Phase-insensitive Ultrasonic Computed Tomography for breast disease diagnosis

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Content

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Motivation

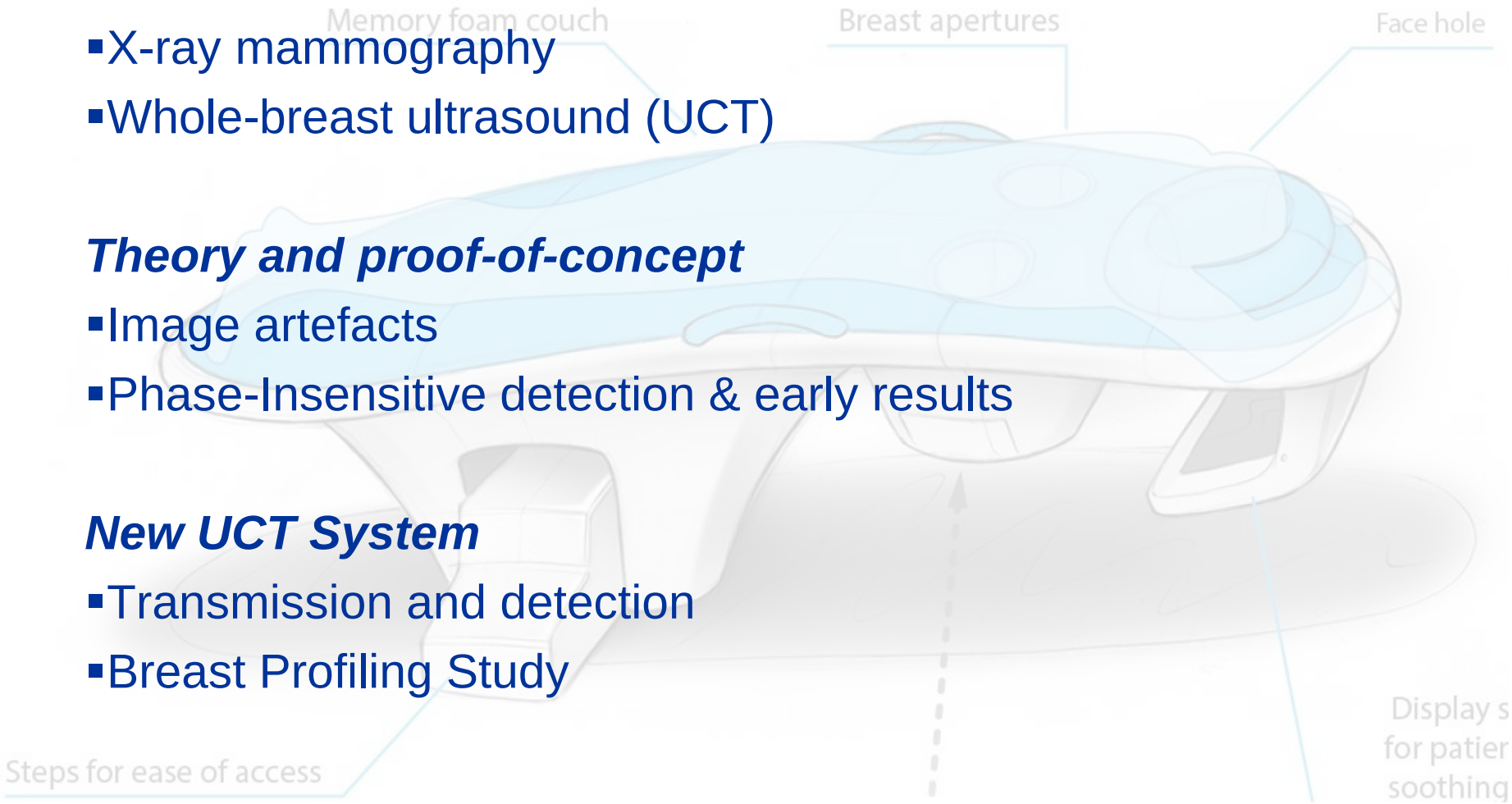
- X-ray mammography
- Whole-breast ultrasound (UCT)

Theory and proof-of-concept

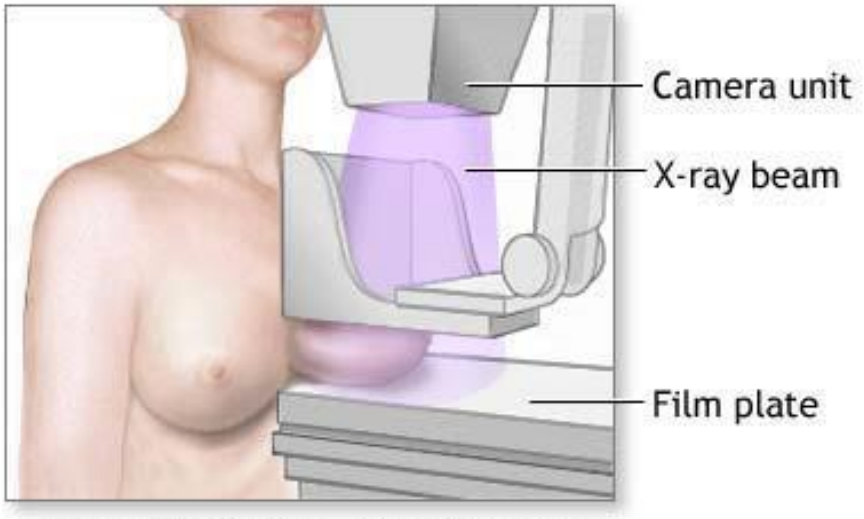
- Image artefacts
- Phase-Insensitive detection & early results

New UCT System

- Transmission and detection
- Breast Profiling Study



X-ray Mammography

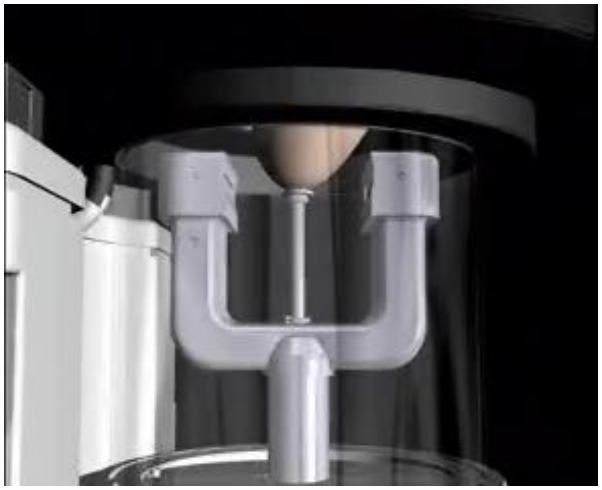


Disadvantages

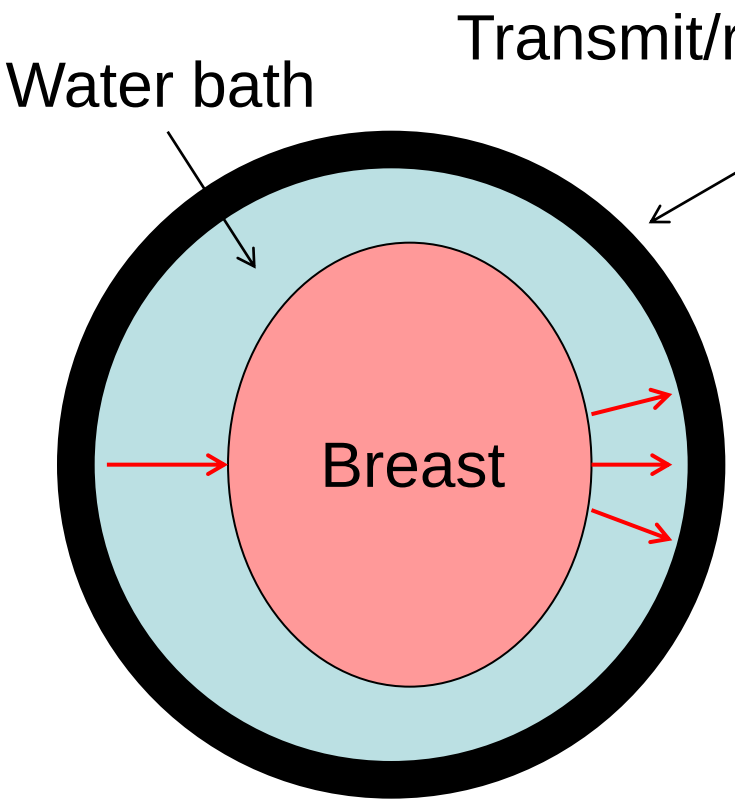
- *Ionising radiation*
- *Qualitative, 2D information*

