CCAUV/17-54

Phase-insensitive Ultrasonic Computed Tomography (piUCT) for the diagnosis of breast disease

Bajram Zeqiri
Acoustics & Ionising Radiation Division
National Physical Laboratory, UK

CCAUV11 Meeting, September 21-22

Background (I)

NPL National Physical Laboratory

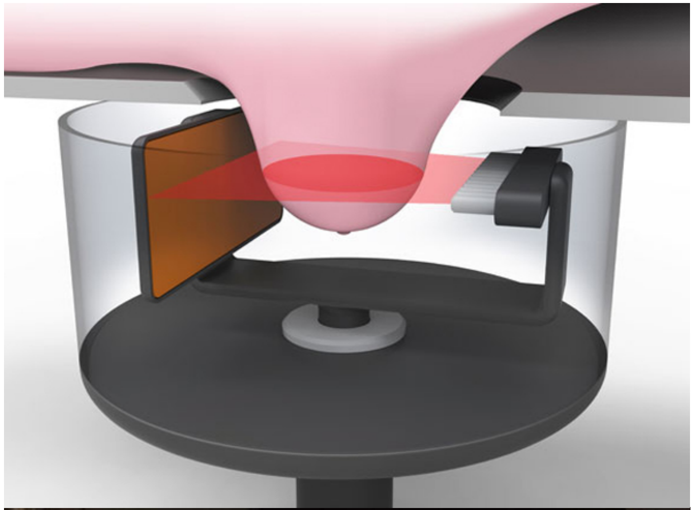
- Within the UK, over 50,000 women are diagnosed with breast cancer per year

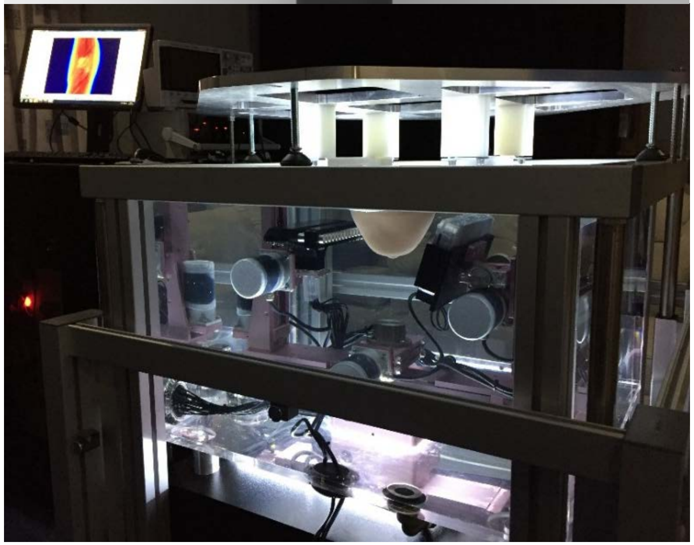
- X-ray Mammography is difficult to apply in younger women with dense breast tissue. These have an increased breast cancer risk.

- About 30% of all mammograms are of questionable value with unwanted artefacts.

- Only one in three biopsies are found to be malignant meaning that 92,000 unnecessary procedures are carried out, at a cost of ~£35 million to the NHS.

- NPL, University Hospitals Bristol, Precision Acoustics, Acoustic Polymers Ltd and Designworks have developed a prototype clinical system for a new breast screening technique - using ultrasound computed tomography (UCT).





Background (II)

