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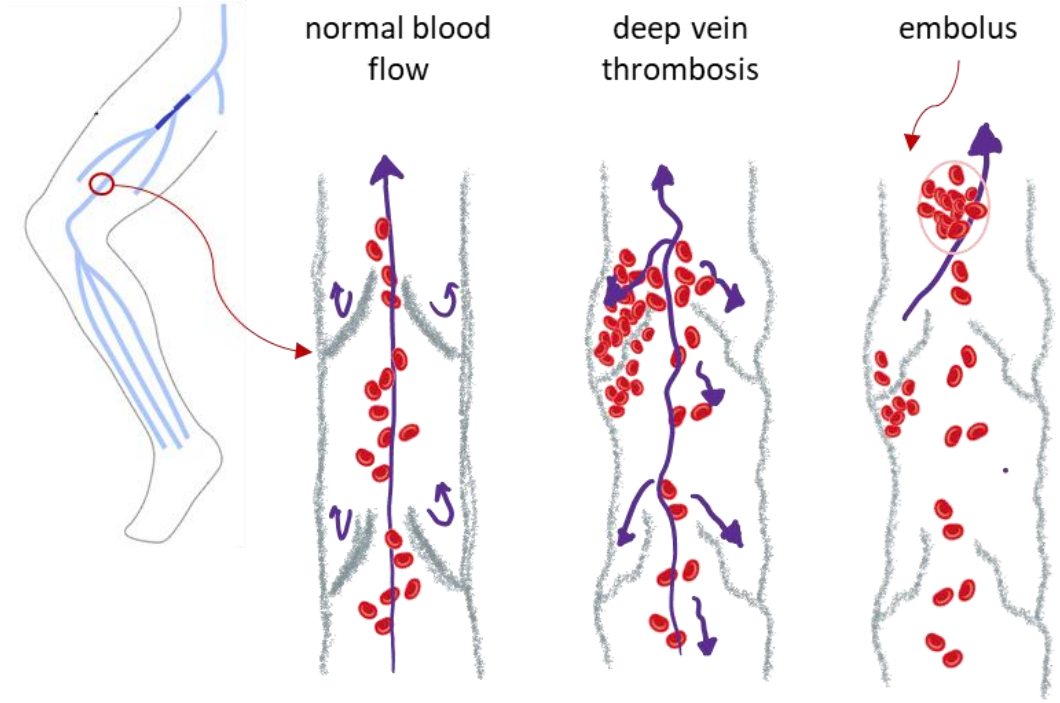
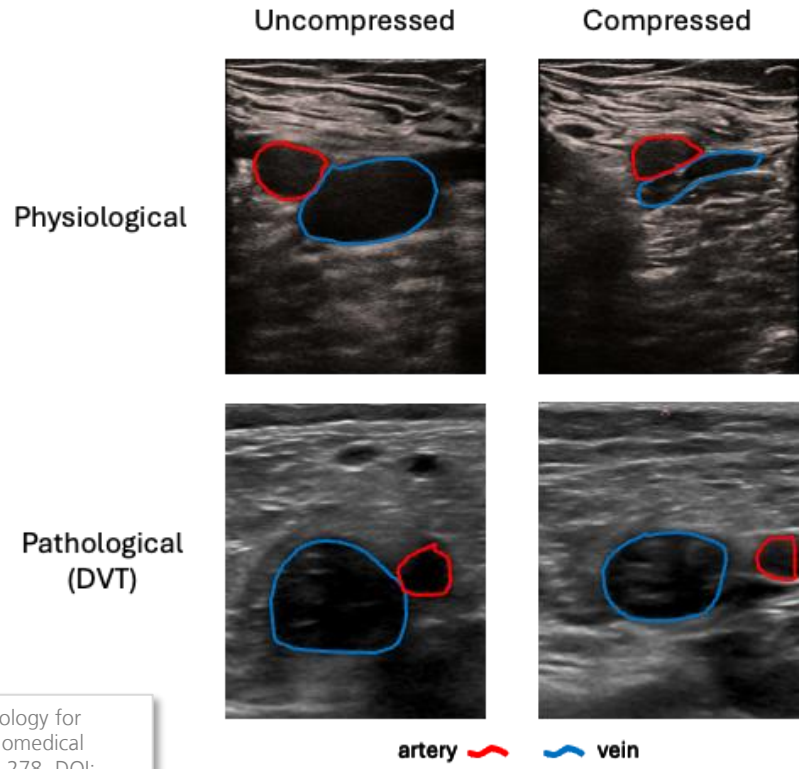
CMUT Array for Deep Vein Thrombosis

Deep Vein Thrombosis (DVT)

- direct visualization of the thrombus
- Doppler to assess venous flow
- compression ultrasound