Ultrasound CT

- Measure ultrasound transmitted through breast
- Reconstructed 3D image
- Comfortable for patient
- No ionising radiation
- Potentially cost-effective



Whole-Breast Ultrasound



- Breast submerged in water bath
- Circular array of point Tx/Rx
- One transmits, others measure speed of sound or attenuation
- Tomographic reconstruction of ‘projections’ from all angles creates cross-sectional image of breast

Whole-Breast Ultrasound

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Advantages

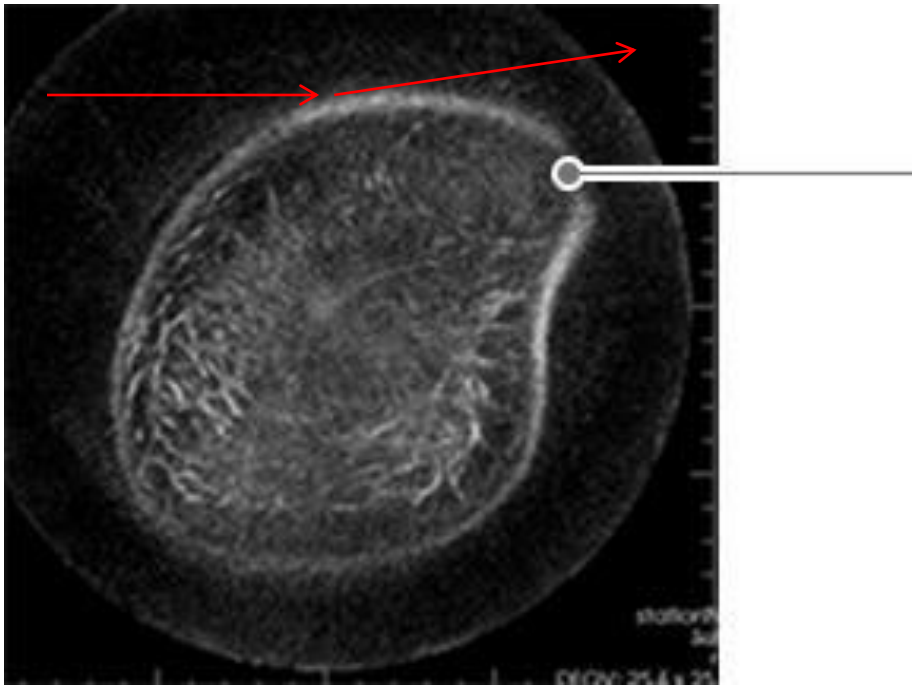
- Operator independent
- Quantitative (SOS and α)

Problems

- Image artefacts due to reflection and refraction
- Reduced using computationally intensive reconstruction algorithms based on physical models of sound propagation

Image: Delphinus Medical Systems, Michigan, USA

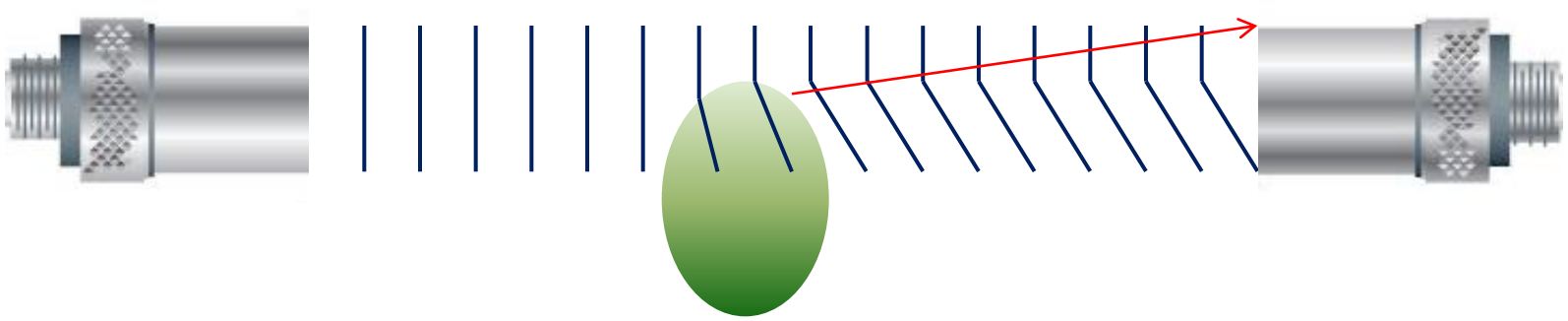
Theory:
Attenuation Image Artefacts

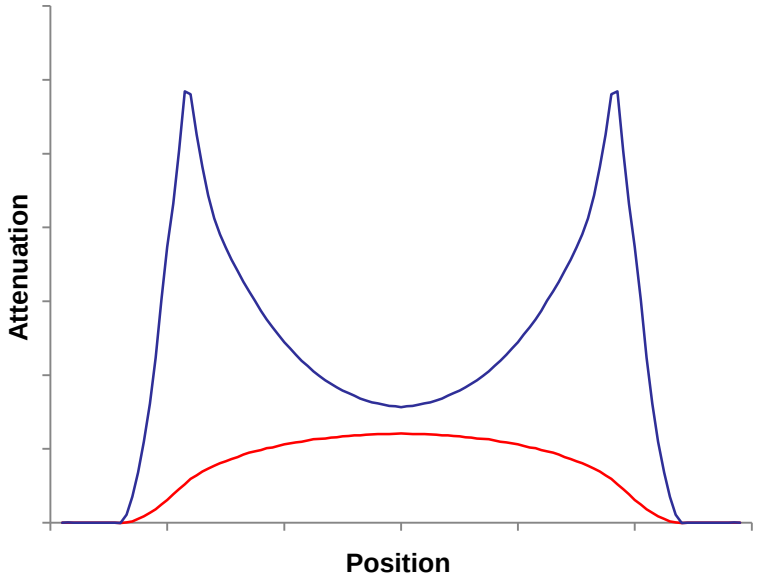


- Boundaries between regions with different speeds of sound show as highly attenuating
- Beam passes over these regions at shallow angles – refraction and phase aberration