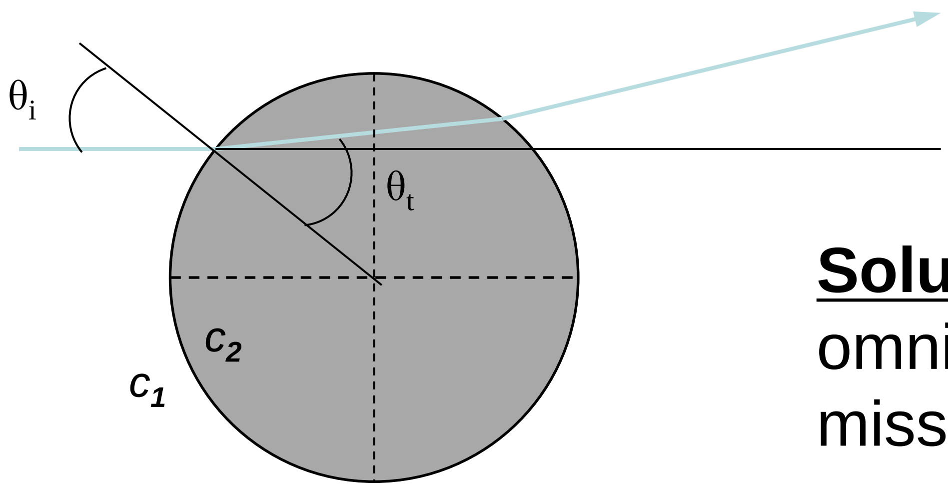
National Physical Laboratory

- Ultrasonic Computed Tomography (UCT) is being investigated for whole breast applications;
- Reconstructions (using existing technologies) are strongly affected by artefacts, particularly when based on ultrasound attenuation of tissue;
- These artefacts arise due to the nature of the detectors used, in particular that they are ***phase-sensitive***;
- In the 1980's, ***phase-insensitive*** detectors based on Cadmium Sulphide acoustoelectric sensors (1980s) seemed to show promise, but were far too insensitive;
- The project developed a UCT system based on ***phase-insensitive*** detector(s) that exploit the pyroelectric effect in a thin polymer.

- Characteristic properties of biological tissues

Speed of sound [m/s]	***Fat***	***Breat fibroglandular tissue***	***Fibroadenoma***	***Carcinoma***	***Cyst***
Wiskins *et al. 2011*	1430 -1460	1550 -1575	1550 -1585	1585 -1630	1520-1540

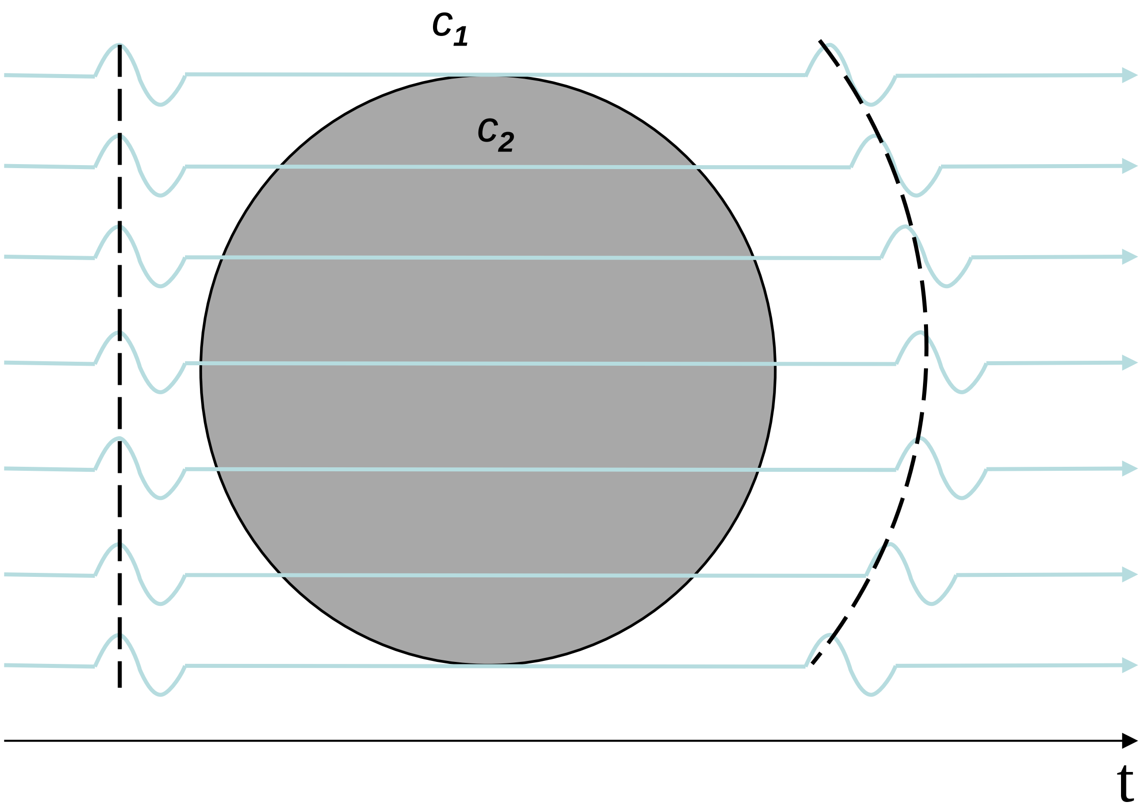
- Refraction of ultrasonic wave-fronts



Snell's law

<u>Solution</u>: need a large omnidirectional sensor to avoid missing refracted radiation

