75 mm thick piezo-active element. Acoustic properties were characterized using a calibrated hydrophone, pulse-echo measurements, and an imaging phantom.

Results/Discussion

Graphene-based ultrasound transducer demonstrates a high signal amplitude of 6.59 V and a signal-to-noise ratio of 433, along with a −6 dB bandwidth of 8.86 MHz (37%). Deposition of PVDF could be tuned to achieve a center frequency ranging from 10 MHz to 28 MHz. A high-quality two-dimensional ultrasound image, including a B-mode image of a cyst phantom, was produced with graphene-based UST, which is comparable to one obtained by the clinical system. To demonstrate the versatility of our approach, we fabricated graphene-based USTs of different geometries and configurations, which included a single circular element 3.5 mm in diameter, an M-shaped UST 7-mm across, a dual-element Doppler transducer, and a 32-element array with 400-µm pitch. Patterning of graphene-based electrodes produced the desired sensor configuration with uniform PVDF deposition across the entire device. Hydrophone scans of the M-shaped and Doppler devices reveal that the acoustic fields are well-matched to the geometry of the underlying graphene pattern, which illustrates the suitability of our novel technique for applications requiring special ultrasound geometries. The method is also amenable to producing transducer arrays for B-mode imaging. The production cost of our UST is estimated to be under $5 per unit, making them a low-cost solution for flexible USTs.

16:00–16:20
SIMULATION-DRIVE MULTILAYER ULTRASOUND TRANSDUCER USING XMASON

Sofia Papa[1], Christoph Leitner[2], Laura Ferrari[1], Luca Benini[2,3], Francesco Greco[1]

[1] BioRobotics Institute, School of Advanced Studies Sant'Anna, Italy; [2] Department of Information Technology and Electrical Engineering, ETH, Zurich, Switzerland; [3] DEI, University of Bologna, Bologna, Italy

Background, Motivation and Objective

Piezoelectric ultrasonic transducers convert electrical signals into acoustic waves and *vice versa* and are widely used in medical and non-destructive applications. Single-layer actuators provide only micrometer-scale displacements under high electric fields, thus they are not effective in high-force or large-actuation scenarios. Multilayer piezoelectric stacks overcome this by combining thin layers to achieve higher displacement, force, and lower driving voltages [1]. However, their design requires careful optimization of geometrical and material parameters, including active layers as well as matching and backing materials, which affect acoustic coupling, bandwidth, and losses. While these layers are easily implemented in bulk PZT devices, they become more challenging in thin-layer or polymer-based structures, making predictive modeling essential for efficient design [2].

Statement of Contribution/Methods

Piezoelectric ultrasonic transducers are commonly modeled using finite element analysis (FEA) or equivalent circuit models. FEA enables accurate characterization of electrical and acoustic behavior in complex two- or three-dimensional geometries but is computationally intensive. In contrast, compact equivalent circuit models are faster and more efficient, though typically limited to one-dimensional representations. Classical approaches, such as Mason and KLM, accurately describe single-element devices but do not capture coupling effects in multilayer structures. To overcome this limitation, the xMasonV2 model [3] provides an open-source framework for cascaded transducers, enabling prediction of resonance behavior in multilayer devices, including the effects of polarization and matching/backing layers. This work presents a step-by-step design procedure using xMasonV2 for the development of a two-layer lead zirconate titanate (PZT) ultrasound transducer.

Results/Discussion

An ultrasound transducer with a diameter of 10 mm is designed using two PZT active layers, each 500 µm thick, and a 325 µm Nylon matching layer. A step-by-step simulation of the electrical behavior is implemented both through a user-friendly interface, and with configurations defined via YAML-based batch simulation. The model predicts a resonance frequency of 2 MHz for the designed transducer, in agreement with the electrical characterization of the device designed in the simulation.

References

[1] Mohith, S., et al. „Recent trends in piezoelectric actuators for precision motion and their applications: A review." *Smart Materials and Structures* 30.1 (2021): 013002.

[2] Yang, Xinyu, et al. „Multi-layer polymer-metal structures for acoustic impedance matching in high-frequency broadband ultrasonic transducers design." *Applied Acoustics* 160 (2020): 107123.

[3] Spisani, Gabriele, et al. "xMasonV2: An Open-Source Model Extension for Cascaded Transducer Arrays." *2025 IEEE International Ultrasonics Symposium (IUS)*. IEEE, 2025.

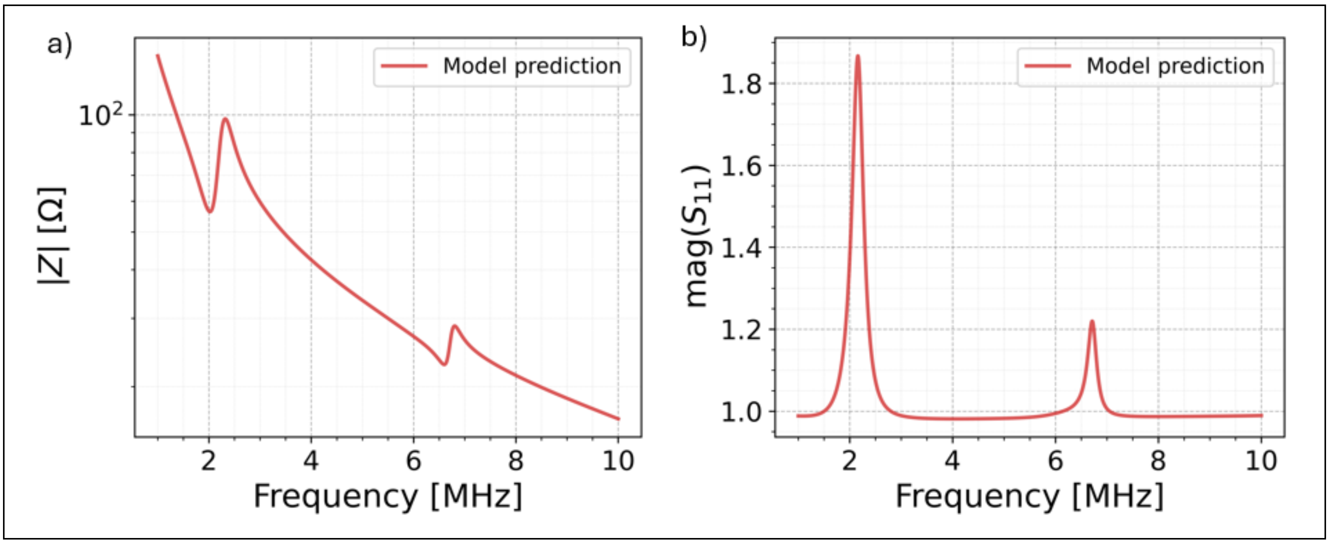


Fig. 1. Plots directly obtained from the simulation of the stack transducer (a) impedance and (b) S11 parameter.

16:20–16:40
HIGHLY SENSITIVE BROADBAND ULTRASONIC HYDROPHONES BASED ON CMUTS

Uwe Völz, Marco Kircher, Sören Köble
Fraunhofer Institute for Photonic Microsystems (IPMS), Dresden, Germany

Background, Motivation and Objective

Capacitive Micromachined Ultrasonic Transducers (CMUTs) are characterized by a high sensitivity in receiving and a wide bandwidth based on their physical properties. Their natural matching to gases or liquids, depending on the mechanical structure, enables a wide range of applications in various areas, such as medical diagnostics and nondestructive testing. The advantages of low manufacturing costs and lead-free construction make it a sustainable alternative to piezoelectric transducers. The in-house developed waterborne CMUTs are optimized for resonance frequencies between 1 and 30 MHz. However, the application as hydrophone needs a high sensitivity also outside of the resonance frequency. To address this area, on the one hand we have extended the bandwidth of the needed preamplifier electronics and on the other hand we have evaluated the currently available CMUTs out of their designed resonance frequency.

Statement of Contribution/Methods

We use a commercially available focused piezoelectric transducer for characterizing the receiving behavior of our waterborne CMUTs. These transducers allow the excitation of extremely short pulses while producing high pressure levels in water and have a wide bandwidth in the range of interest. Fig. 1 presents the comparison of the frequency spectra of our best suited CMUT (red line) and a commercially available piezoelectric hydrophone (blue line).

Results/Discussion

We can show that our broadband CMUTs – in combination with another ultrasound emitter, such as a piezoelectric transducer or a photoacoustic source – can be used as highly sensitive ultrasonic hydrophones in a wide frequency range. The result, presented in Fig. 1, shows an useable -6dB bandwidth from 0.5 to 30 MHz. Hence our waterborne CMUTs are a cost-efficient alternative to other hydrophones which are working in the same frequency range.