Image: Delphinus Medical Systems, Michigan, USA

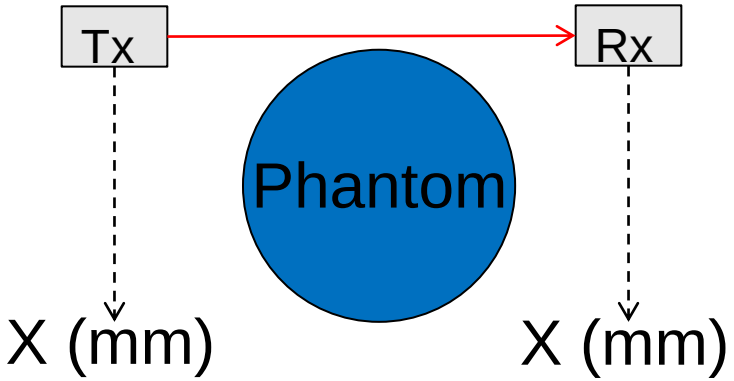
Ultrasound CT Artefacts

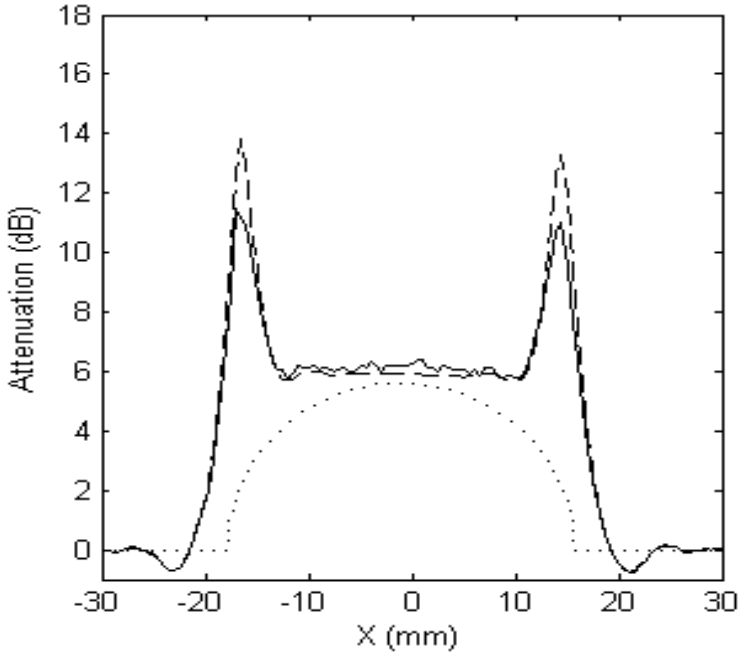




Simple Case: Single Small Detector

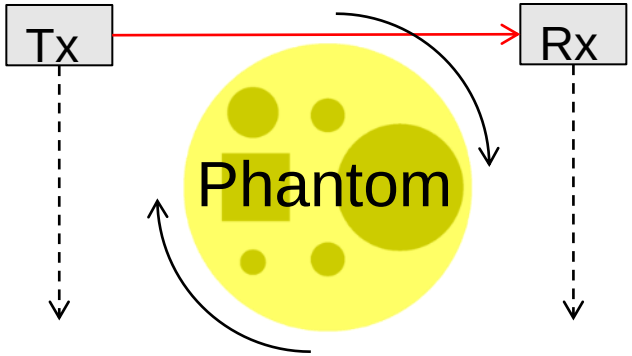
- Homogenous, cylindrical test phantom
- Single, linear projection

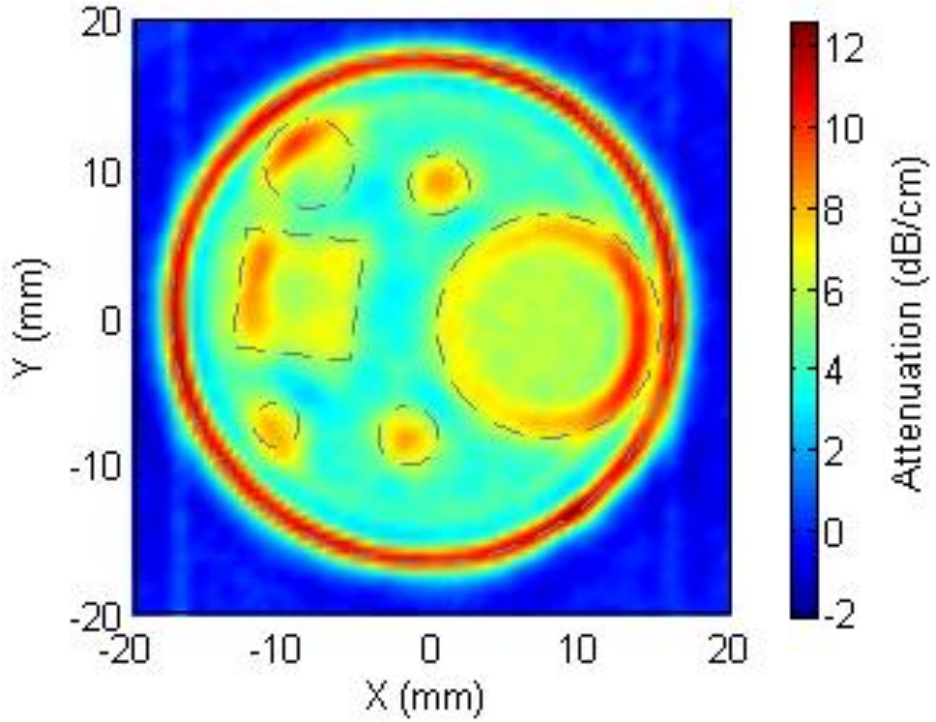




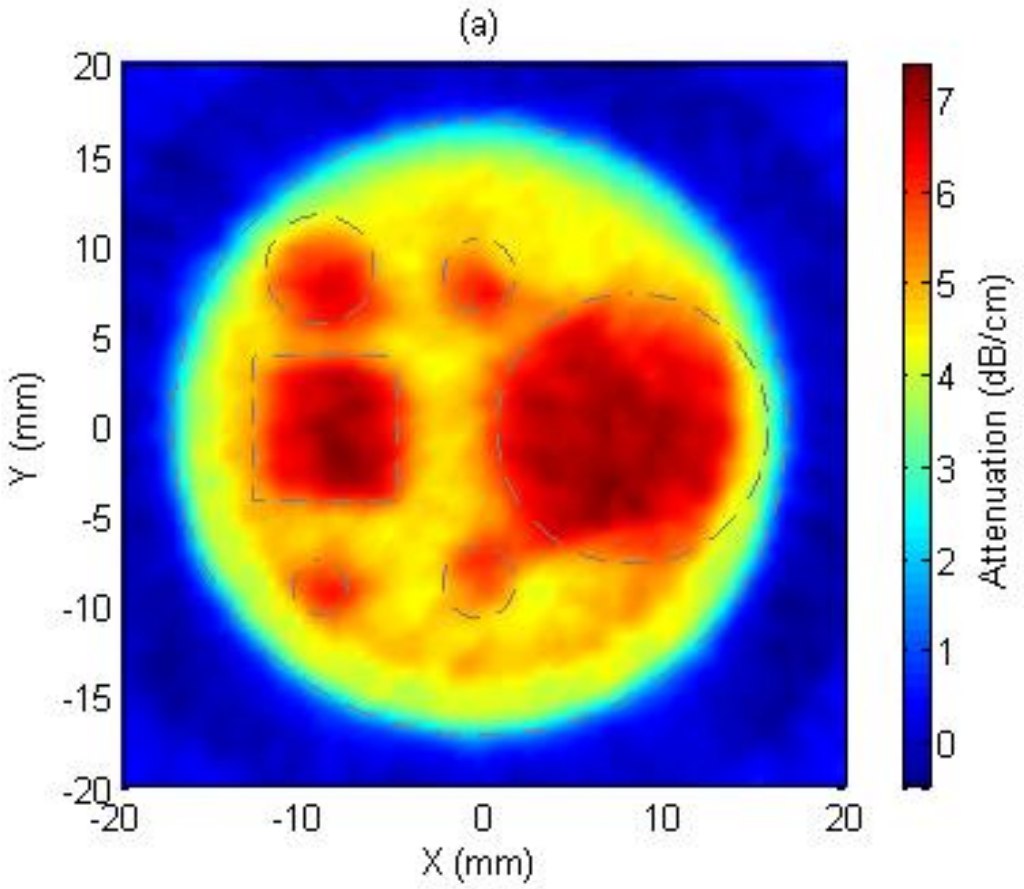
Simple Case: Single Small Detector

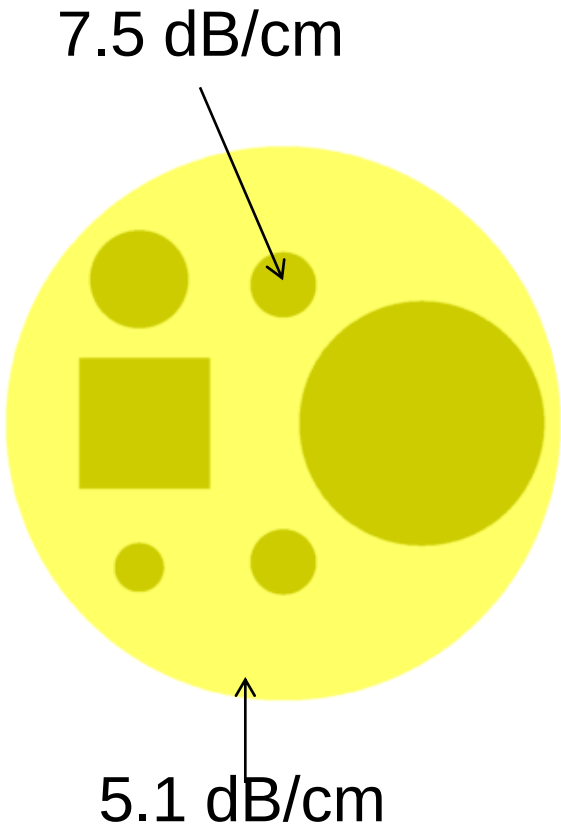
- Cylindrical phantom with inserts
- Tomographic reconstruction