- Distortion of travelling acoustic wave-fronts



$c_2 > c_1$

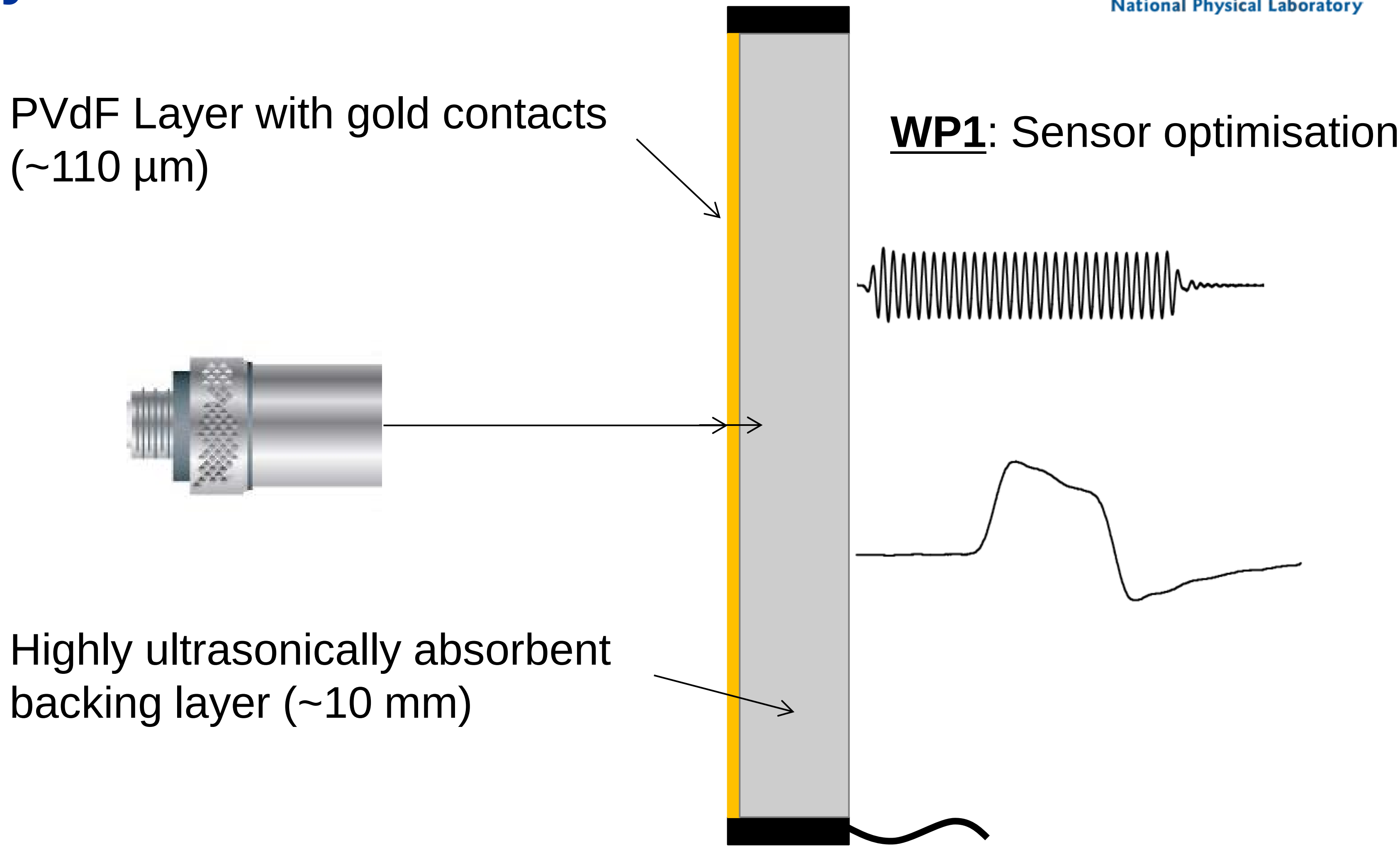
Solution: need a phase-insensitive (PI) detector

Biological tissue	α (dB cm^{-1}) 1 MHz	α (dB cm^{-1}) 2.5 MHz	Speed of sound (ms^{-1})
Subcutaneous fat	0.89	1.71	1470
Internal fat	0.92	1.8	1470
High attenuation tumour	0.92	3.2	1549
Cyst	0.06	0.38	1569
Glandular parenchyma	1.02	2.94	1515

Duric et al. Development of ultrasound tomography for breast imaging, Medical Physics, 32 (5), 2005.