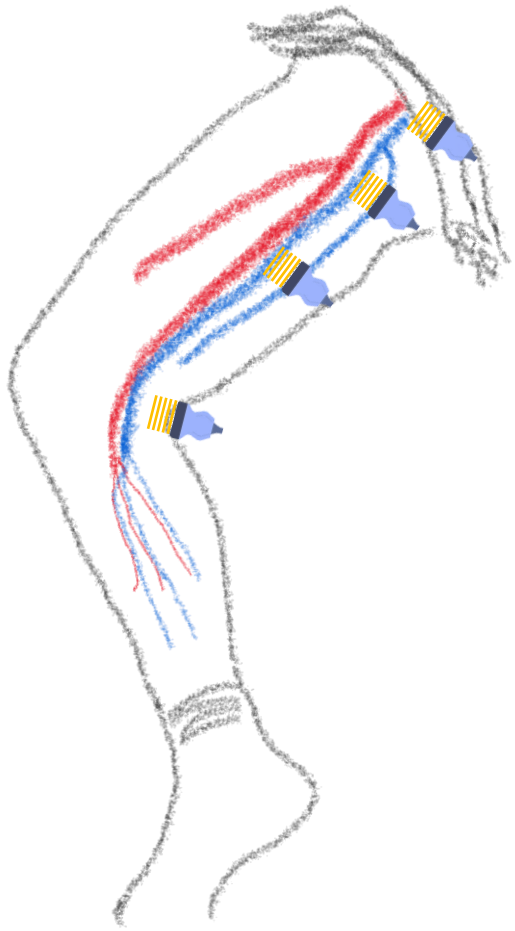




Tzatzimaki, K., Portokallidis, N., Drosatos, G., Kaldoudi, E. and Didaskalou, S. (2026). A Comprehensive Infrastructure and Methodology for Multi-Modal Data Acquisition to Empower AI-Based Rehabilitation. In Proceedings of the 19th International Joint Conference on Biomedical Engineering Systems and Technologies - Volume 3: HEALTHINF; ISBN 978-989-758-802-0; ISSN 2184-4305, SciTePress, pages 269-278. DOI: 10.5220/0014351200004070

DVT diagnosis

Current mod of choice



Patients are referred for an ultrasound when they present DVT-related clinical symptoms

however....

affects more than 700,000 Europeans per year and up to 2/3 of DVT episodes are clinically silent and patients are symptom free

pulmonary embolism events are acute, and 1/4 of these result in death immediately or in a few hours, before a treatment can be applied

prompt diagnosis of DVT is crucial!

Olaf M et al. Deep Venous Thrombosis. Emerg Med Clin North Am. 2017. https://doi.org/10.1016/j.emc.2017.06.003

Cohen AT et al. Thromb Haemost. 2007 Oct, https://doi.org/10.1160/TH07-03-0212

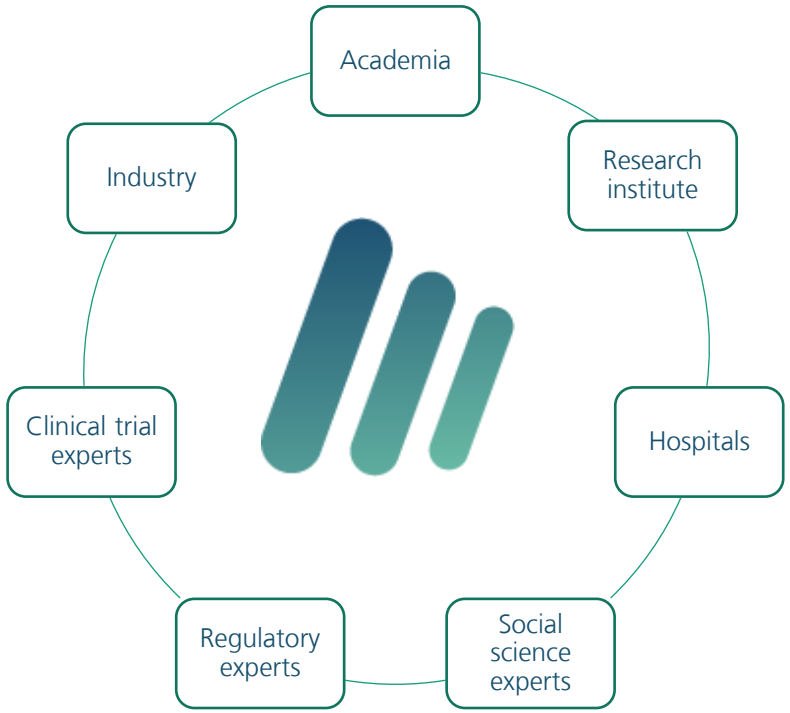
Barco S et al.Thromb Haemost. 2016. https://doi.org/10.1160/TH15-08-0670

Jha AK, et al. The global burden of unsafe medical care: analytic modelling of observational studies. BMJ https://doi.org/10.1136/bmjqs-2012-001748

The ThrombUS+ project

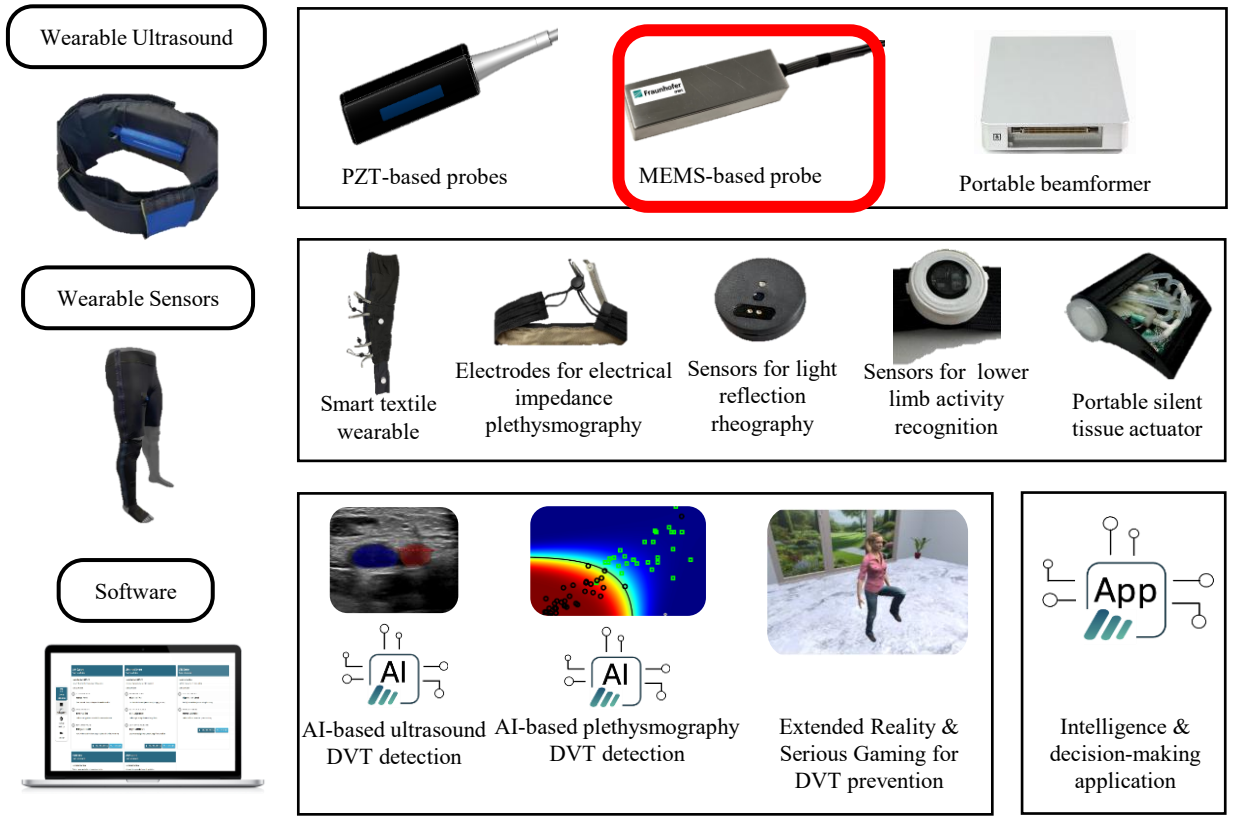
Overview of the proposed wearable for continuous monitoring of the lower limb for early deep vein thrombosis detection.