Phase-Insensitive Sensor Scan





Quantitative ultrasonic computed tomography using phase-insensitive pyroelectric detectors Bajram Zeqiri *et al* 2013 *Phys. Med. Biol.* **58** 5237

Current UK Collaborative Project: Phase-Insensitive UCT System

2014	2016	2017
Improve speed and sensitivity of transmission and detection technology	Build clinical demonstrator scanning platform and test on phantoms	Small trial (<30 patients) of system on women with known breast pathologies
NPL, Precision Acoustics Ltd	*NPL, Designworks Ltd*	*NPL, University Hospitals Bristol*

System components

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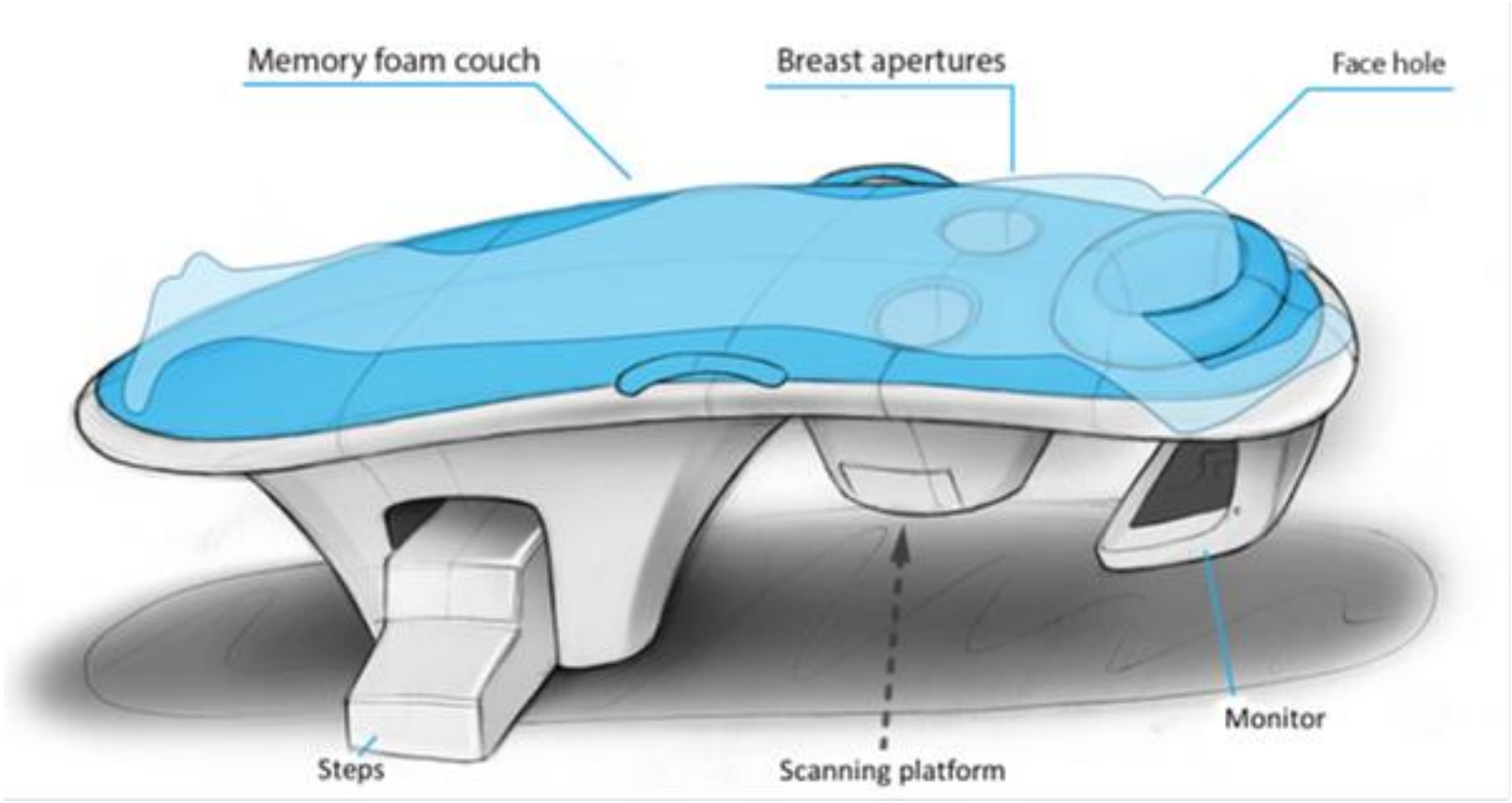
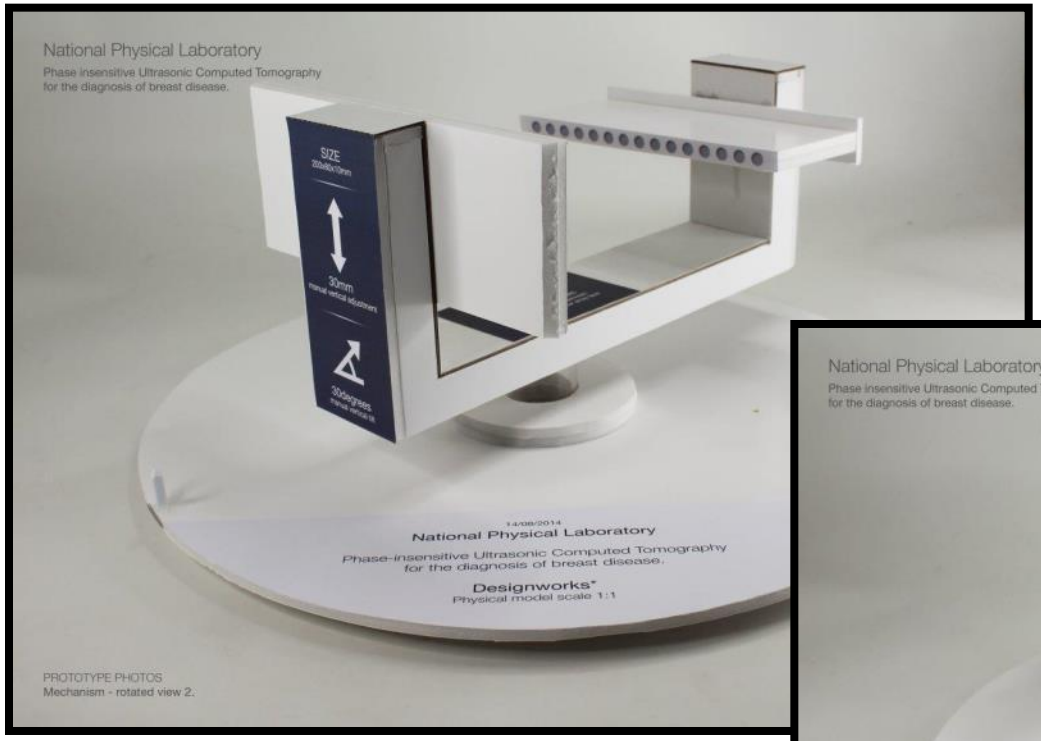