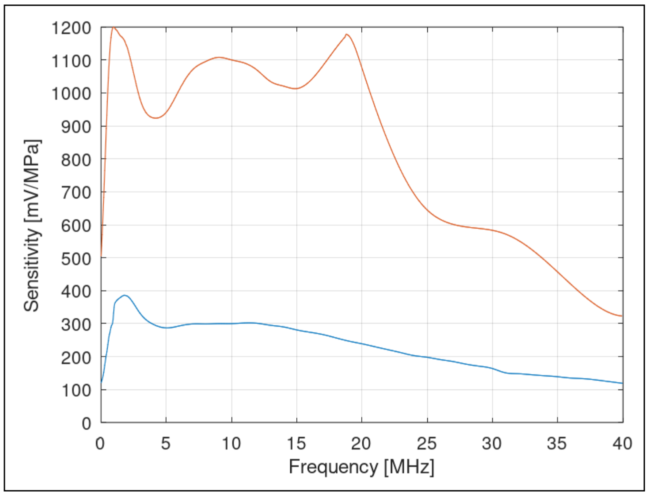


Fig. 1. Frequency Spectra of the Hydrophones; Red: CMUT-Hydrophone 0.5x0.5mm², 250Pa NEP; Blue: Commercially available Piezo-Hydrophone Æ 0.5mm, 200Pa NEP (NH0500 from Precision Acoustics Ltd.).

TRACK MEDICAL

23 June 2026, Tuesday

Oral session 1

11:40–12:40
THERANOSTIC OXYGEN–PERFLUOROCARBON NANOBUBBLES FOR ENHANCED ULTRASOUND IMAGING AND TUMOR OXYGENATION

Bartosz Płóciennik[1,2], Andrzej Zając[1], Aleksandra Bienia[1,2], Agnieszka Drzał[1], Theresa Kosmides[3], Agata Exner[3], Martyna Elas[1]

[1] Department of Biophysics and Cancer Biology, Faculty of Biochemistry, Biophysics and Biotechnology, Jagiellonian University, Cracow, Poland; [2] Doctoral School of Exact and Natural Sciences, Faculty of Biochemistry, Biophysics and Biotechnology, Jagiellonian University, Cracow, Poland; [3] Laboratory of Image-guided Therapeutics, Case Western Reserve University, Ohio, USA

Background, Motivation and Objective

Tumor hypoxia remains a major limitation of anticancer therapies, while accurate ultrasound (US) imaging of tumors is critical for diagnosis and therapy guidance. Lipid nanobubbles filled with gas can serve as effective US contrast agents, while also enabling localized oxygen delivery. This study aims to develop and evaluate nanobubbles with tunable oxygen–perfluorocarbon gas cores, focusing on their ultrasound contrast performance, stability, and *in vivo* imaging efficiency in tumor models.

Statement of Contribution/Methods

Lipid nanobubbles with varying oxygen/perfluoropropane (C3F8) ratios were synthesized and characterized in terms of size and stability using dynamic light scattering. Acoustic performance and stability were evaluated in agarose phantoms under ultrasound exposure. In vivo imaging was performed in an orthotopic 4T1 breast cancer model in Balb/c mice following intravenous administration. Contrast enhancement kinetics were assessed using contrast-mode ultrasound, and tumor vascularization was analyzed using Power Doppler imaging. Tumor oxygenation was evaluated using EPR oximetry.

Results/Discussion

Nanobubbles exhibited diameters in the range of 200–400 nm, with increasing perfluorocarbon content improving stability and circulation persistence. In agarose phantoms, all formulations provided measurable ultrasound contrast, with mixed gas compositions (10–25% C3F8) offering an optimal balance between signal intensity and stability. *In vivo*, nanobubbles enabled significant tumor contrast enhancement, with distinct signal kinetics depending on gas composition. Power Doppler imaging revealed improved visualization of tumor vascularization following nanobubble administration. Oxygen-containing formulations induced a measurable, though moderate, increase in tumor oxygenation after ultrasound-triggered cavitation, supporting their theranostic functionality.

12:00–12:20
A NOVEL ULTRASOUND-BASED METHOD FOR MUSCLE VISCOELASTIC PARAMETERS ASSESSMENT

Jan Łusakowski-Milencki, Szymon Cygan, Jakub Żmigrodzki

Warsaw University of Technology, Institute of Metrology and Biomedical Engineering, Warsaw, Poland

Background, Motivation and Objective

The estimation of muscle mechanical parameters values is of growing interest in recent years. Most of proposed methods are based on Shear Wave Elastography or Muscle Dynamic Response. However there has not been a proposed objective, operator-independent method for assessing muscle stiffness or viscoelastic parameters based on large muscle deformations caused by external pressure measured with Strain Elastography. This approach offers new opportunities to study the nonlinearity of muscle mechanics and facilitates the examination of different ROIs sizes, potentially enabling the detection of local pathological changes. This abstract present a proof of concept of this approach.

Statement of Contribution/Methods

The proposed method is an extension of the method for skeletal muscle stiffness assessment (patent no

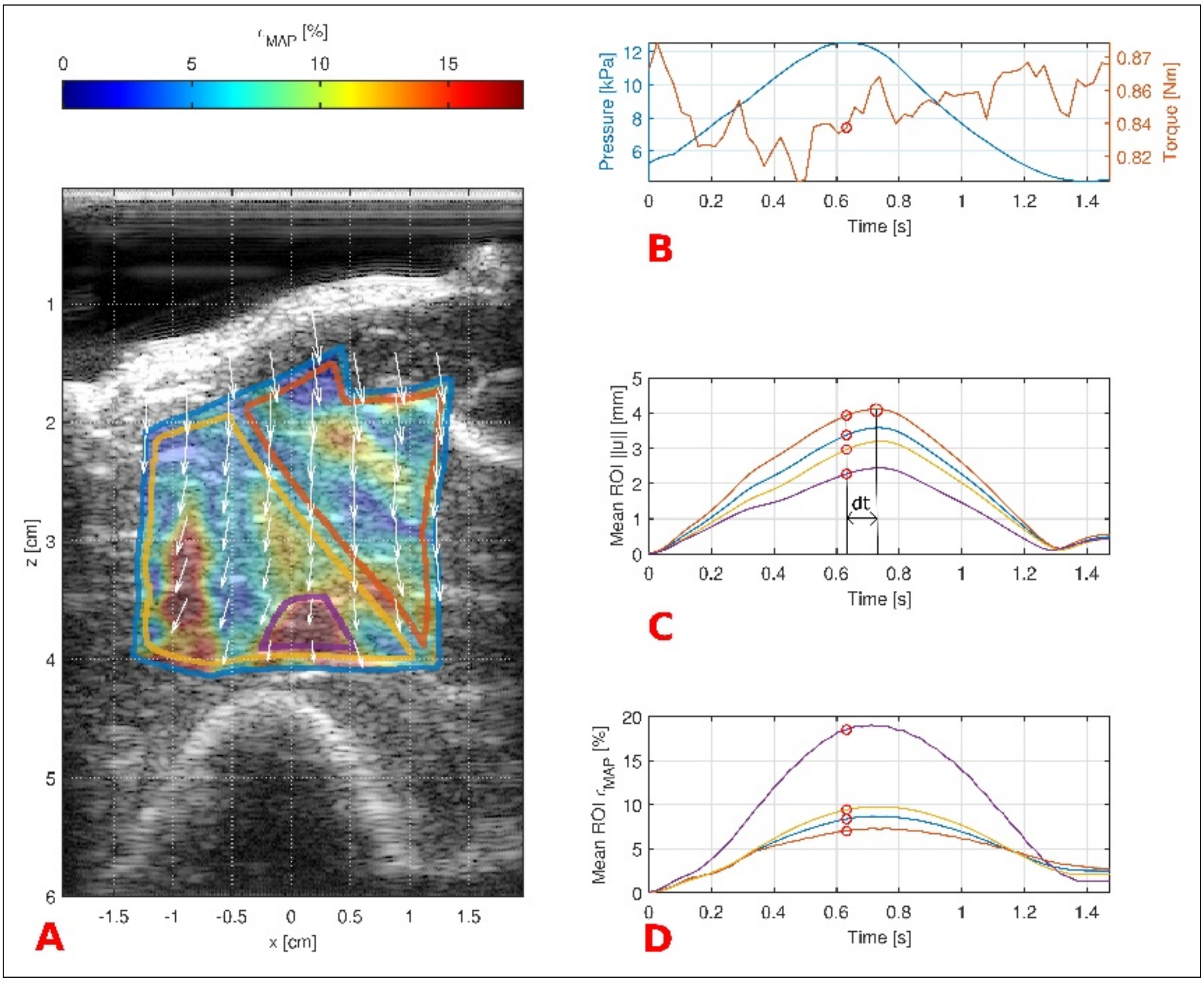
430692). The system consists of an ultrasound scanner, a soft, non-elastic cuff for applying a pressure load, a pressure sensor and a force sensor for measuring the force generated by the examined muscle. Using speckle-tracking elastography, the deformation of the muscle of interest were measured. By comparing the waveforms of mean deformation and pressure in the cuff, the time delay in the selected ROI were determined, providing viscoelastic characterisation of the muscle.