Marozas V, Didaskalou S,Eitminavičius R, Portokallidis N,Jurkonis R, Daukantas S, Jucevičius M,Rapalis A, Pousset N, Legros M,et al. ThrombUS+ Project: TowardWearable Continuous Point-of-CareMonitoring for Deep Vein Thrombosisof the Lower Limb. Comput. Struct.Biotechnol. J. 2026;35(2):Article0082.
https://doi.org/10.34133/csbj.0082



18 partners
from 8 countries

Greece, Lithuania, France, Germany, USA, Finland, Italy, Spain



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Fraunhofer Institute for Photonic Microsystems IPMS

- ✓ Fraunhofer IPMS is a leading international research and development service provider for electronic and photonic microsystems in the application fields of Smart Industrial Solutions, Bio and Health, Mobility as well as Green and Sustainable Microelectronics.
- ✓ It has more than 600 employees at 4 sites in Germany (Dresden, Cottbus and Erfurt).
- ✓ Our clean rooms with industrial standard equipment:
  - ✓ 200mm MOEMS/MEMS – technology development up to pilot manufacturing of innovative microsystems (1.500m²)
  - ✓ 200mm Microdisplays clean room (300m²)
  - ✓ 300mm Micro- and Nanoelectronics clean room (2.700m²)

Sensors

- Ultrasonic sensors
- Optical sensors (MEMS scanners, spectrometers)
- Electro-chemical sensors (ISFET, IMS, OFET)

Actuators

- Mechanical actuators (CMUT, NED)
- Optical actuators (MEMS scanners, SLM)

Microdisplays

- Ultra-low power OLED-microdisplays
- Bidirectional OLED microdisplays
- Functional layers for displays

Computing

- Memory technologies
- 300 mm technologies
- Quantum computing
- Neuromorphic computing

Data Communication

- Li-Fi data transmission
- IP core design for FPGA and ASIC
- RISC V IP cores

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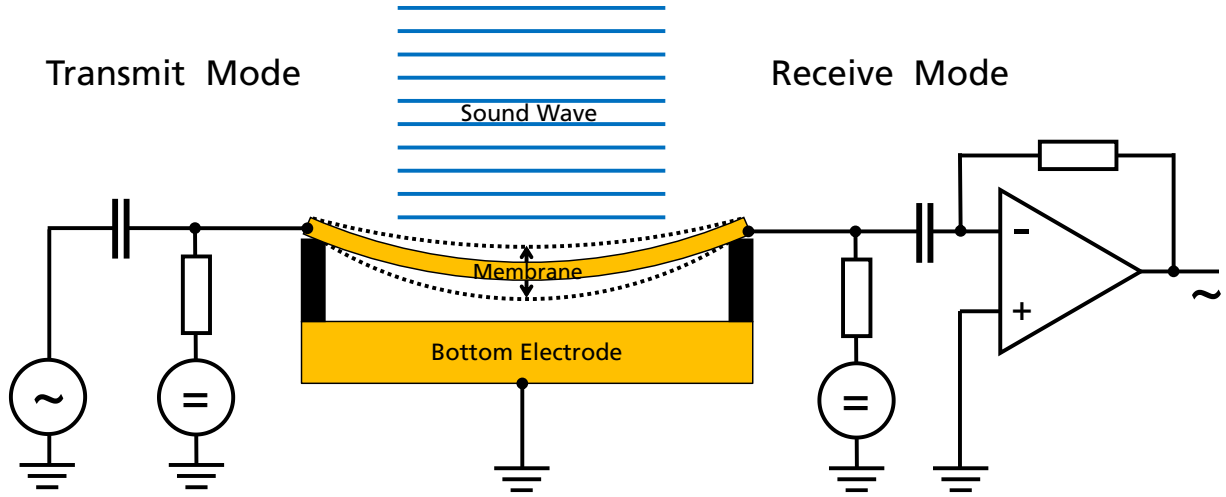
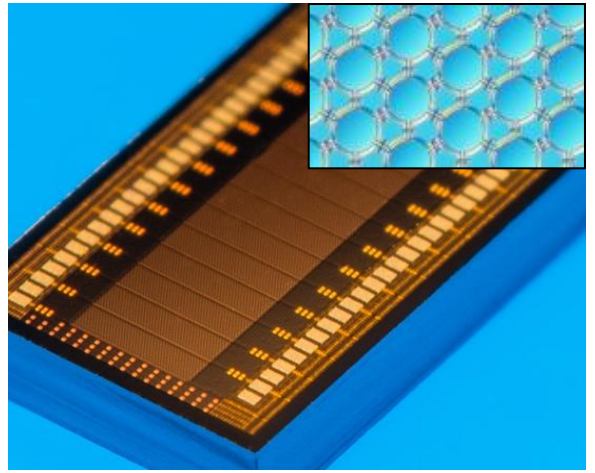
CMUT – Capacitive Micromachined Ultrasonic Transducer