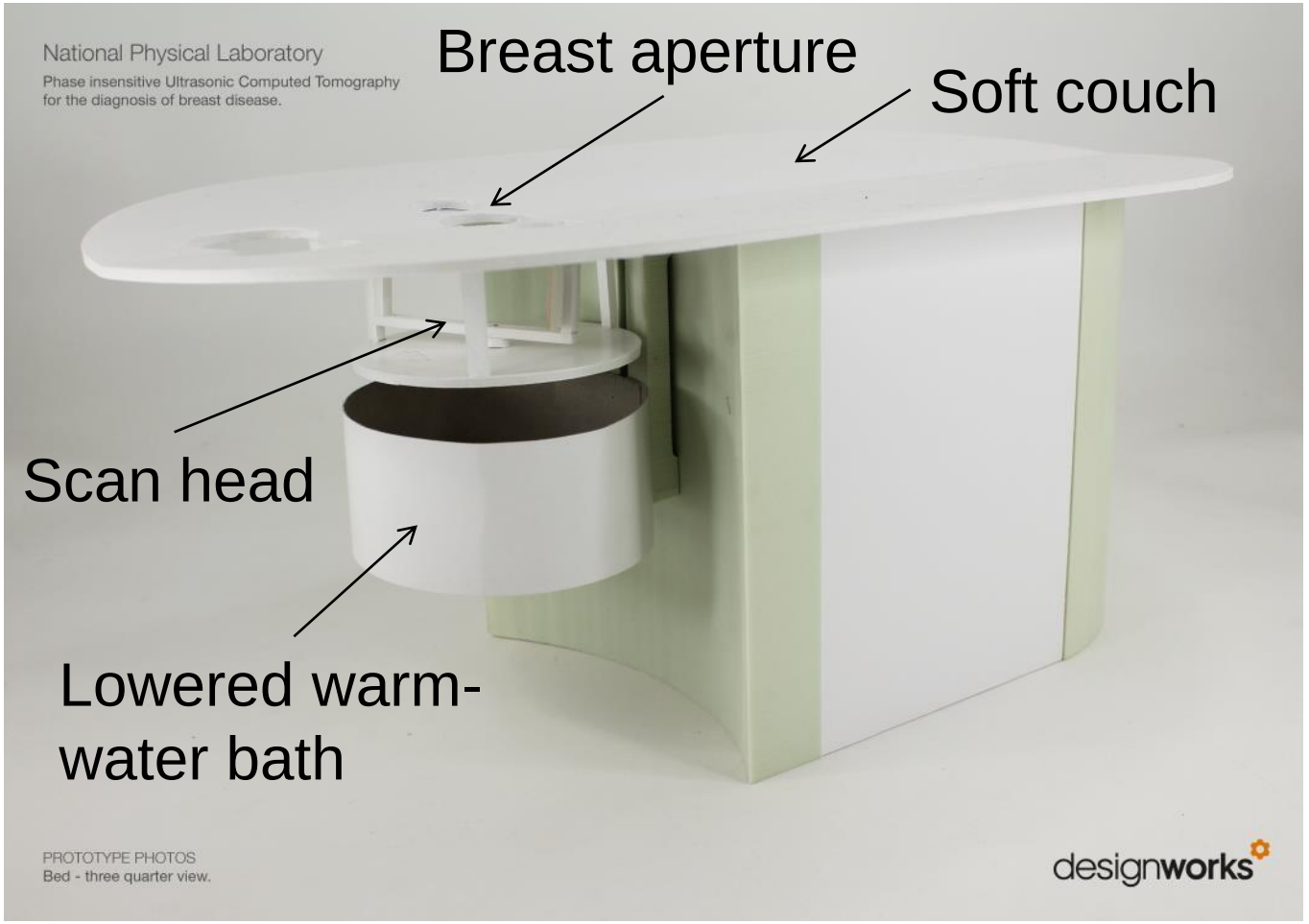
Transmission and Detection



- Sensor and amplifier ~100x faster than in previous project

- High-power narrow-beam transducers designed and built

Scanning Platform



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SENSORS

Large-Area Phase-Insensitive Sensor

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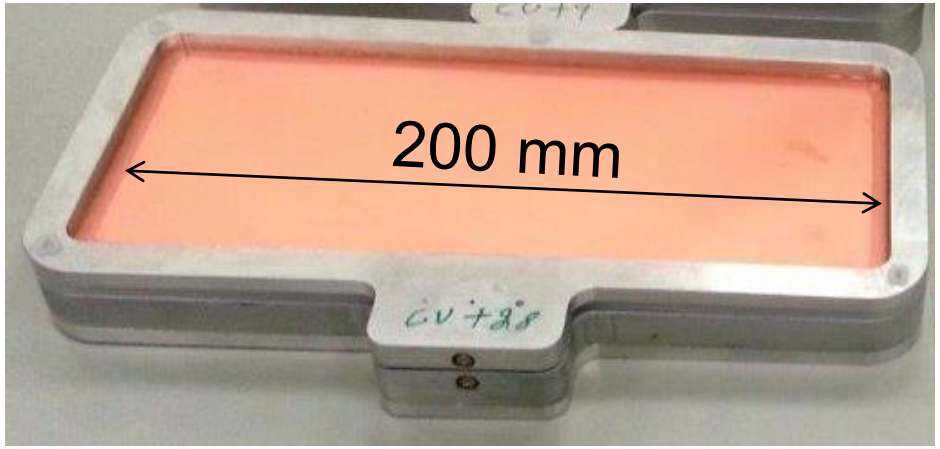
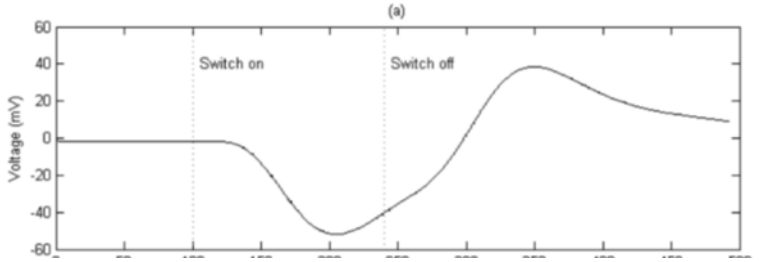
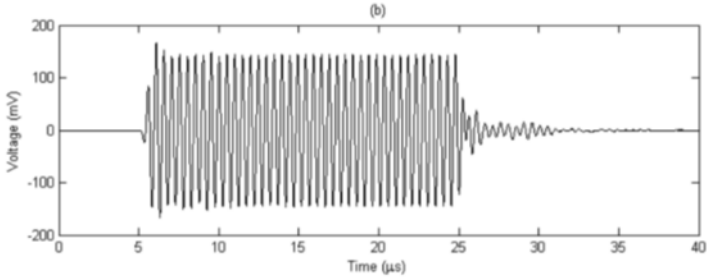


Power Response (Pyroelectric)