Phase-insensitive (PI) detectors

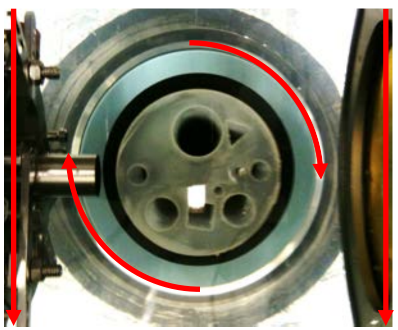
Pyroelectric Detection

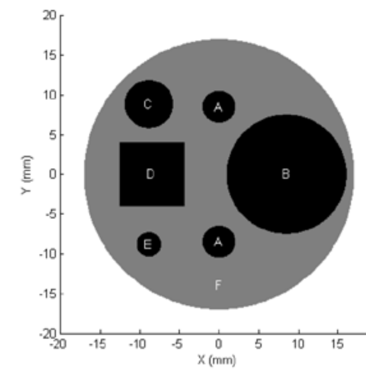


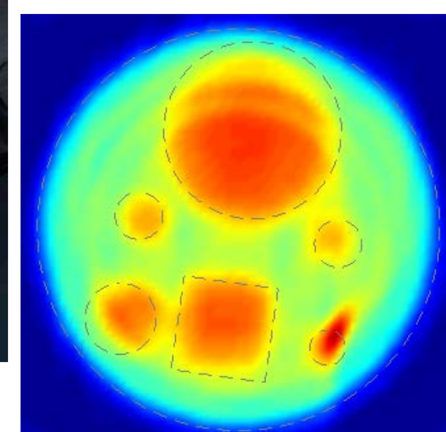
B. Zeqiri, P. N. Gélat, J. Barrie and C.J. Bickley. “A Novel Pyroelectric Method of Determining Ultrasonic Transducer Output Power: Device Concept, Modelling and Preliminary Studies”, IEEE Trans. Ultrason., Ferroelectr., Freq. Contr., Vol. 54, No. 11, 2318-2330, 2007.

NIHR PoC funding

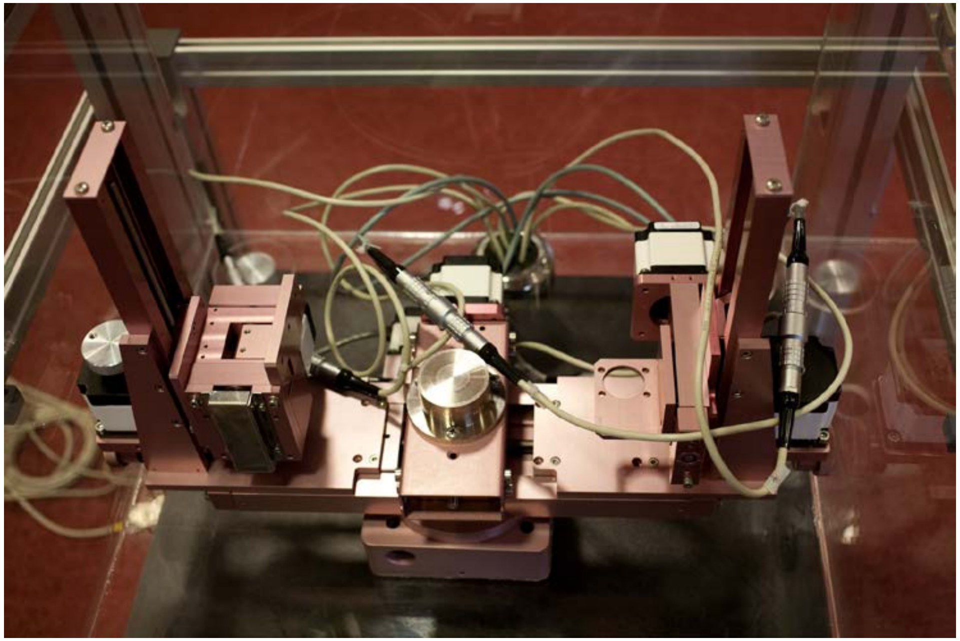
- Bajram Zeqiri, Christian Baker, Giuseppe Alosa, Peter NT Wells and Haidong Liang, “Quantitative computed tomography using phase-insensitive detectors”, *Phys. Med. Biol.* 58 (2013), 5237-5268.