Principle and Advantages

- ✓ Principle
  - ✓ Transmits like an electrostatic loudspeaker
  - ✓ Receives like a capacitor microphone



- ✓ Advantages
  - ✓ High receive sensitivity → ultrasonic imaging in medical diagnostics
  - ✓ Acoustic properties (impedance, frequency, …) adjusted by basic cell structures
    → plane transducers with optional shape, size and element number
    → allows arrays with huge element number without gap
  - ✓ Natural matching to air or water → wide bandwidth (especially in receiving)
  - ✓ Processing on silicon wafers → compatible with CMOS fabrication process
  - ✓ No hazardous substances → meet the RoHS directive of the EU



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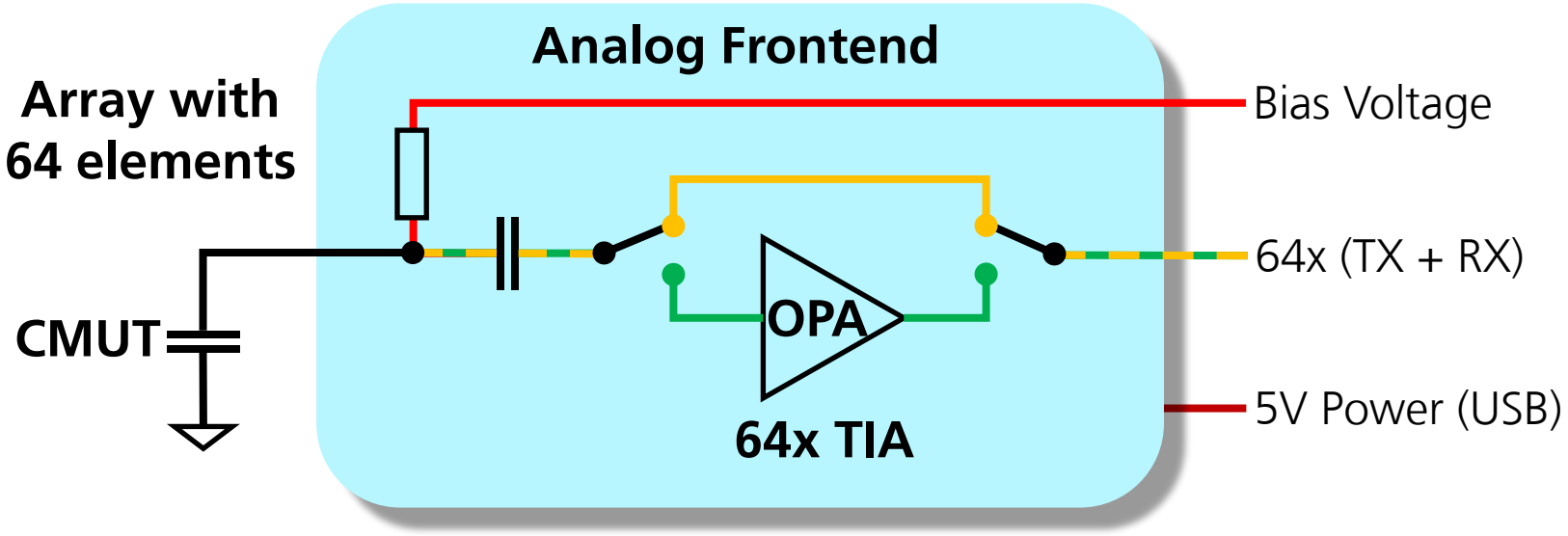
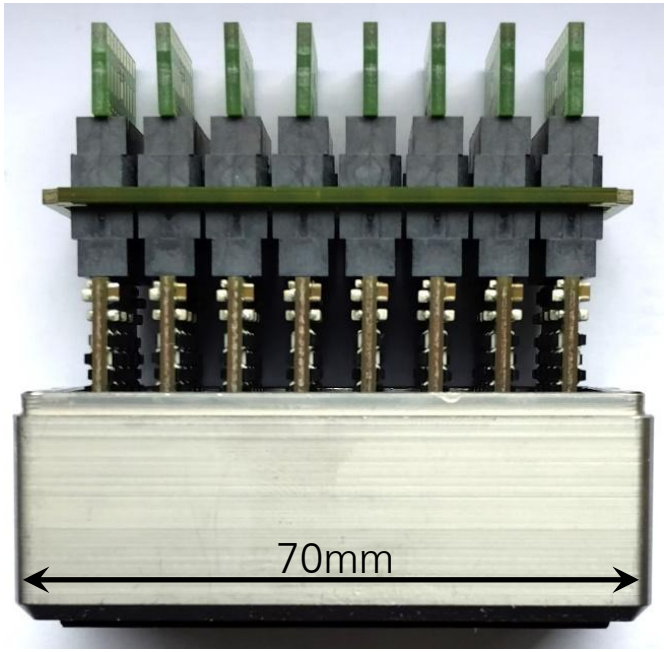
The CMUT-Array Probe

Standard Array Setup

- ✓ Integrated preamplifier electronics inside the case of the probe
- ✓ DC-DC converter for the bias voltage, powered by the 5V power supply, is integrated in the connector