0 ms 5 ms

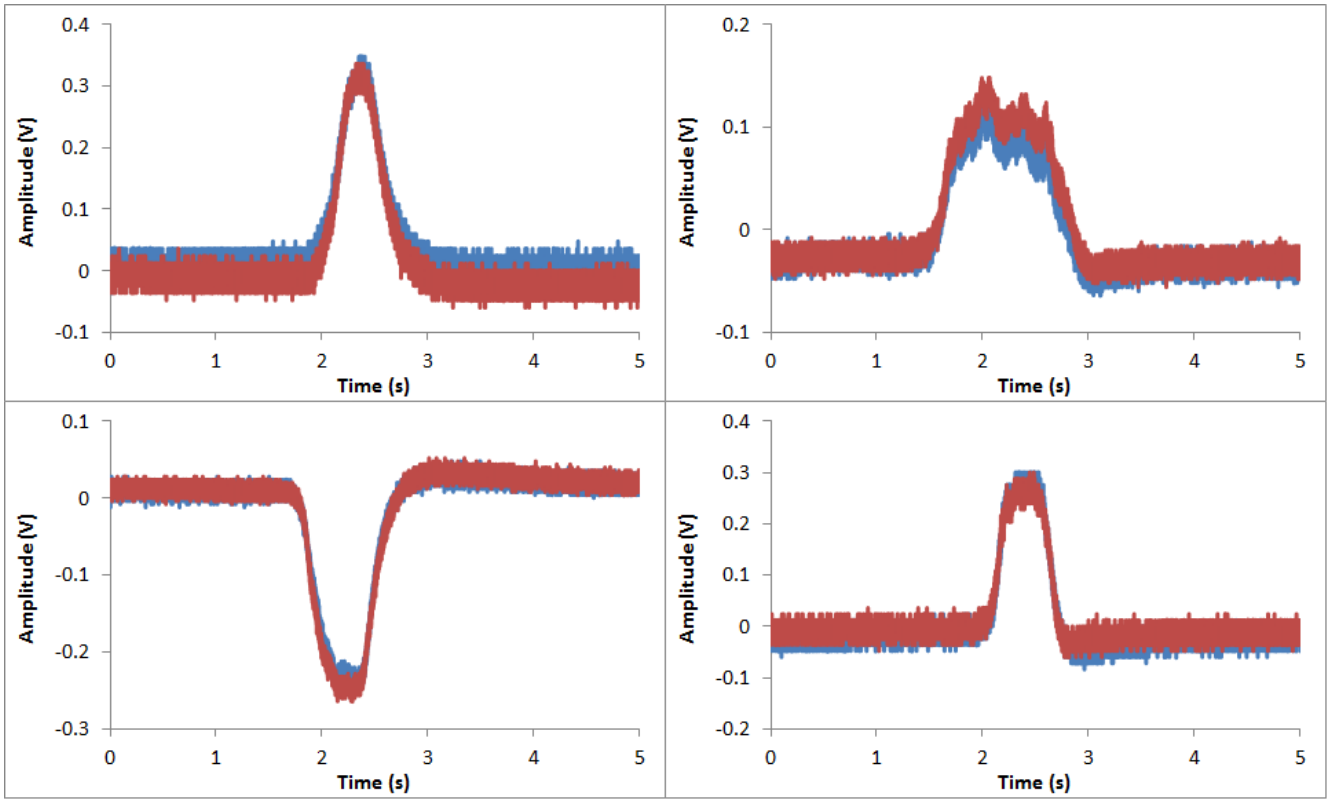
Pressure Response (Piezoelectric)



- PVDF Membranes with absorbing PU filling
- Pyroelectric – responds to acoustic power via heating (kHz)
- Simultaneous piezoelectric response for SOS (MHz)

New Double Sensors

- Individual sensor elements are identical in performance



New Amplifier
- Computer Control

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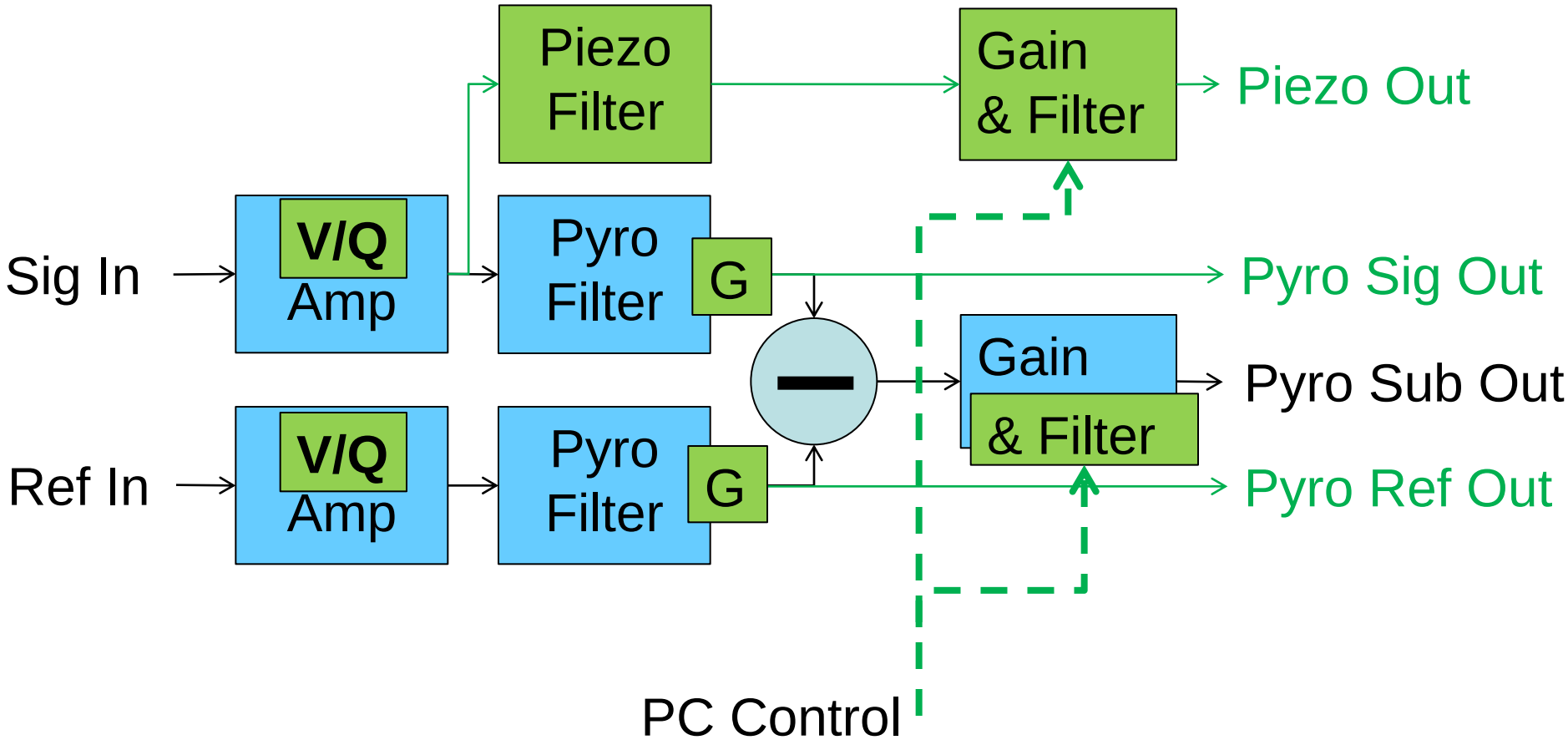

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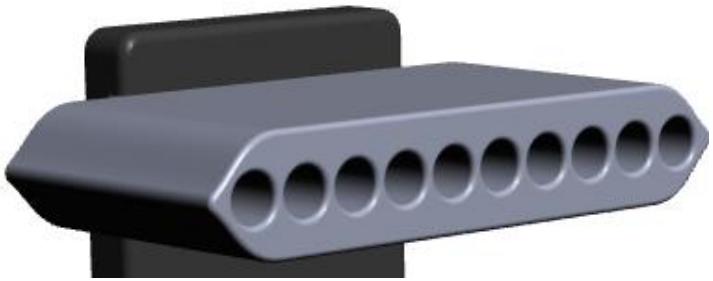
TRANSMIT



Transmit

- ~ 3 MHz transducer array, up to 20 elements in line
- Piezocomposite transducer design, able to generate sufficient power to transmit ultrasound across breast tissue
- Transducers undergoing optimisation in terms of frequency, output power and beam-shape
- Beam-size will affect the *spatial resolution* of the scan, and the ability to detect small inclusions in tissue, for which the goal is a few mm