Conceptualization: JŻ, SC, JŁM; Methodology: JŻ, SC, JŁM; Software: JŻ; Formal analysis and investigation: JŻ, SC, JŁM; Supervision: JŻ.

Results/Discussion

The figure below presents the result of an examination of a relaxed muscle under time-varying external pressure applied via the cuff. The left panel shows a B-mode ultrasound image with three ROIs covering both examined muscles and a blood vessel. Strain maps are colour-coded within those ROIs, and the arrows indicate the direction of tissue displacement. A 16-degree phase delay was observed between pressure and deformation which is consistent with published results. [1]

[1] Kobayashi et al. "Non-minimum phase viscoelastic properties of soft biological tissues" 2020.



External pressure is applied to a relaxed muscle. Ultrasound image data with εMAP map in colour on the ROI (left). Time evolutions of registered and calculated quantities (right). Chart C shows the time delay between peak pressure and peak displacement.

12:20–12:40

SEISMIC PROJECT — SEAMLESS INTEGRATION OF IMAGE GUIDANCE TO BREAK DOWN THE BARRIERS AND ENHANCE THE EFFICIENCY OF MINIMALLY INVASIVE AND HYBRID NEUROSURGICAL CARE

Marcin Lewandowski[1], Pieter Kruizinga[2], Jason Voorneveld[2]

[1] us4us Ltd, Warsaw, Poland; [2] Erasmus University Medical Center, Rotterdam, Netherlands

Background, Motivation and Objective

SEISMIC (SEamless Integration of image guidance to break down the barrierS and enhance the efficiency of Minimally Invasive and hybrid neurosurgical Care) is an innovative medical R&D project aimed at revolutionizing neurosurgical care by integrating advanced medical imaging technologies with minimally invasive surgical techniques. While minimally invasive approaches are increasingly adopted across surgical specialties, neurosurgery remains dominated by traditional open procedures requiring large cranial openings, resulting in elevated risks of complications including brain damage, infections, poor cosmetic outcomes, and reduced quality of life. The project targets three critical neurological conditions requiring surgical intervention: intracerebral hemorrhage (ICH), chronic subdural hematoma (cSDH), and brain tumors. For ICH, SEISMIC explores imagingguided placement of small drainage devices through minimal skull openings to precisely remove deep brain bleeds while preserving healthy tissue. Regarding cSDH, the team investigates combining bleed drainage with middle meningeal artery blocking—a significant advancement given that 30% of patients experience postsurgical bleeding recurrence. For brain tumor diagnosis, SEISMIC addresses the blood-brain barrier (BBB) challenge by developing methods to inject microbubbles activated by focused ultrasound, temporarily opening the BBB to allow tumor markers into the bloodstream for blood-based diagnosis, potentially eliminating the need for surgical biopsies. Additionally, the project assesses cryoablation—using extreme cold to destroy tumors—inserted via small skull openings and guided by X-ray and ultrasound imaging. All four procedures will undergo clinical trials evaluating effectiveness, operational efficiency, economic viability, and real-world scalability. The initiative also addresses current barriers to imaging integration, including equipment size, lengthy setup times, and extensive training requirements, by developing innovations in ultrasound and X-ray imaging technologies. Ultimately, SEISMIC aims to dramatically reduce open brain surgery requirements, improving patient outcomes, shortening recovery times, and minimizing complication risks across these three neurological conditions.

Statement of Contribution/Methods

We are going to implement real-time feedback during neurosurgical interventions by leveraging ultrafast ultrasound technology. This initiative is powered by the latest ultrasound research systems, specifically the programmable us4R and us4R-lite platforms (us4us, Poland), coupled with a dedicated active matrix-array probe (Oldelft Ultrasound, Netherlands) featuring a built-in micro-beamformer. Our methodology focuses on developing and testing Ultrafast Doppler Ultrasound to enable high-sensitivity micro-flow visualization, alongside high-resolution B-mode imaging. Furthermore, we will integrate Functional Ultrasound Imaging (fUS), which utilizes neurovascular coupling—the physiological principle that neural activity triggers localized blood flow changes—to non-invasively infer neural activity in real-time. These advanced imaging modes will be rigorously validated *in-vitro* by the BrainEcho Lab (Erasmus MC, Netherlands) using custom-built ultrasound brain vascular models, establishing a robust framework for nextgeneration intraoperative image guidance.

Oral session 2

13:40–14:00

ECHOCARDIOGRAPHY IN EXPERIMENTAL MODELS OF CARDIOVASCULAR DISEASES – EXPERIENCE IN POLAND

Tymoteusz Żera

Faculty of Medicine, Medical University of Warsaw, Poland

Abstract missing.

14:00–14:20
ULTRASOUND IMAGING OF THE MOUSE HEART – FROM 2D TO 4D WITH PHYSIOLOGICAL GATING

Agnieszka Zimna[1], Natalia Rozwadowska[1], Tomasz Kolanowski[2]

[1] Instytut Genetyki Człowieka PAN Zakład Patologii Molekularnej, Poznań, Poland; [2] Instytut Genetyki Człowieka PAN Zakład Zaawansowanych Terapii Biomedycznych i Niepłodności, Poznań, Poland

Background, Motivation and Objective/ Statement of Contribution/Methods

Why Do We Need 3D and 4D Ultrasound Imaging in Murine Cardiology?

Ultrasound imaging is a cornerstone of preclinical cardiovascular research, particularly in murine models of cardiac disease. While conventional two- dimensional (2D) echocardiography provides excellent temporal resolution, it remains limited in capturing the full spatial complexity of cardiac motion. Advances in three-dimensional (3D) and four- dimensional (4D) imaging, incorporating time as a dynamic component, now enable more comprehensive assessment of cardiac structure and function. However, the small size and rapid heart rate of mice present major technical challenges. This lecture will discuss how modern ultrasound approaches overcome these limitations and expand the possibilities of functional cardiac imaging in small- animal models.

Results/Discussion

How Can Physiological Gating Improve Detection of Cardiac Pathology?

We present advanced ultrasound imaging approaches combining high-frequency transducers with retrospective and prospective physiological gating based on electrocardiography (ECG) and respiratory signals. Synchronization of image acquisition with cardiac and respiratory cycles reduces motion artifacts and improves spatial- temporal resolution, enabling high-quality visualization throughout the entire cardiac cycle. Beyond assessing basic cardiac function, these techniques allow detection of subtle pathological changes associated with cardiovascular disease. In particular, 3D and 4D ultrasound combined with Tissue Doppler imaging enable visualization of regional wall motion abnormalities and local myocardial dysfunction, while Colour Doppler imaging facilitates identification of microvascular and hemodynamic alterations, including subtle ischemic changes following coronary artery ligation. Together, these methodologies provide powerful tools for studying disease progression and evaluating therapeutic interventions in preclinical cardiovascular research, with future directions focusing on automation and artificial intelligence-based image analysis.

Finacial Support: „CARDIOPRINT- Cardiac Advanced Regenerative Design Integrating Organic PRINTing/ Rozwój zaawansowanej konstrukcji tkankowej w celach naprawy uszkodzonego mięśnia sercowego z wykorzystaniem biodruku" - 2024/ABM/03/KPO/KPOD.07.07-IW.07-0091/24.

14:20–14:40
INTRACARDIAC ECHOCARDIOGRAPHY IN INTERVENTIONAL CARDIOLOGY

Michał Marchel

Medical University of Warsaw, Warsaw, Poland

Abstract missing.

14:40–15:00
PATHOPHYSIOLOGY OF CARDIAC SHUNTS – PRACTICAL APPLICATION OF ULTRASOUNDS

Małgorzata Wojciechowska

Medical University of Warsaw, Warsaw, Poland

Abstract missing.

15:00–15:20
BEYOND STANDARD ECHOCARDIOGRAPHY - MULTIMODAL IMAGING OF THE HEART IN CLINICAL SETTINGS

Agnieszka Kołodzińska
Medical University of Warsaw, Warsaw, Poland

Abstract missing.

Oral session 3

15:40–16:00
CAN ULTRASOUND GEOMETRY DIFFERENTIATE FOLLICULAR THYROID TUMORS?

Hanna Piotrzkwska-Wróblewska[1], Agnieszka Żyłka[2], Katarzyna Dobruch-Sobczak[2], Jerzy Litniewski[1]
[1] Institute of Fundamental Technological Research PAS, Warsaw, Poland; [2] Maria Sklodowska-Curie National Research Institute of Oncology, Warsaw, Poland

Background, Motivation and Objective

Diagnosis of follicular-derived thyroid lesions using ultrasound remains a significant clinical challenge. Risk stratification systems such as TI-RADS effectively identify features typical of papillary thyroid carcinoma but have limited ability to differentiate follicular-pattern lesions. Even fine-needle aspiration biopsy is often inconclusive in these tumors, frequently leading to unnecessary surgery. The aim of this study was to evaluate whether hierarchical quantitative ultrasound analysis can improve differentiation of follicular-derived thyroid lesions.