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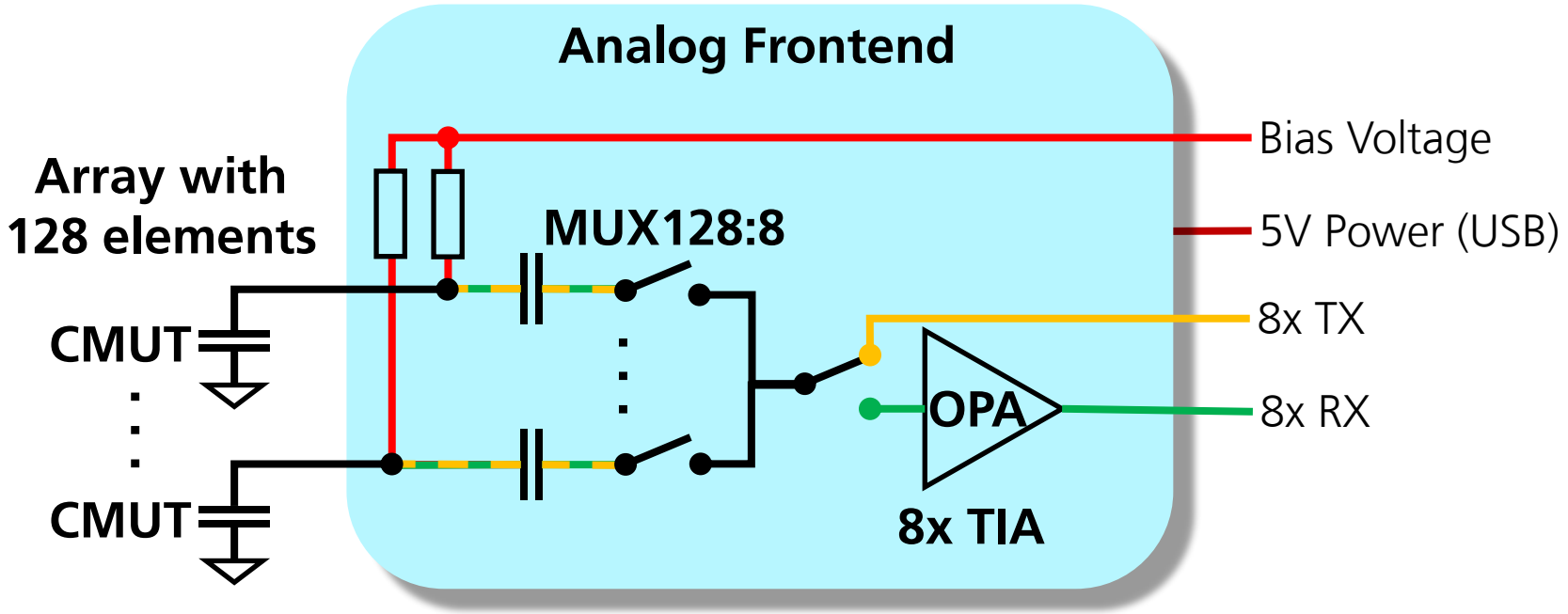
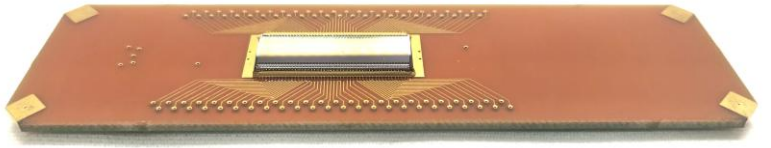
The CMUT-Array Probe

Wearable Array Setup

- ✓ Integrated preamplifier electronics inside the case of the probe
- ✓ DC-DC converter for the bias voltage, powered by the 5V power supply, is integrated in the connector





Height 8mm

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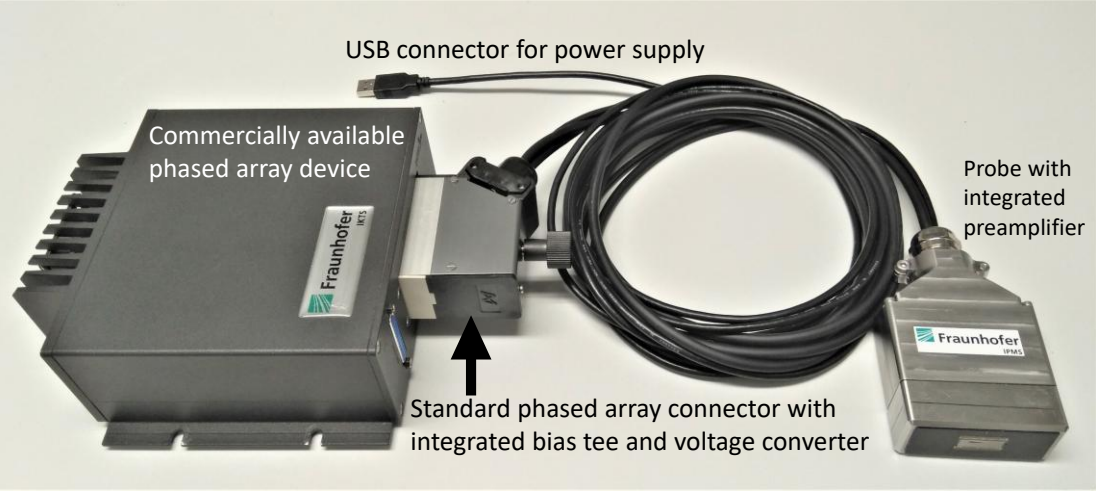
The CMUT-Array Probe

Array Setup Comparison

- ✓ Both with bias voltage up to $200V_{DC}$
- ✓ TX voltage max. $200V_{AC}$ reduced to max. $100V_{AC}$ (limited by the MUX)
- ✓ Channel (Element) number extended from 64 to 128
- ✓ Reduced cover size and power consumption (10W → 1.5W)
- ✓ Applicable with commercially available phased array devices