Prototype transducers

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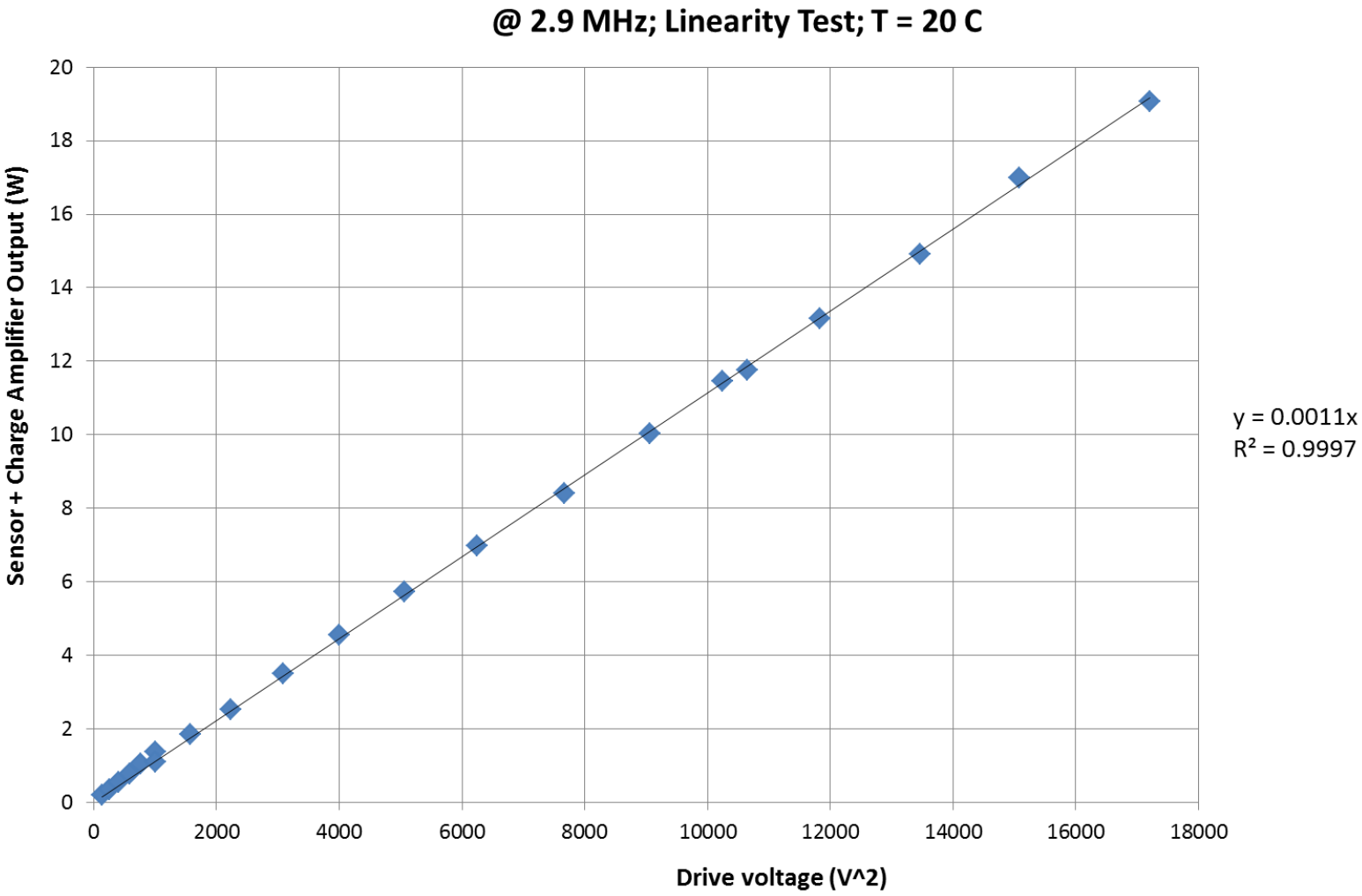
Results – Linearity @ 2.9 MHz



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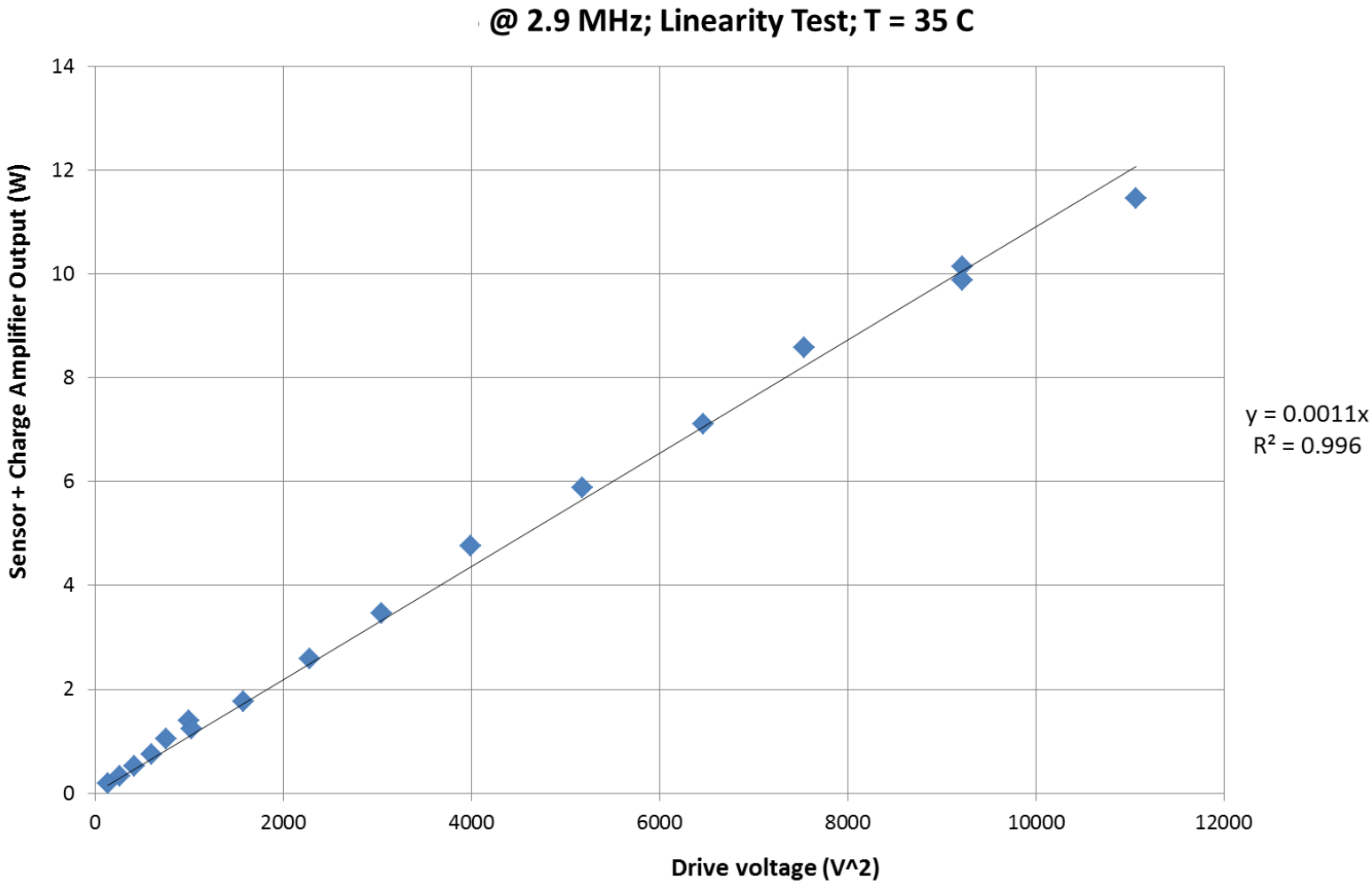

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BREAST PROFILING STUDY

Breast profiling study

- To provide anatomical data (sparse in published literature) and to examine new sensor sensitivity to scanning and patient environment
- Following announcement and invitation to all female staff at NPL: **74 responses**, and **60 completed questionnaires**; **40 invitees**
- Carried out with assistance from project partners: ethical approval obtained
- Charitable donations (£10 per participant) made to Breakthrough Breast Cancer