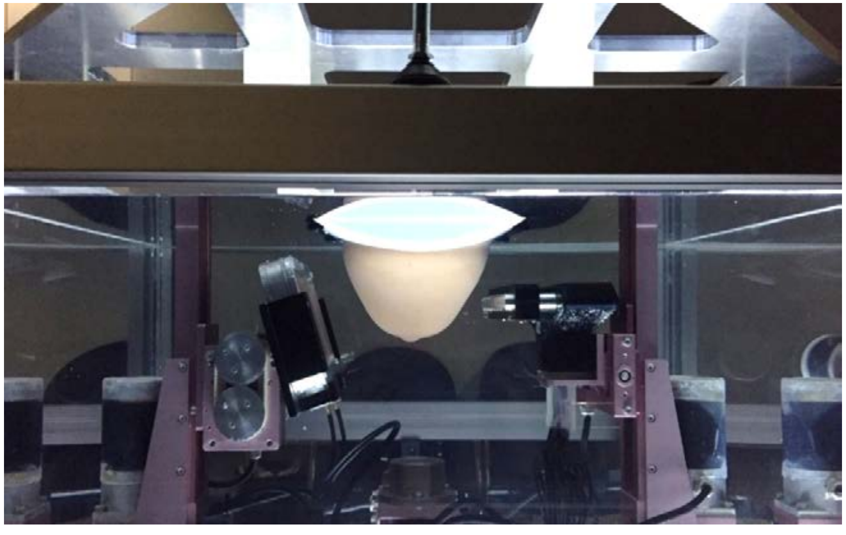






Completed system





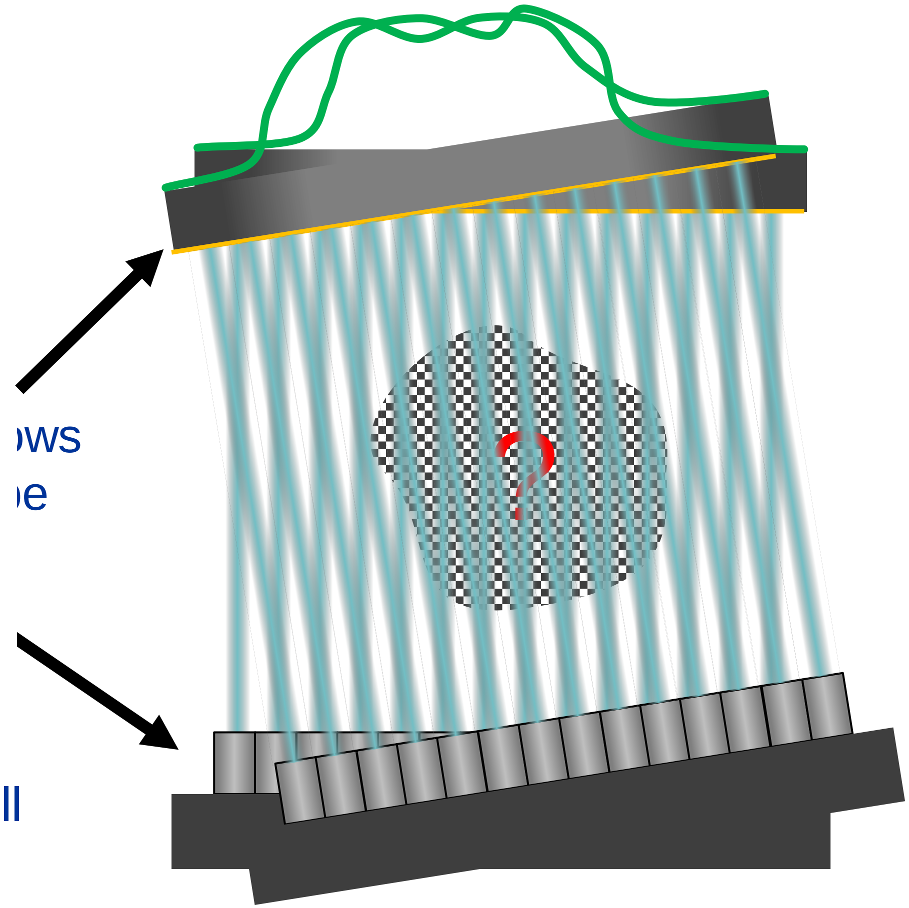

NPL
Improved ultrasound CT of breasts for cancer screening
WARNING
Class FLEXITABLE

piUCT Scanning Process

- piUCT uses a parallel beam tomographic configuration
- 14 parallel transmitters
- 1 large area sensor
- ***Frame***: each of the transmitters

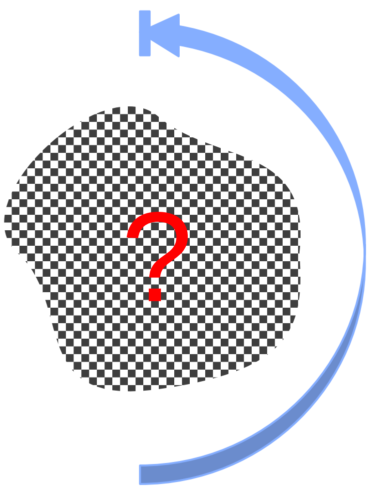
- ows e