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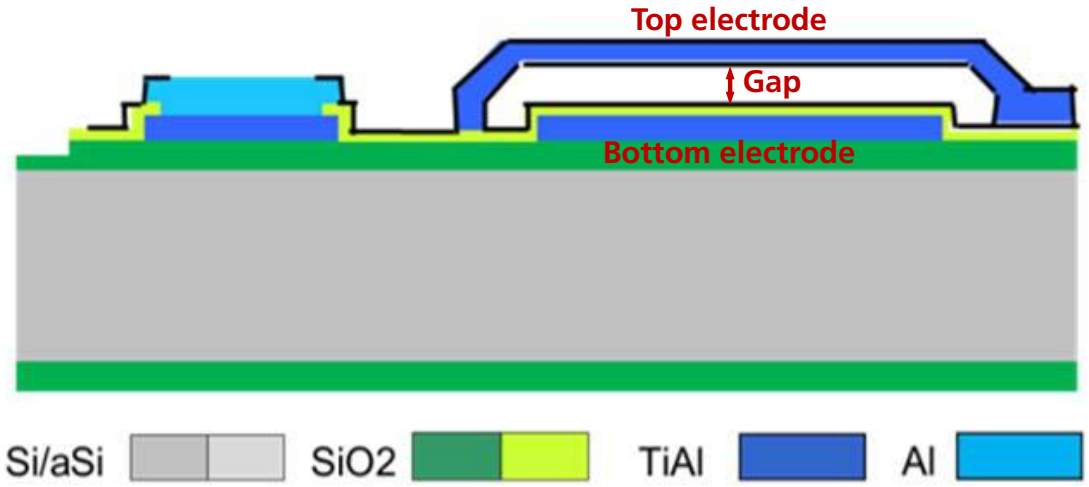
The CMUT-Array Probe

Optimized CMUT Design



- ✓ 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 electromechanical coupling and thus higher sensitivity of the CMUT at smaller gaps, resulting in similar SNR.
- ✓ 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.

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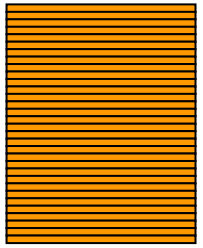
The CMUT-Array Probe

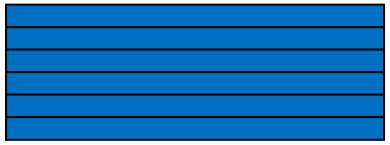
Comparison with Piezoelectric Probe

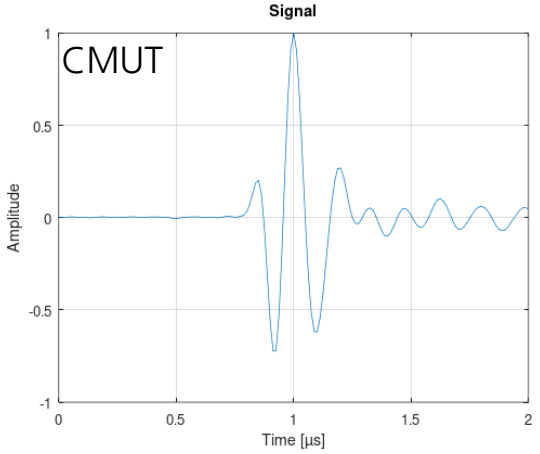
- Excitation by single square pulse 20V / 100ns

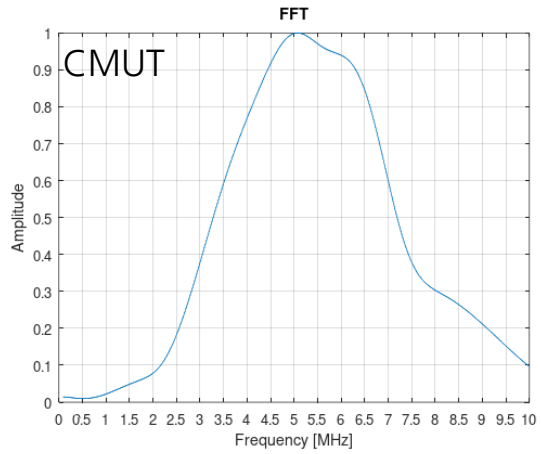
- CMUT-Array 5 MHz / 96 elements
  - matching to water
  - 32 elements 0.2 x 5 mm² in use
  - focus 45mm

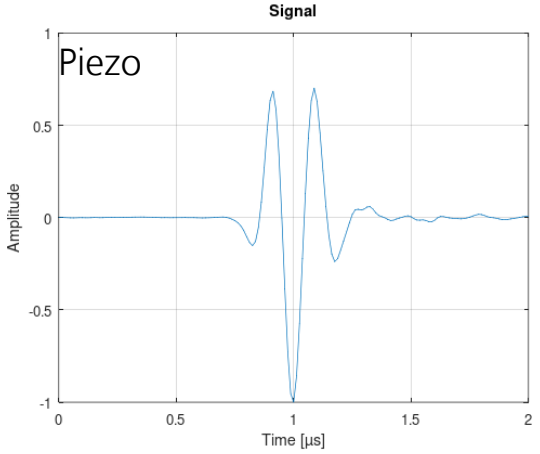


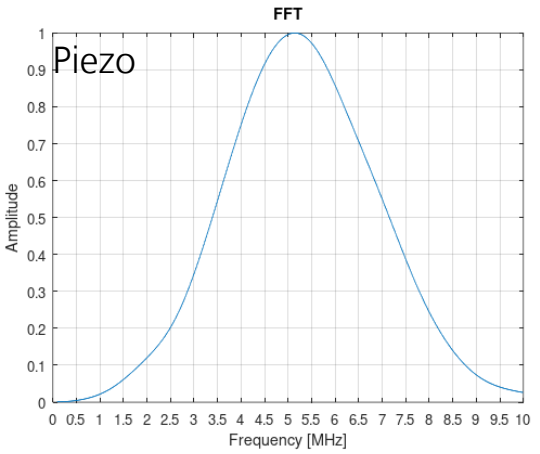
- Piezo-Array 5 MHz / 32 elements
  - matching to polystyrene
  - 6 elements 0.5 x 10 mm² in use
  - focus 90mm