Statement of Contribution/Methods

A retrospective study included 171 histopathologically confirmed thyroid nodules (342 B-mode images). Quantitative analysis was performed using a hierarchical framework reflecting sequential clinical decision questions. Features describing global lesion morphology, local boundary complexity, and internal signal microarchitecture were extracted, including shape descriptors, local contour irregularity metrics, and intensity and texture-based parameters.

Results/Discussion

The strongest discrimination between follicular adenomas (FA) and malignant lesions (Stage I) was observed for the global shape descriptor perimeter-to-area ratio (P/A), which showed the highest diagnostic performance in differentiating FA and FTC (AUC=0.827). In the overall comparison of FA and malignant tumors, significant differences were also observed for solidity and P/A, indicating increased contour irregularity and loss of convexity in malignant lesions. In the Stage II analysis, focused on follicular-pattern tumors potentially associated with capsular invasion, local boundary complexity metrics provided additional diagnostic value. Both LocalPA_med (AUC=0.784) and KinkCount (AUC=0.793) were significantly associated with malignant follicular-pattern lesions, suggesting that focal contour irregularities may reflect microscopic capsular invasion. In Stage III, parameters describing internal signal microarchitecture improved differentiation between papillary thyroid carcinoma and follicular-pattern malignancies. In particular, Kullback–Leibler divergence (AUC=0.771) demonstrated the strongest discriminative ability among the analyzed microarchitectural features. These findings suggest that combining multiple quantitative features may improve the diagnostic performance of ultrasound-based models for differentiating follicular thyroid lesions.

16:00–16:20

FROM 2D TO 3D: ULTRASOUND-BASED RECONSTRUCTION OF MURINE TUMOR VOLUME AND CROSS-SECTIONAL VALIDATION ACROSS IMAGING MODALITIES

Weronika Smolak-Dyżewska[1,2], Jerzy Bazak[3], Wiktoria Brandys[3,4], Aleksandra Bienia[2,4], Aleksandra Murzyn[2,4], Bartosz Płóciennik[2,4], Gniewosz Drwięga[3], Julia Kozik[4], Agnieszka Drzał[4], Bartosz Leszczyński[5], Przemysław Spurek[1], Martyna Elas[4], Martyna Krzykawska-Serda[4]

[1] Jagiellonian University, Faculty of Mathematics and Computer Science, Kraków, Poland; [2] Jagiellonian University, Doctoral School of Exact and Natural Sciences, Kraków, Poland; [3] Jagiellonian University, Faculty of Biochemistry, Biophysics and Biotechnology, Department of Computational Biophysics and Bioinformatics, Kraków, Poland; [4] Jagiellonian University, Faculty of Biochemistry, Biophysics and Biotechnology, Department of Biophysics and Cancer Biology, Kraków, Poland; [5] Jagiellonian University, Department of Medical Physics, Kraków, Poland

Background, Motivation and Objective

Accurate longitudinal assessment of tumor burden in murine models remains a major challenge in preclinical oncology, particularly for deep-seated, irregularly shaped, or poorly accessible lesions. Ultrasound offers a rapid and non-invasive alternative, but reliable volumetry requires reconstruction of 3D tumor geometry from serial 2D B-mode images. This study presents a standardized workflow for 3D ultrasound-based tumor reconstruction and evaluates the key sources of error affecting volumetry in preclinical models.

Statement of Contribution/Methods

Murine tumors representing several models and anatomical locations were imaged in vivo using Vevo F2 and Vevo 2100 high-frequency ultrasound systems. The dataset included 21 tumors. Consecutive 2D B-mode slices acquired with a motorized stage at a constant inter-slice spacing of 0.1016 mm were converted into binary masks and stacked into voxelized 3D volumes. Ultrasound-derived volumes were compared with *in vivo* and *ex vivo* caliper measurements, mold-based volume determination, micro-CT, and tumor weight.

Results/Discussion

Volumes reconstructed from sagittal and axial ultrasound stacks generally preserved the same relative ranking of tumor size, indicating internal consistency of the method. In pancreatic tumors, axial and coronal B-mode reconstructions were in overall agreement, with the mean discrepancy between caliper- and ultrasound-derived volumes remaining low. Cross-modal validation further showed that ultrasound-based volumes were of the same order of magnitude as those obtained by micro-CT, ex vivo calipers, mold-based assessment, and tumor weight. The principal volumetric limitations were linked to coarse through-plane sampling, voxel anisotropy, interpolation bias, partial-volume effects, and possible probe-induced tissue deformation. This work demonstrates that ultrasound-based 3D reconstruction provides a practical and shape-agnostic approach to murine tumor volumetry, suitable for longitudinal preclinical studies. The key challenge is not merely tumor detection, but the reliable reconstruction of volume from 2D data.

TRACK NDT

23 June 2026, Tuesday

Keynote 1

11:40–12:40
ULTRASOUND MEETS COMPOSITES: IMAGING DAMAGE, STRUCTURE AND STIFFNESS

Dr. Mathias Kersemans
Ghent University, Ghent, Belgium

Ultrasonic inspection remains the gold standard for non-destructive evaluation of fiber-reinforced polymers in the aerospace industry. However, the full potential of ultrasound for characterizing these complex materials is still far from fully realized. In this talk, we present recent advances in ultrasonic inspection of fiber-reinforced polymers, highlighting how ultrasound data can be leveraged to enable novel imaging modalities. Specifically, we demonstrate: (1) Damage imaging, using statistical time–energy analysis to resolve complex and distributed defects; (2) Structural imaging, employing a tomographic approach to reconstruct the three-dimensional multilayered fiber architecture; (3) Functional imaging, based on inverse methods to identify the anisotropic viscoelastic stiffness tensor. For each imaging modality, the underlying principles are briefly introduced and supported by experimental demonstrations, illustrating the potential of ultrasound as a comprehensive tool for advanced material characterization.

Oral session 1

13:00–13:20
FULL-FIELD IMAGING OF LAMB WAVES IN ANISOTROPIC STRUCTURES

Jakub Spytek, Łukasz Pieczonka
AGH University of Kraków, Kraków, Poland

Background, Motivation and Objective

Full-field imaging of Lamb waves is an emerging non-destructive testing technique that allows for detection and localization of damages. This technique can be effectively applied to the inspection of both homogeneous and multilayered thin-walled components to detect defects such as corrosion and delaminations. However, the inspection of anisotropic structures, such as carbon-fiber reinforced polymer (CFRP) composites, may be challenging due to high attenuation and direction-dependent wave velocity. These features make imaging results difficult to interpret, and the artifacts related to anisotropy often obfuscate damages in the structure.

Statement of Contribution/Methods

In this work, we present an improved version of a well-established local wavenumber estimation (LWE) algorithm, which enables damage detection based on local wavenumbers of Lamb waves propagating in thin-walled components. Due to the dependence of Lamb waves on plate thickness, the wavenumbers vary in locations where damages are present, corresponding to effective thickness reduction. However, the original LWE algorithm is primarily intended for isotropic materials, and its application to anisotropic structures results in significant artifacts. To address this issue, we propose a modified version of LWE in the form of anisotropic LWE (ALWE). The proposed algorithm introduces an improved filtering scheme in the wavenumber domain to adapt the wavenumber estimation procedure to the anisotropy of the structure. These modifications significantly improve the quality of wavenumber maps for damage detection.

Results/Discussion

The effects of ALWE compared to LWE are presented in the figure below. Both results were obtained from full-field Lamb wave simulations of an anisotropic plate with artificial defects. ALWE compensates for direction-dependent wavenumber and produces a more uniform background, significantly improving the visibility of defects (regions with increased wavenumber values).

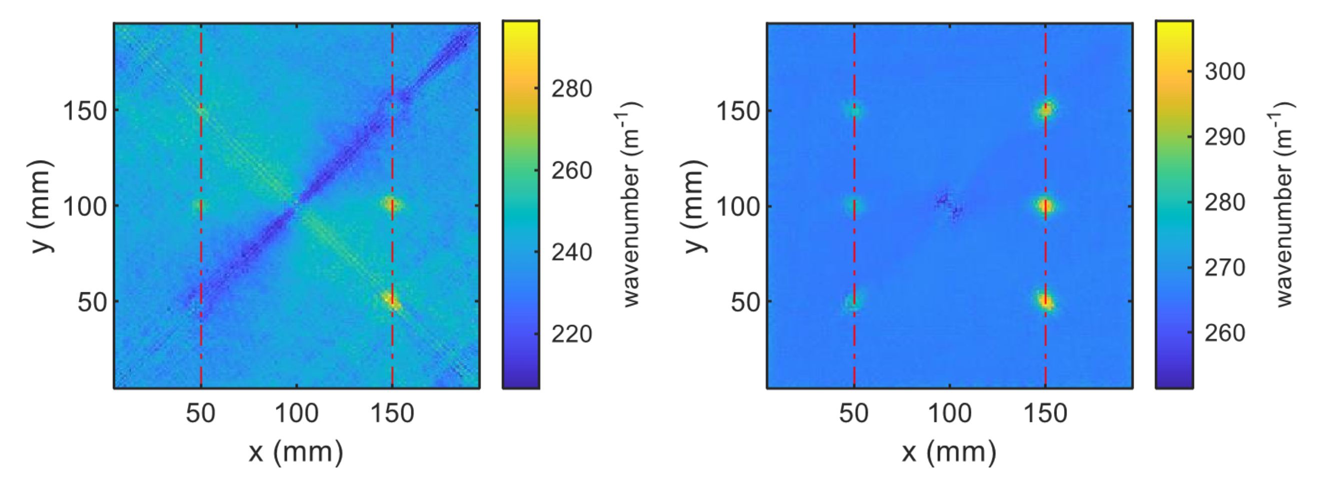


Figure: Map of anisotropic plate obtained using standard LWE (left) and map obtained using modified ALWE algorithm (right).