and sensor together builds up the full picture around the object



piUCT Scanning Process

- The transmitters and receiver rotate the full 180º together
- ***Scan***: a series of projections from multiple angles around the object
- An image of the object is reconstructed from a full set of projections



Real Object

Set of Projections

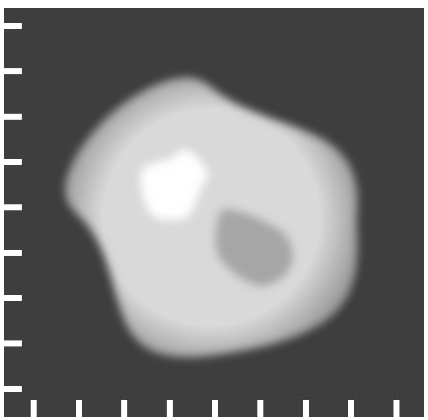
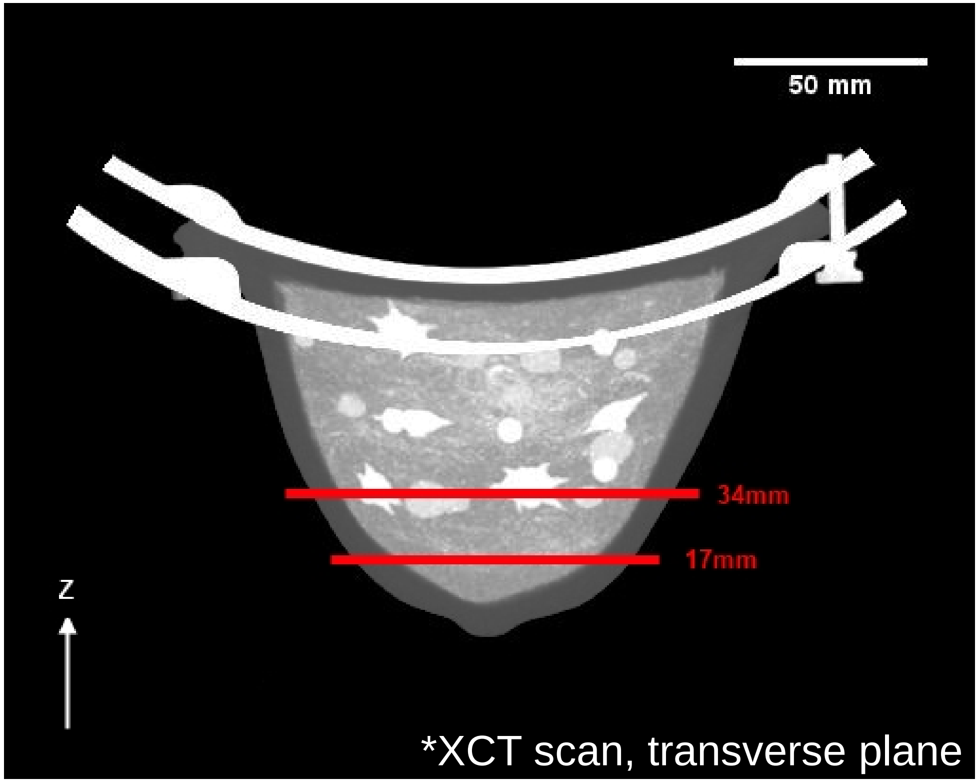
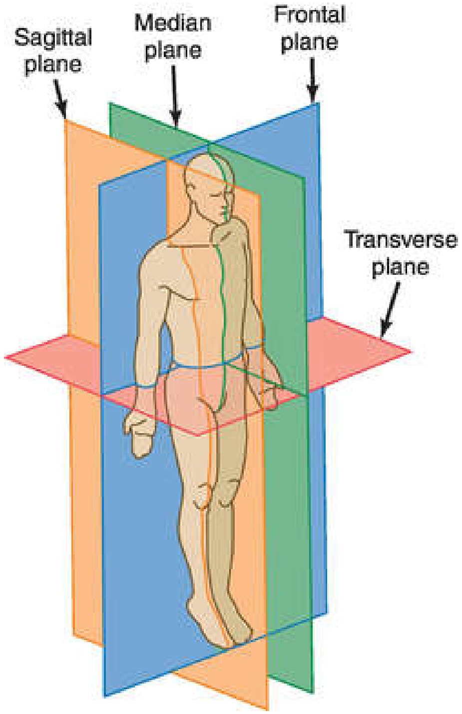