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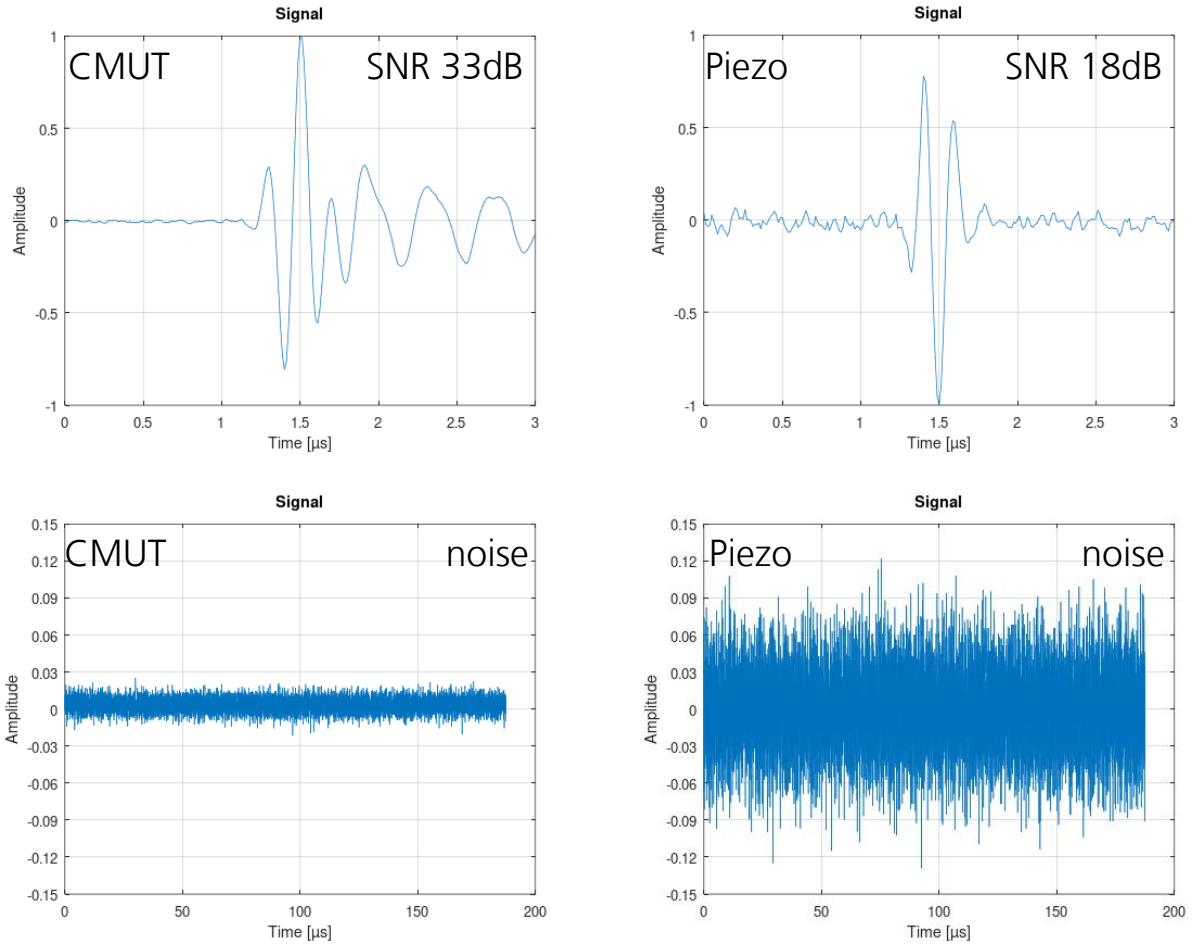
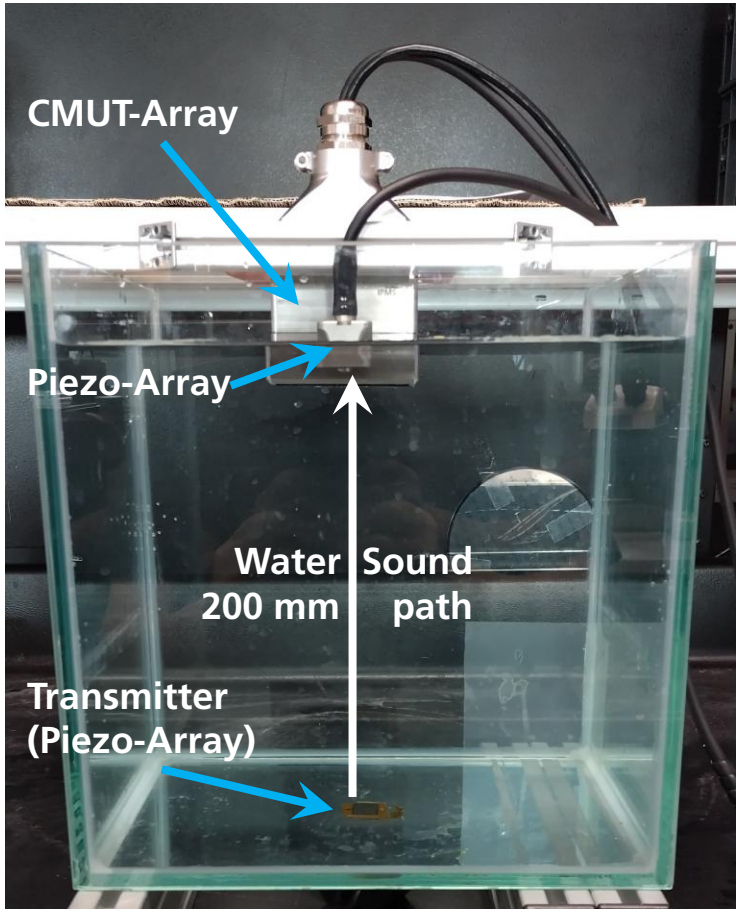
The CMUT-Array Probe