13:20–13:40

ULTRASONIC INSPECTION OF POLYMER-BASED COMPOSITES BASED ON MULTIMODE APPROACH AND ML

Krzysztof Dragan
Air Force Institute of Technology, Airworthiness Division, Warsaw Poland

Motivation and Objective

Fiber-reinforced composites (FRC's) have become integral to many industries, such as aerospace, automotive, and sports equipment, due to their high specific strength, stiffness, and excellent fatigue properties. While FRC's have many advantages over traditional materials, such as metals, they are also susceptible to structural degradation under high-strain loading conditions, limiting their mechanical performance and leading to catastrophic failure. Therefore, understanding the mechanisms and factors contributing to the structural degradation of FRC's is critical for their continued use in these industries.

Statement of Contribution/Methods

Article will present the data from pulse echo of the inspection of the aerial composite structures. The inspection scope is to detect and monitor the development of failure modes based on the signal and image processing. One of the critical issue is determination of the failure mode presence as well as delivery the quantification tool for damage comparison. That can be achieved with the use of human in the loop expertise together with the trial of ML models based on collected data.

Results/Discussion

Article will present approach for inspection of composite structure with the used of automated and signal processing tools for failure mode quantification. The approach for inspection is based on signal processing methods as well as framework for the use of ML models for damage quantification and evaluation. The aspects of geometry constraints, automatization, structure complexity, precision and quality will be highlighted.

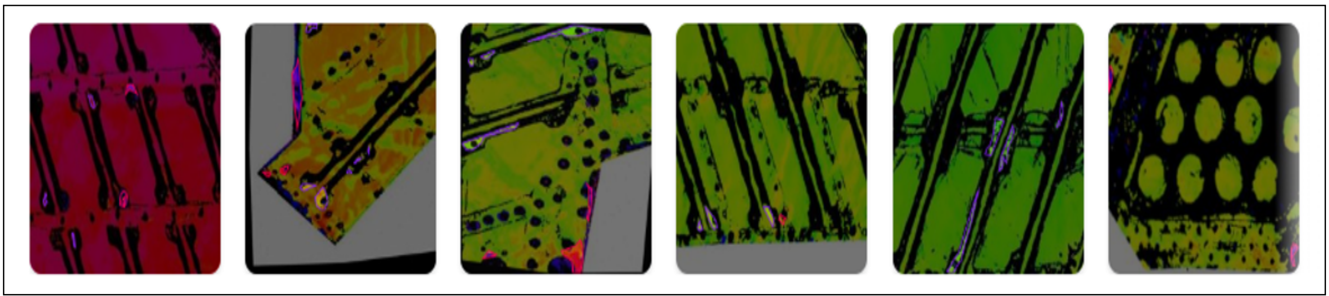


Figure: The C-scan snapshots of the real structure inspection with visible failure modes.

13:20–13:40

3D ULTRASOUND-BASED ASSESSMENT OF POROSITY IN CARBON FIBER REINFORCED POLYMERS

Piotr Karwat[1], Marcin Lewandowski[1], Krzysztof Dragan[2]

[1] us4us Ltd., Warsaw, Poland; [2] Air Force Institute of Technology, Warsaw, Poland

Background, Motivation and Objective

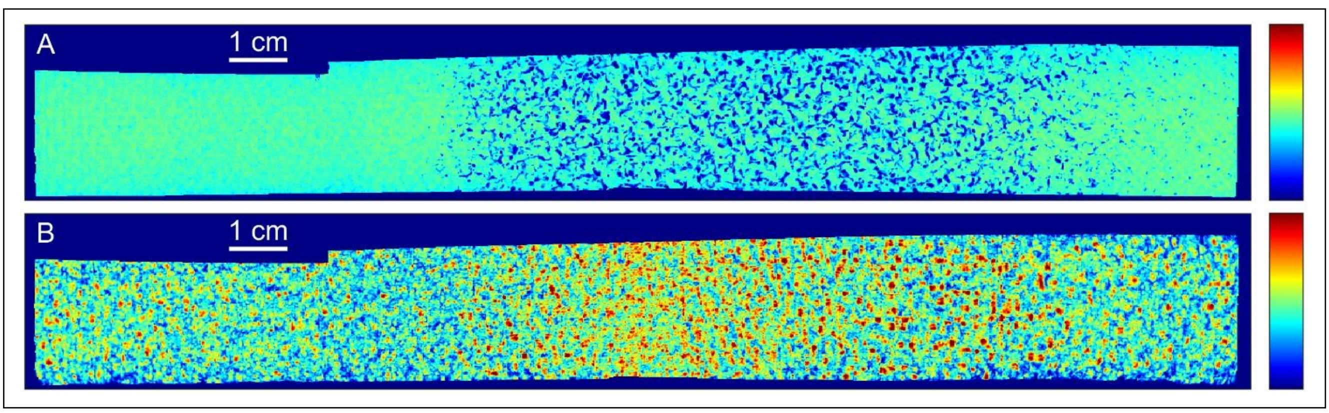
Porosity is one of the most critical manufacturing defects in carbon-fiber-reinforced polymers (CFRP), especially in aerospace applications, where it adversely affects stiffness, strength, and fatigue resistance of the material. Although ultrasonic testing (UT) is routinely employed for porosity assessment, it typically relies on attenuation and scattering metrics, which provide only an indirect, spatially averaged estimate rather than a precise measurement. This limitation is further worsened by the intrinsic anisotropy of CFRP as well as the increasing complexity of component geometry, both of which introduce additional uncertainty into ultrasonic inspections. As a result, conventional UT-based approaches to porosity quantification are inherently imprecise. The present study aims to explore whether ultrasonic techniques can be pushed towards visualization of individual voids, thereby offering a more reliable assessment of porosity and the associated degradation of material properties.

Statement of Contribution/Methods

The study was carried out on 2.2-mm-thick thermoplastic CFRP plates containing regions with porosity of up to 3%. Ultrasonic data were acquired using a us4R-lite research scanner and an Olympus 10M11×11 matrix-array probe. During immersion measurements, the probe was positioned approximately 30 mm above the sample and translated mechanically to enable full coverage of the inspected area. A Full Matrix Capture (FMC) acquisition scheme was employed, and the recorded data were reconstructed using the Total Focusing Method (TFM) with refraction correction based on the pre-reconstructed surface profile of the sample. The use of a 2D array in combination with FMC/TFM and refraction correction was intended to enhance focusing performance to resolve individual voids. The resulting 3D volumetric images were validated against independent reference X-ray computed tomography (CT) measurements.

Results/Discussion

At the macroscopic scale, the area of porosity visible in the reference CT image (Fig. A)—where voids are manifested by lower amplitudes—is also clearly reproduced in the ultrasonic image (Fig. B), where increased reflections from void surface lead to higher amplitudes. At the sub-millimeter scale, some of the voids visible in the CT data are also detected in ultrasonic images, while others remain unresolved. Given the strongly directional response of the applied array elements, which limits TFM performance, the obtained results are promising. They suggest that further improvements—particularly using arrays with reduced directivity—could lead to a more reliable ultrasonic assessment of porosity in CFRP materials.



Carbon Fiber Reinforced Polymer sample with a local porosity of up to 3%, visualized as C-Scans using a) X-ray CT, b) Ultrasound FMC/TFM.

Keynote 2

13:40–14:40
NDE AND SHM ULTRASONIC BASED – REVIEW

Prof. Tadeusz Stepinski
AGH University of Science and Technology, Kraków, Poland

Abstract missing.