Breast profiling study

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Breast profiling study

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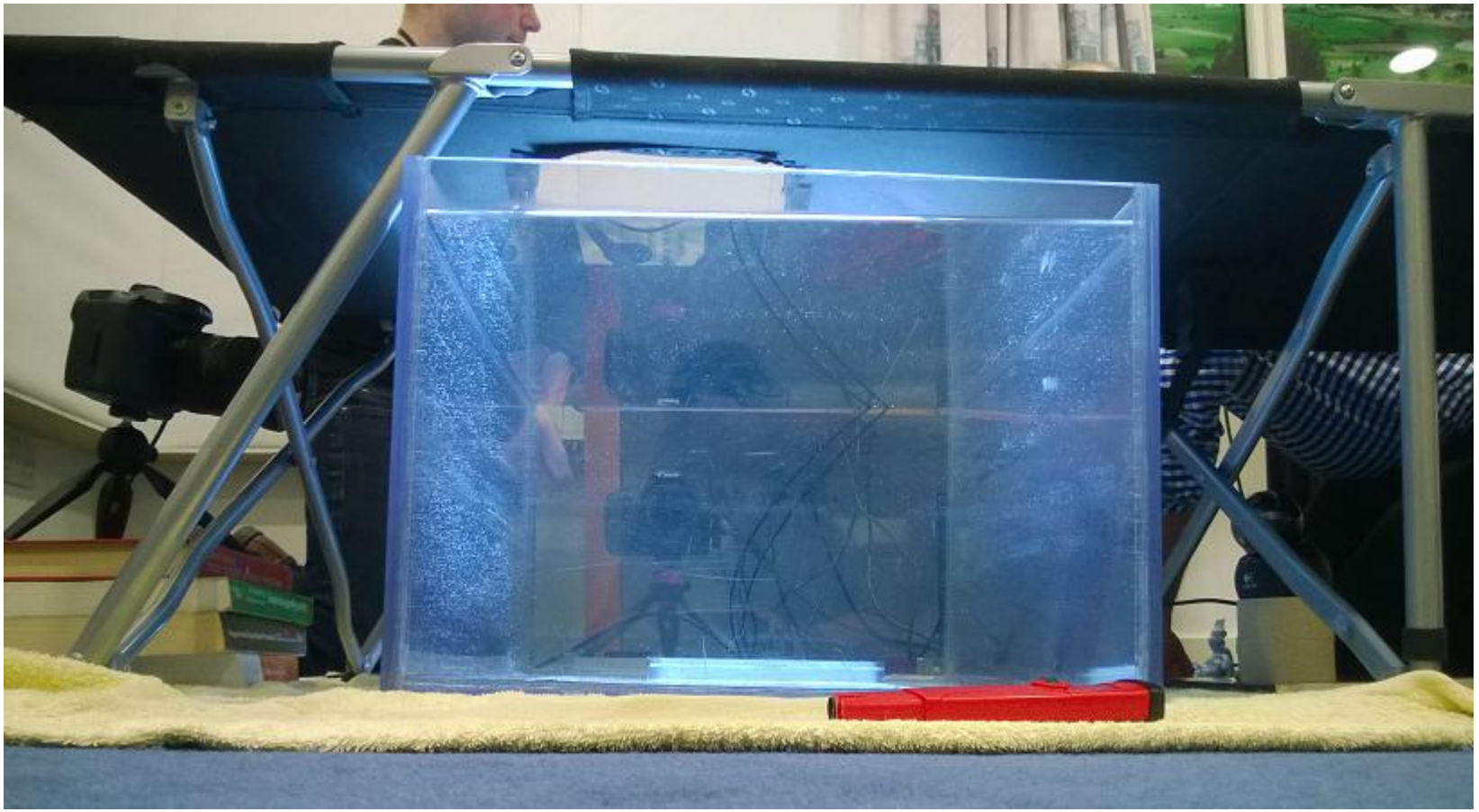
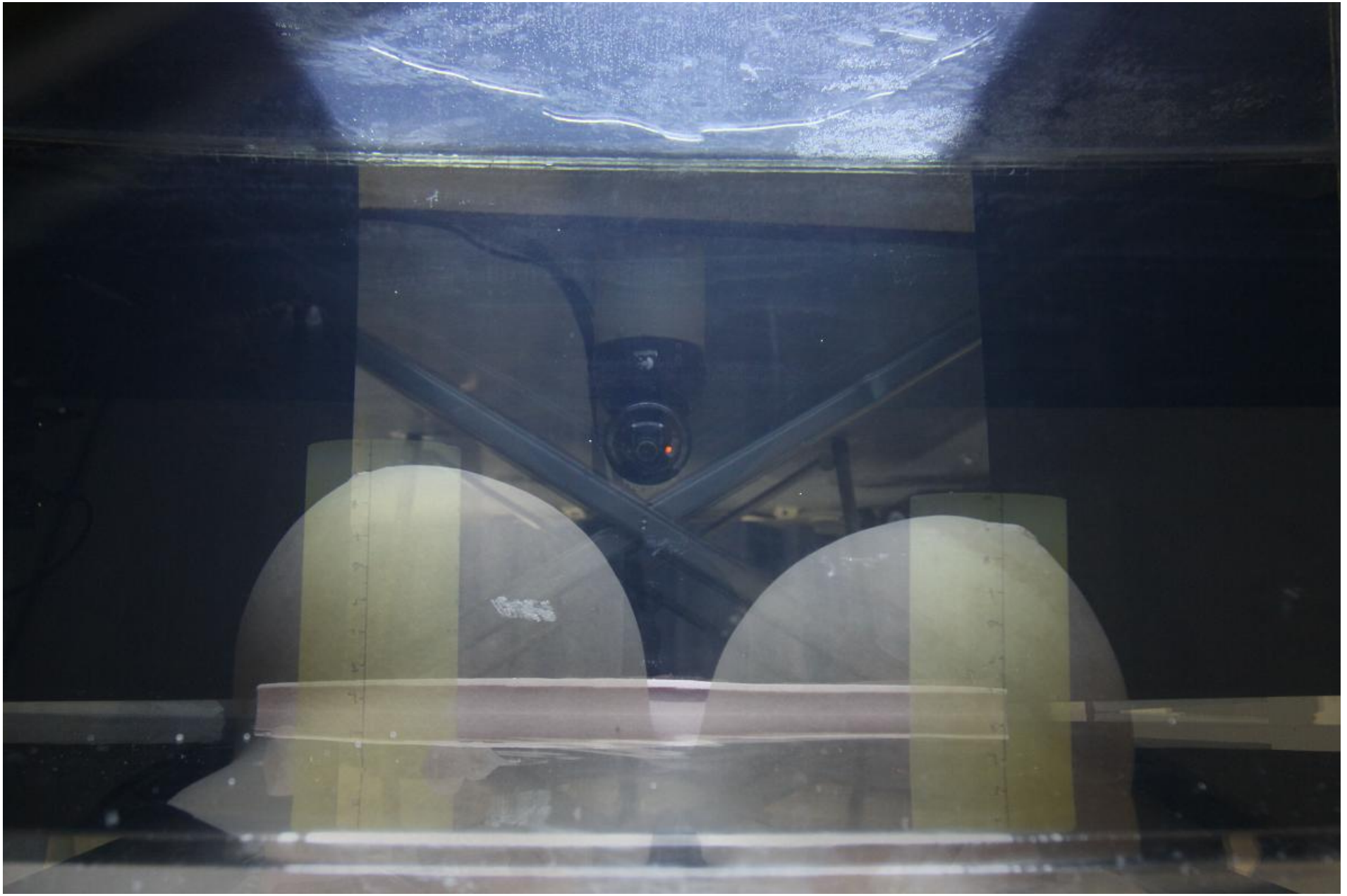


Two DSLR's, webcam, LED panel uplight, and new sensor on base



Breast profiling study

- Data being analysed, but early conclusions are that breast buoyancy in water is pronounced in the prone position: examining literature (typically for MRI data, in air) shows that pendant breast lengths for comparable cup sizes are at least 25% smaller
- Differing dimensional findings over age range of 20-70, for comparable cup sizes, showing anatomical differences
- Breast movement is minimal over 2 minute durations
- Informative on patient positioning (arms up or down) and comfort, particularly for consideration of older and larger patients

Next steps

- Transmitter array design finalised and manufactured
- Incorporation of transmitters and sensors into the prototype scanning platform
- Testing of scanning system using anatomical phantoms and lesioned test objects
- Clinical demonstration of system on patients of known pathologies

Thank you

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NHS
National Institute for Health Research

Acknowledgements

The project team!

Technology Strategy Board
Driving Innovation