Water Tank – Through-Transmission





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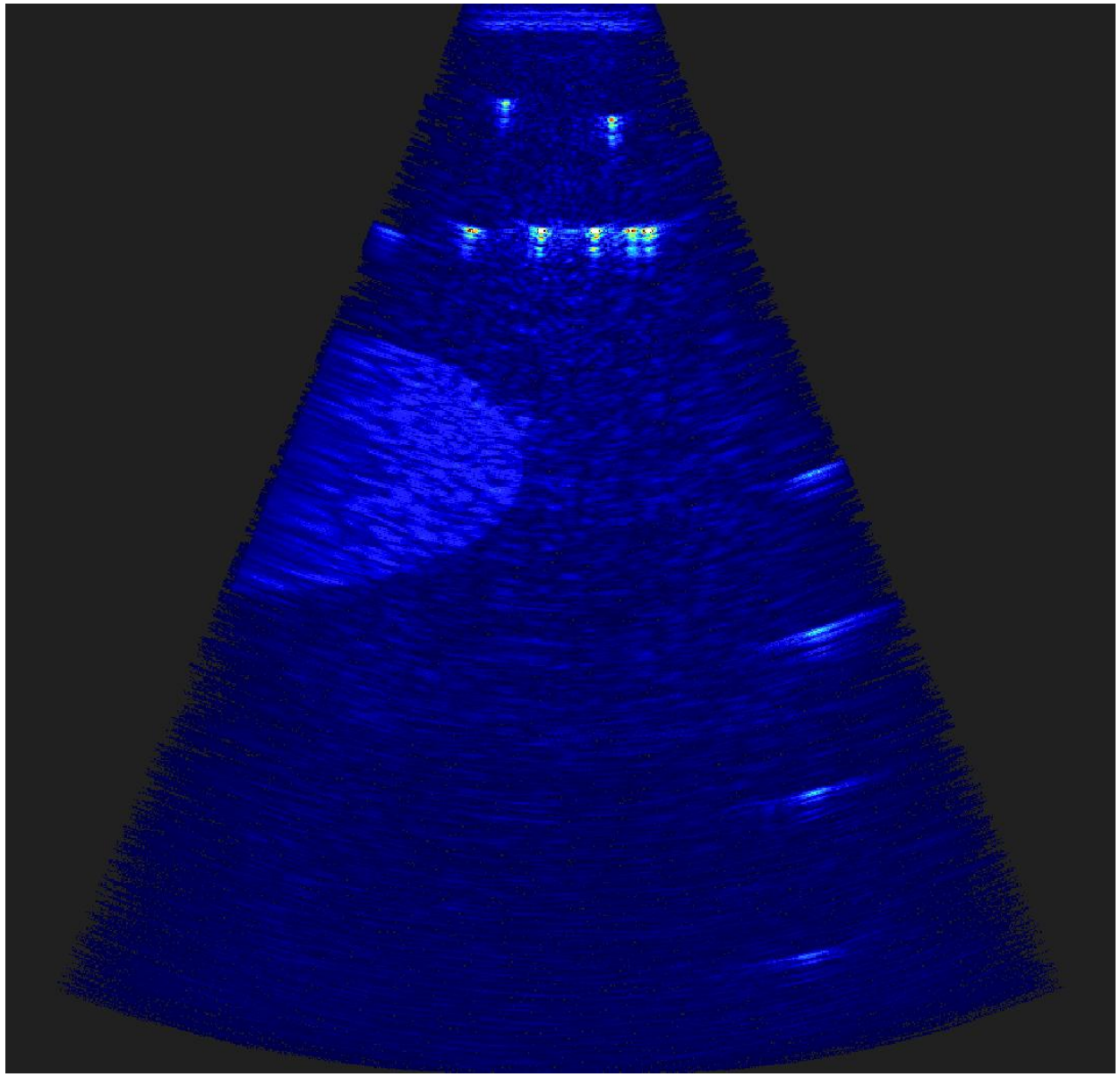
The CMUT-Array Probe

Reference Measure on a Body Phantom



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Conclusion and Outlook

- ✓ Our previous CMUT-array probe for manually handling was successfully enhanced for wearable applications in medical diagnostics.
- ✓ Two standard array probes for ultrasonic diagnostics in medicine and non-destructive testing can be provided by the Fraunhofer IPMS.
- ✓ These CMUT-arrays can be applied with commercially available phased array devices by the integration of the preamplifier electronics inside the housing of the probe.
- ✓ The acoustic properties of the CMUTs can be adjusted in a wide range to the requirements of the customers.
- ✓ Current enhancements of our CMUT technology addresses a reduced bias voltage which is essential for the integration of the CMUT structures and the preamplifier electronics on a silicon chip.

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Wearable in Action

1 min

Sakalauskas A, Novikov D, Jurkonis R. Report on testing of arrays, pump and image formation electronics for image quality and required enhancements, Deliverable D3.5, ThrombUS+ Horizon Europe Innovation Action, EC Grant Agreement No. 101137227, 5 August 2025. https://doi.org/10.5281/zenodo.16415191

ThrombUS+

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Thank you for your attention!

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