Oral sesion 2

15:40–16:00
ADVANCES IN ULTRASONIC INSPECTION OF HIGH-TEMPERATURE HYDROGEN ATTACK USING NUMERICAL SIMULATION

Łukasz Sarniak
Warsaw University of Technology, Faculty of Materials Science and Engineering, Warsaw, Poland

Background, Motivation and Objective

High-temperature hydrogen attack (HTHA) is a critical degradation mechanism affecting carbon and low-alloy steels operating in hydrogen-containing environments at elevated temperatures. The damage process leads to the formation of methane-filled microvoids and decarburization, which may significantly reduce the load-bearing capacity of industrial components such as pressure vessels, reactors and piping. Early detection of HTHA remains challenging because the damage develops as distributed microstructural features that are difficult to detect using conventional nondestructive testing methods. Ultrasonic techniques are widely used in industry for the inspection of components susceptible to HTHA, and significant advances have been made in recent years in both acquisition and data processing methods. The objective of this work is to review and analyze current ultrasonic inspection techniques used for the detection of HTHA and to illustrate their capabilities using numerical simulations.

Statement of Contribution/Methods

The study combines a literature-based analysis of ultrasonic inspection methods with numerical simulations of ultrasonic wave interaction with representative HTHA damage morphologies using CIVA software. The review focuses on techniques commonly applied in industrial practice and research, including conventional ultrasonic testing (UT), phased array ultrasonic testing (PAUT), time-of-flight diffraction (TOFD), advanced ultrasonic backscatter techniques (AUBT), full matrix capture (FMC) and imaging approaches based on the total focusing method (TFM). Numerical simulations are used to illustrate the ultrasonic response of distributed microvoid clusters typical for HTHA damage and to demonstrate the influence of inspection parameters such as frequency, probe configuration and imaging algorithms.

Results/Discussion

The results highlight the capabilities and limitations of different ultrasonic inspection approaches for the detection and characterization of HTHA. Attention is given to the detectability of early-stage damage consisting of distributed microvoids. Numerical simulations provide insight into the interaction between ultrasonic waves and representative HTHA damage structures and help illustrate the expected inspection responses for different inspection configurations. The analysis also identifies current trends in ultrasonic inspection strategies for HTHA, including the increasing use of advanced array techniques and imaging algorithms.

16:00–16:20
CHALLENGES OF MULTI-MODAL LASER ULTRASOUND FOR DAMAGE IMAGING IN METALLIC STRUCTURES

Patrycja Pyzik, Łukasz Ambroziński

AGH University of Krakow, Department of Robotics and Mechatronics, Krakow, Poland

Background, Motivation and Objective

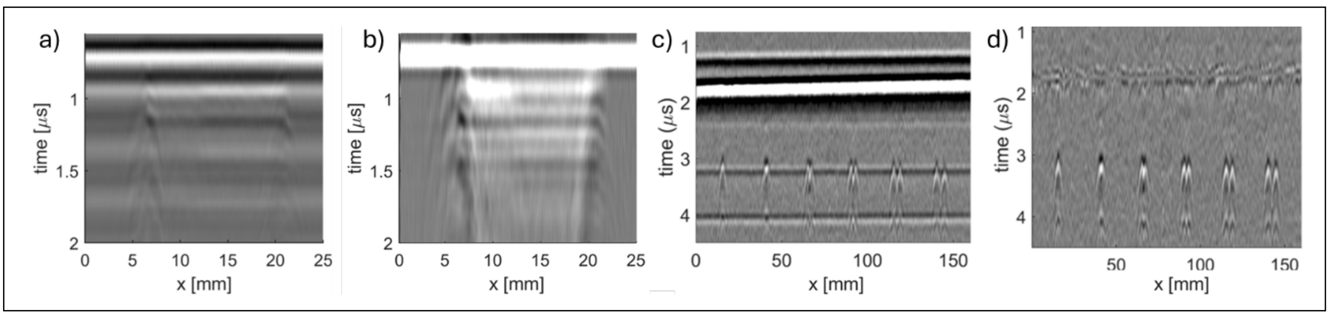
Laser ultrasound techniques benefit from their all-optical non-contact features, which make them attractive for the inspection of adhesively bonded and layered metallic structures. In this context, combining controlled shear-wave generation, optical interferometric detection, and model-based analysis provides a promising route toward more reliable imaging and characterization of disbonds in multilayer joints or defects in tailored welded tin plates. However, the multi-modal nature of laser-generated excitation produces complex wavefields that hinder signal interpretation and damage imaging. This challenge motivates research on signal-processing techniques aimed at suppressing unwanted modes and enhancing defect-sensitive wave components.

Statement of Contribution/Methods

In this paper, the challenges associated with the multi-modal nature of laser-ultrasound generation and detection are addressed and discussed in the context of disbond or weld inspection in multilayer metallic joints. Particular attention is given to the coexistence of several wave modes and their impact on signal interpretation and damage imaging. The contribution focuses on how these limitations can be mitigated through a combination of measurement design, mode-selective analysis, and signal-processing strategies aimed at suppressing unwanted wave components while enhancing defect-sensitive response.

Results/Discussion

The figure below shows examples of spurious-mode suppression in LU-based imaging of metallic structures. Figures (a) and (b) illustrate imaging results for an aluminum bonded sample with a defect at the bonding interface. Panels (a) and (b) show the results before and after surface-wave suppression using inverse filtering, respectively. Figures (c) and (d) illustrate the inspection of tailor-welded blanks. In panel (c), several modes generate coherent noise, which is visible together with a set of reflections from drilled holes. Panel (d) shows the result of spurious-mode removal using a reference filter bank. In the latter image, only reflections from point-like structures remain visible.



16:20–16:40

INTRODUCING THE CIRCULAR PHASED ARRAY ULTRASONIC POLAR SCAN (C-PA-UPS) FOR MATERIAL CHARACTERISATION

Emil Aleksiewicz-Drab[1], Erik Verboven[1], Daniel Speicher[2], Franz Josef Becker[2], Christian Grandinetti[2], Steffen David Weber[2], Martin Benecke[2]; Marc Fournelle[2], Mathias Kersemans[3,4], Koen Van Den Abeele[1]

[1] KU Leuven Campus Kulak, Kortrijk, Belgium; [2] Fraunhofer IBMT, Sulzbach, Germany; [3] Ghent University, Zwijnaarde, Belgium;
[4] FlandersMake@UGent, corelab MIRO, Lommel, Belgium

Background, Motivation and Objective

In a traditional Ultrasonic Polar Scan, single-element transducers are used to measure the specular reflection, transmission or backscattered reflection of a broadband ultrasonic signal sequentially from multiple oblique incidence angle pairs ψ(θ,ϕ) on a hemisphere (θ and ϕ being the out-of-plane and in-plane orientation), all directed towards the same material spot on the surface of a sample. The angle dependent (back-)reflection or transmission amplitudes, displayed in a polar representation, provide a local fingerprint of the visco-elastic properties of the material and its surface characteristics. To improve the performance of the UPS technique in terms of speed, scope and applicability, a new concept for a next-generation UPS device was designed and developed based on Phased Array technology.

Statement of Contribution/Methods

The new design consists of a semi-circular array, populated with 64 transmit/receive on one side and 384 receive elements (12×32) on the other side, capable of sending and receiving signals from all possible directions. The 64 TX/RX elements are directly connected to IBMTs portable 64 channel system (MOUSE). The opposing RX elements are connected to an eight to one multiplexer. This multiplexing scheme allows to shift a block of up to 64 RX channels elementwise over the 384 receivers. Both sides of the arc can be rotated independently from each other about the zenith position. The operational bandwidth is 1.2–2.4 MHz.

Results/Discussion

This configuration optimizes measurement speed by replacing the traditionally used 5 degree mechanical scanning system with electronic controlled multiplexing hardware and software. In addition, it allows to collect extra information arising from bounded beam effects such as non-specular reflection and skewing, or due to scattering by surface corrugations. From a practical point of view, underwater immersion of samples can be eliminated by coupling the array and the sample to a water bag, which allows a more preferred single sided access inspection and results in a compact and portable device fit for in-situ applications. In the present contribution we will comment on the first experiments using the C-PA-UPS to determine the full visco-elasticity tensor and/or surface characteristics of shell-like orthotropic composite material, and compare its performance (speed, accuracy and capabilities) to the traditional measurement technique.

24 June 2026, Wednesday

Keynote 1

11:40–12:40

STUDYING CRYSTAL ACOUSTICS USING LASERS – RECENT PROGRESS

Prof. Hanuś Seiner

Institute of Thermomechanics of the CAS, Praha, Czech Republic

Laser-ultrasonic (LU) methods are experimental techniques utilizing laser beams for generation and detection of ultrasonic waves and vibrations. These methods, thus, enable characterization of mechanical properties of solids without mechanically touching them. During the past two decades, several unique LU experimental arrangements have been developed at the Institute of Thermomechanics, among which LU measurements of anisotropic acoustic properties of single crystals have achieved particular recognition. These approaches allowed us to contribute to developing new alloys for applications ranging from bone implants, over flexible electronics, to space research. The lecture will present two our recent advancements in this direction: reaching Weyl's asymptotic behavior in resonant ultrasound spectroscopy, and detecting ultra-transient oscillations in transient-grating experiments. Both these advancements have close relations to mathematical foundations of elastodynamics. In the former, we observe statistics of several hundreds of experimentally obtained eigenvalues and eigenvectors of an operator representing a freely vibrating single crystal; in the latter, we obtain a direct visualization of Green's function for a hyperbolic differential operator representing elastodynamics of a free surface.