Image of Object

First piUCT Scans – CIRS Phantom

- Breast phantom scanned by XCT and MRI at Bristol
- Scans used to compare to the piUCT system
- Suitable scan planes identified





XCT vs. piUCT comparison (z=17 mm)

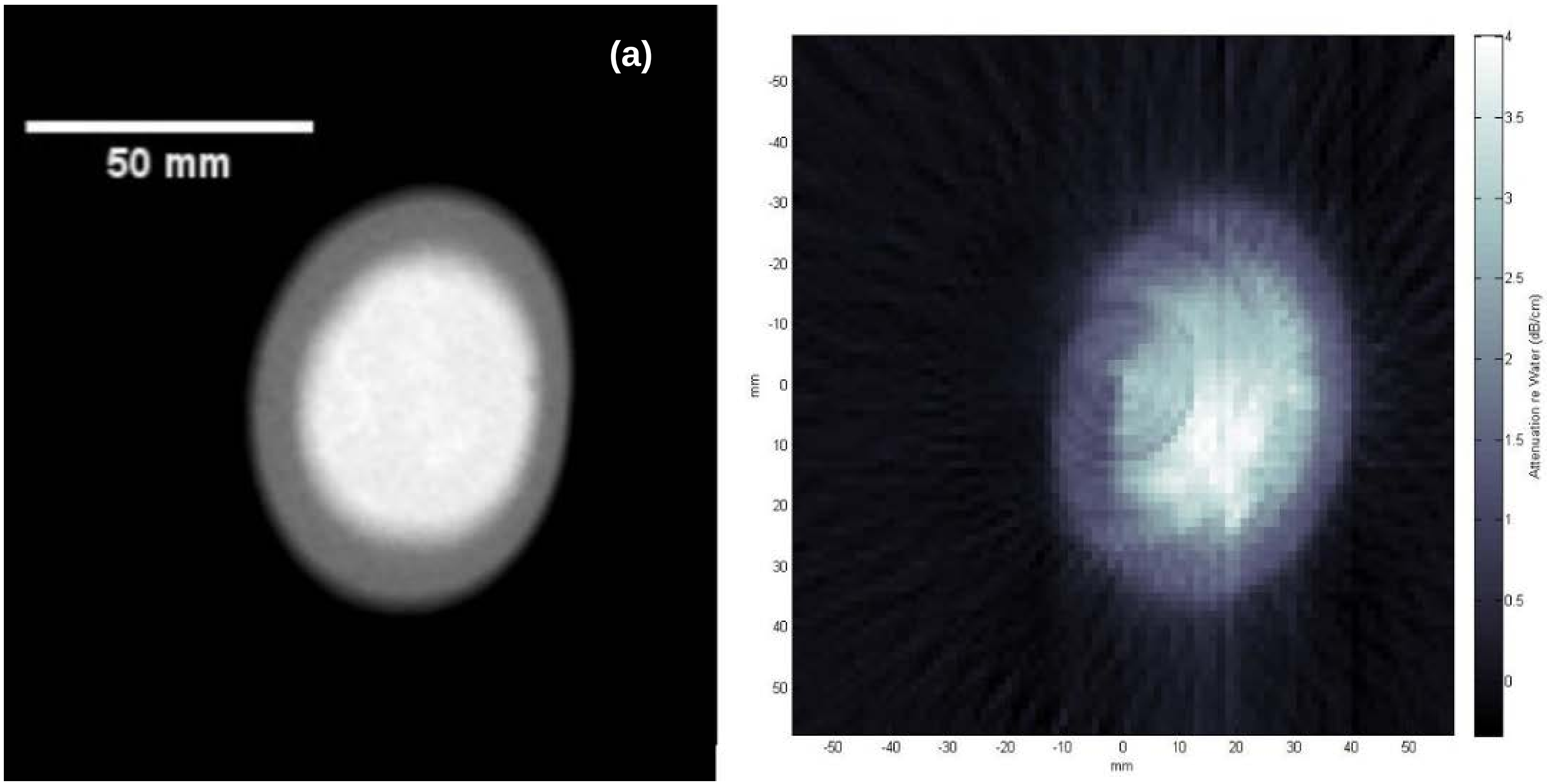
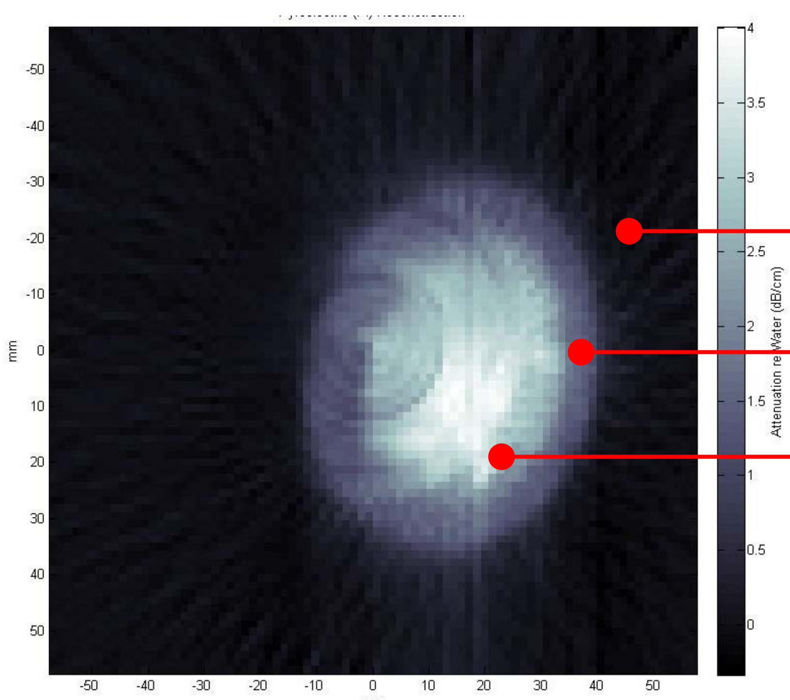


Figure A comparison of two imaging modalities of a CIRS Model 043 breast phantom in the frontal plane at z = 17mm by: (a) XCT and (b) piUCT scans

Quantitative Comparison

National Physical Laboratory

- Material measurements on CIRS phantom samples performed at NPL
- piUCT scans slightly underestimate attenuations



Material Type	Material Measurements (dB.cm-1)	piUCT Scan Data (dB.cm-1)
Water	-	-
Z-Skin	1.5	1.1 - 1.4
Bulk Material	3.6 - 3.9	2.9 – 3.8

Summary

- We have developed a through-transmission ultrasound tomography system for imaging of breast tissue.
- The system uses a large area phase-insensitive detector which should remove many of the artefacts see in UCT.
- The system uses an array of 14 transducers operating at 3.2 MHz and is currently being optimised for Quantitative Imaging performance.
- Initial scans completed on a CIRS phantom are encouraging.
- The technique shows promise as an operator-independent, non-ionising, quantitative technique for assessing the pathology of soft tissue.