Oral sesion 1

13:00–13:20

AUTOMATED DETECTION OF INTERNAL DEFECTS IN RESISTANCE SPOT WELDS USING SAM AND IMAGE PROCESSING METHODS

Paweł Kustroń, Marcin Korzeniowski

Wroclaw University of Science and Technology, Wroclaw, Poland

The presentation discusses the application of scanning acoustic microscopy (SAM) combined with machine vision techniques for the evaluation of technological parameters and quality of resistance spot welds. Resistance spot welding is widely used in industrial manufacturing, particularly in automotive body construction, where a single vehicle may contain several thousand welds. Ensuring the quality and repeatability of these joints is crucial, as defects such as cracks, voids, lack of fusion, and dimensional irregularities can significantly affect structural integrity and product reliability.

Scanning acoustic microscopy is a non-destructive testing method that uses high-frequency ultrasonic waves to visualize the internal structure of materials. Compared to conventional ultrasonic techniques, SAM enables detailed inspection of thin metal sheets and allows detection of internal discontinuities within welded joints. However, traditional interpretation of C-scan images requires manual evaluation by an operator, which can be time-consuming and prone to subjective errors.

To address these limitations, a machine vision system called Weld Quality Assessment was developed using Aurora Vision Studio software. The system automatically processes C-scan images obtained from SAM measurements and determines geometric parameters of welds, including diameter, shape regularity, and the presence of internal or external imperfections. The developed algorithm uses macrofilters and image preprocessing techniques to identify relevant regions and quantify weld quality indicators.

Experimental validation demonstrated that the proposed approach significantly reduces human involvement while maintaining high accuracy in parameter determination. The system is capable of analysing multiple welds rapidly (e.g., 90 welds in approximately 5.8 seconds), enabling efficient quantitative and qualitative assessment. The results confirm that the integration of scanning acoustic microscopy with machine vision constitutes an effective tool for automated weld inspection and has strong potential for implementation in industrial quality control processes.

13:20–13:40

ULTRASONIC BACKSCATTER COMMUNICATION FOR SENSOR INTEGRATING BOLTS

Dirk Leiacker[1], Peter Oppermann[2], David Riehl[1], Bernd-Christian Renner[2], Klaus Hofmann[1]

[1] Integrated Electronic Systems Lab, TU Darmstadt, Darmstadt, Germany; [2] Institute for Autonomous Cyber-Physical Systems, TUHH, Hamburg, Germany

Background, Motivation and Objective

Embedding sensors into existing or space-constrained machines often requires complex and costly redesigns. Sensor-integrating machine elements (SiMes) address this challenge by embedding sensors and electronics into machine elements while preserving their standardized outer dimensions. A key challenge for these deeply embedded systems is data transfer. Metal casings strongly attenuate electromagnetic waves, making conventional wireless transfer difficult or infeasible. Ultrasonic backscatter communication is an ultra-low-power approach that utilizes the metallic structure as the transmission medium. However, it has only been explored for simple geometries such as walls or pipes. We demonstrate reliable data transfer within the highly complex mechanical geometry of a fully integrated SiMe.

Statement of Contribution/Methods

We integrate a piezoelectric transducer into an M20 bolt while retaining enough cavity space to house an actual sensor. Previous experiments validated the communication hardware on plain steel bars; this work verifies the application through a bolted connection, where thickness and boundaries of the acoustic channel substantially impact transmission efficiency and signal quality. A custom-designed base station is used to transmit a carrier signal on a tuned frequency. Inside the bolt, the transducer is connected to a custom printed circuit board (PCB) equipped with a sensor measuring ambient parameters. To minimize power consumption, the in-bolt circuitry transmits the sensor readings back to the base station utilizing acoustic backscatter communication. A software-defined receiver on an external computer demodulates the data in real time.

Results/Discussion

Sensor data can be transmitted successfully from a transducer inside the bolt to the external receiver through the metal channel shown in Fig. 1. Despite the challenging acoustic path, the backscatter approach maintained a robust and reliable data link. The results confirm ultrasonic transmission as a wireless alternative for deeply embedded SiMes in metal, while avoiding the limitations of electromagnetic waves in metallic environments. Future work will focus on integrating a multi-axial force sensor's data stream and optimizing the carrier frequency to improve both continuous power transfer and communication.

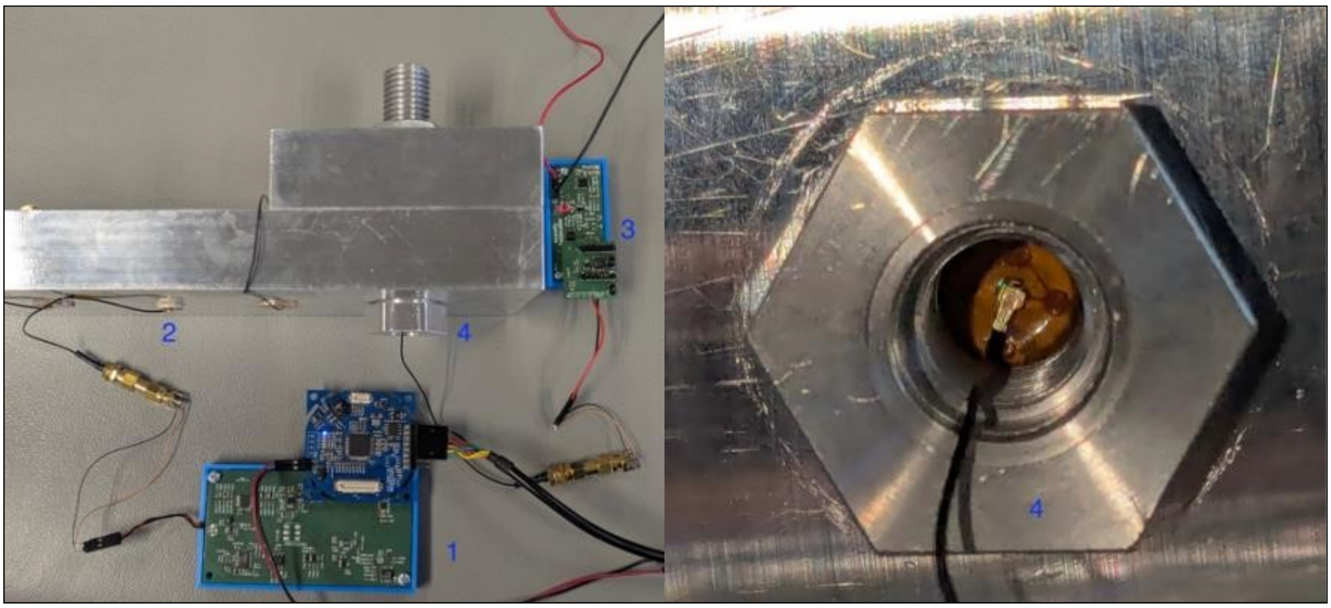


Fig. 1. The implemented setup consists of a base station (1) with transceiver (2) and a tag (3) connected to a piezo transducer mounted inside the M20 bolt (4).

13:40–14:00

HIGH-FREQUENCY ULTRASOUND BARKER CODE IMAGING FOR POWER CHIP MODULE

Yujeong Shin, Sungwoo Kang, Hyeongyu Park, Ilhee Kim, Jin Ho Chang

Department of Electronic Engineering and Computer Science, Daegu Gyeongbuk Institute of Science and Technology (DGIST), Daegu, Republic of Korea

Background, Motivation and Objective

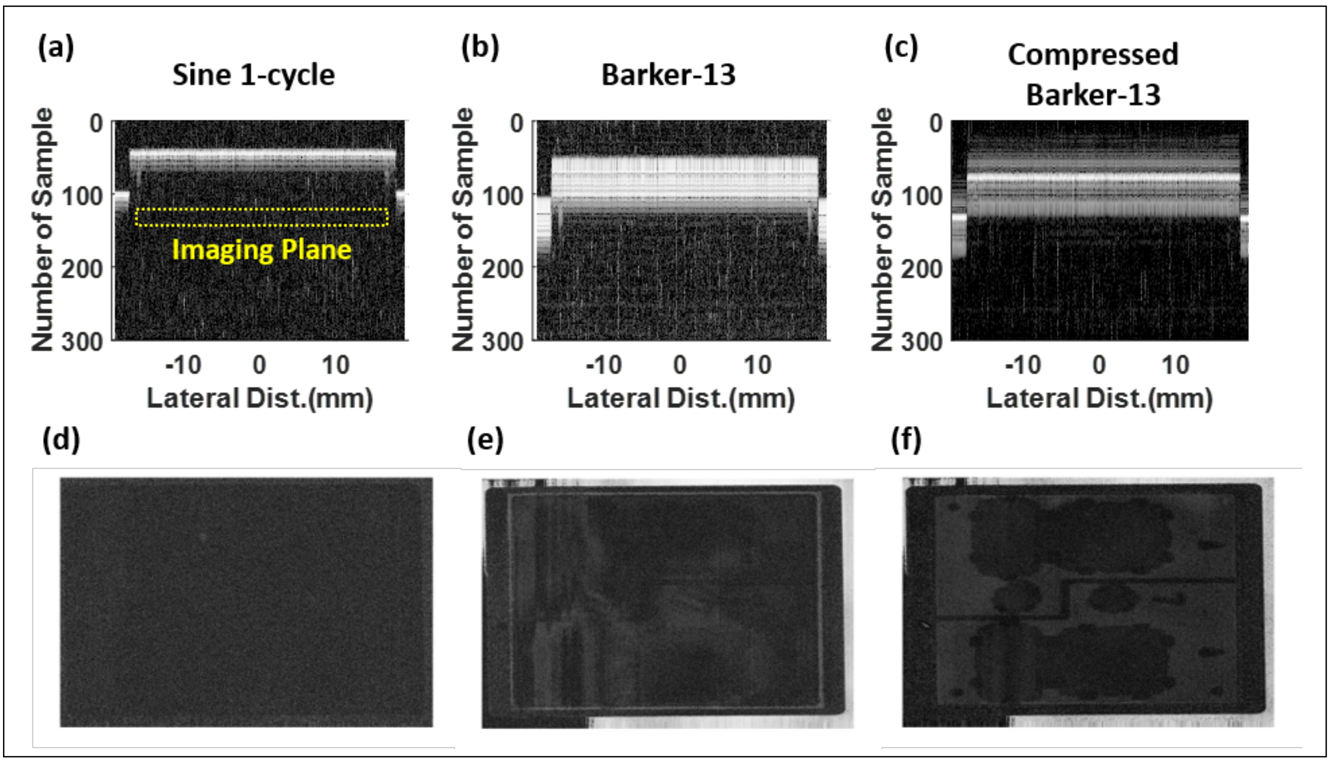
Ultrasound-based non-destructive testing (U-NDT) is a method for inspecting internal patterns and defects in semiconductor devices, such as power chip modules, without causing damage. The resolution of U-NDT imaging is proportional to the operating frequency of the transducer, and it has the advantage of fewer penetration limitations depending on the medium compared to other NDT methods. However, strong reflections from the target surface reduce the signal-to-noise (SNR) of the internal images, which limits the achievable imaging depth. In this study, Barker code transmission, one of the coded excitation, was applied to address the limitation in imaging depth and pulse compression was also performed to maintain axial resolution.

Statement of Contribution/Methods

Ultrasound transducer used in this study was lens-focused at approximately 8 mm and operated at a center frequency of about 50 MHz. The length of the transmitted Barker code was 13, and the sampling frequency was set to 200 MHz, which is four times the operating frequency. The Barker code was generated using an arbitrary waveform generator and then amplified by an amplifier before being applied to the transducer. Image acquisition of the power chip module was controlled using a LabVIEW program, and the signal were received through a pulse-receive system and a 200 MHz sampling Gage card.

Results/Discussion

In the Sine 1-cycle image, the chip pattern is limited due to the degradation of SNR in the depth direction (Fig. d). In contrast, the chip pattern becomes clearly visible in the 13-bit Barker code image after the compression process (Fig. f). Furthermore, the peak value in Fig. a, b and c are 0.552, 0.8175, and 10.0622, respectively, indicating an increase of more than 18 times after compression. The SNR of sine 1-cycle and compressed 13-bit Barker code on the chip surface were measured to be 41.04 dB and 65.91 dB, respectively, and 14.47 dB and 29.74 dB on the chip inner pattern layer.



14:00–14:20

SCREW LENS-FOCUSED ULTRASOUND TRANSDUCER FOR REMOVING LENS INNER NOISE

Sungwoo Kang, Ilhee Kim, Hyeongyu Park, Yujeong Shin, Jin Ho Chang

Department of Electronic Engineering and Computer Science, Daegu Gyeongbuk Institute of Science and Technology (DGIST), Daegu, Republic of Korea

Background, Motivation and Objective

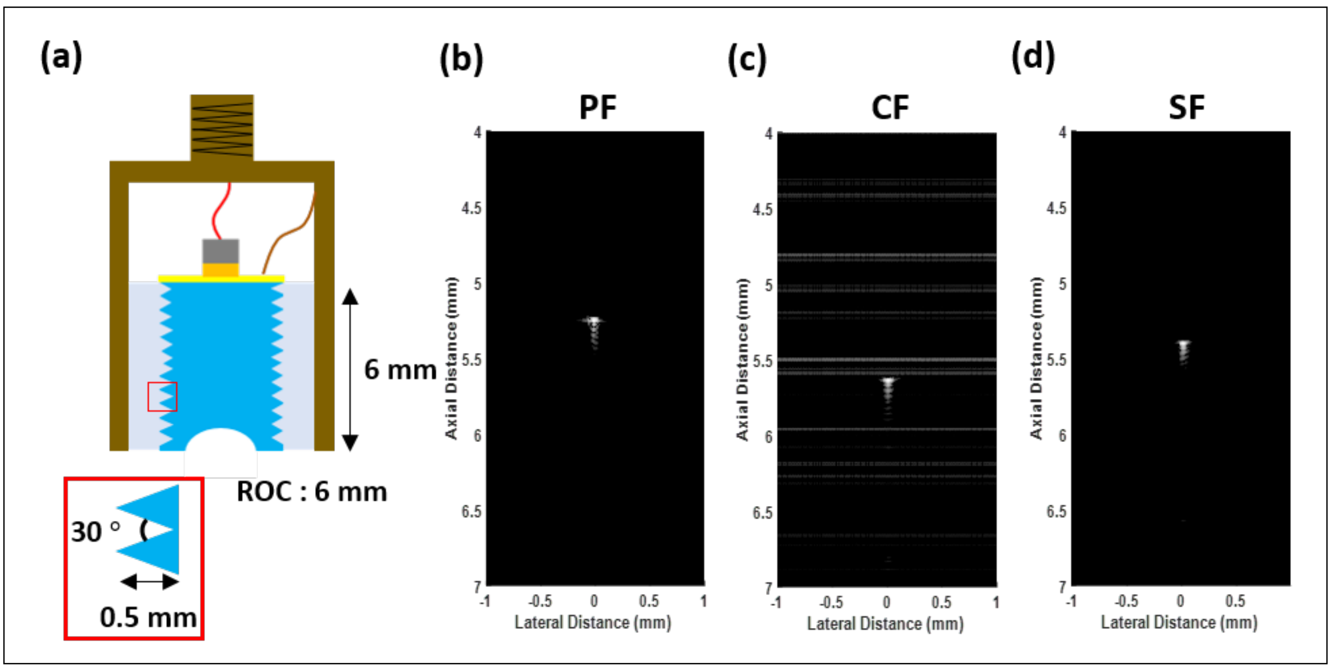
There are two methods for focusing a single-element ultrasound transducer: Press Focusing (PF), which mechanically applies pressure during fabrication, and Lens Focusing (LF), which uses a focused lens. The PF method may damage the piezoelectric layer due to high-temperature pressing and has limitations in fabrication uniformity, making mass production difficult. In contrast, the LF transducer enables more uniform fabrication and high reproducibility, and is therefore widely used in industry. However, ultrasound wave reflections within the lens can generate noise that degrades imaging resolution. In this study we propose a screw lens-focused (SF) transducer with a screw-type side structure to reduce internal reflection noise.

Statement of Contribution/Methods

The SF transducer consists of a quartz lens, a piezoelectric layer, and a backing layer, as shown in Figure. a. The quartz lens was designed with a thickness of 6 mm and a radius of curvature (ROC) of 4 mm. To reduce noise generated inside the lens, a screw structure with a height of 0.5 mm and an angle of 30° was applied to the side of the lens. The piezoelectric layer is made of 36° rotated Y-cut $LiNbO_3$ with a thickness of 60 µm. E-solder was used as the backing layer. The conventional lens-focused (CF) transducer differs from the SF transducer in that the side surface of the lens is flat, while all other parameters remain the same.

Results/Discussion

The operating frequency of the fabricated transducers was approximately 50 MHz. The focal lengths of the PF, CF, and SF transducers were measured to be 5.2 mm, 5.6 mm, and 5.4 mm, respectively (Fig. b, c, and d). At the focal depth, the lateral/axial resolutions were 54 µm / 37 µm for PF, 63 µm / 22 µm for CF, and 53 µm / 26 µm for SF. In the case of CF, internal lens noise was observed at a level of up to approximately -9 dB relative to the target signal. In contrast, the SF suppressed this internal lens noise to below -20 dB.



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