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What can THz do for NDT of composites?

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What is terahertz (THz)?

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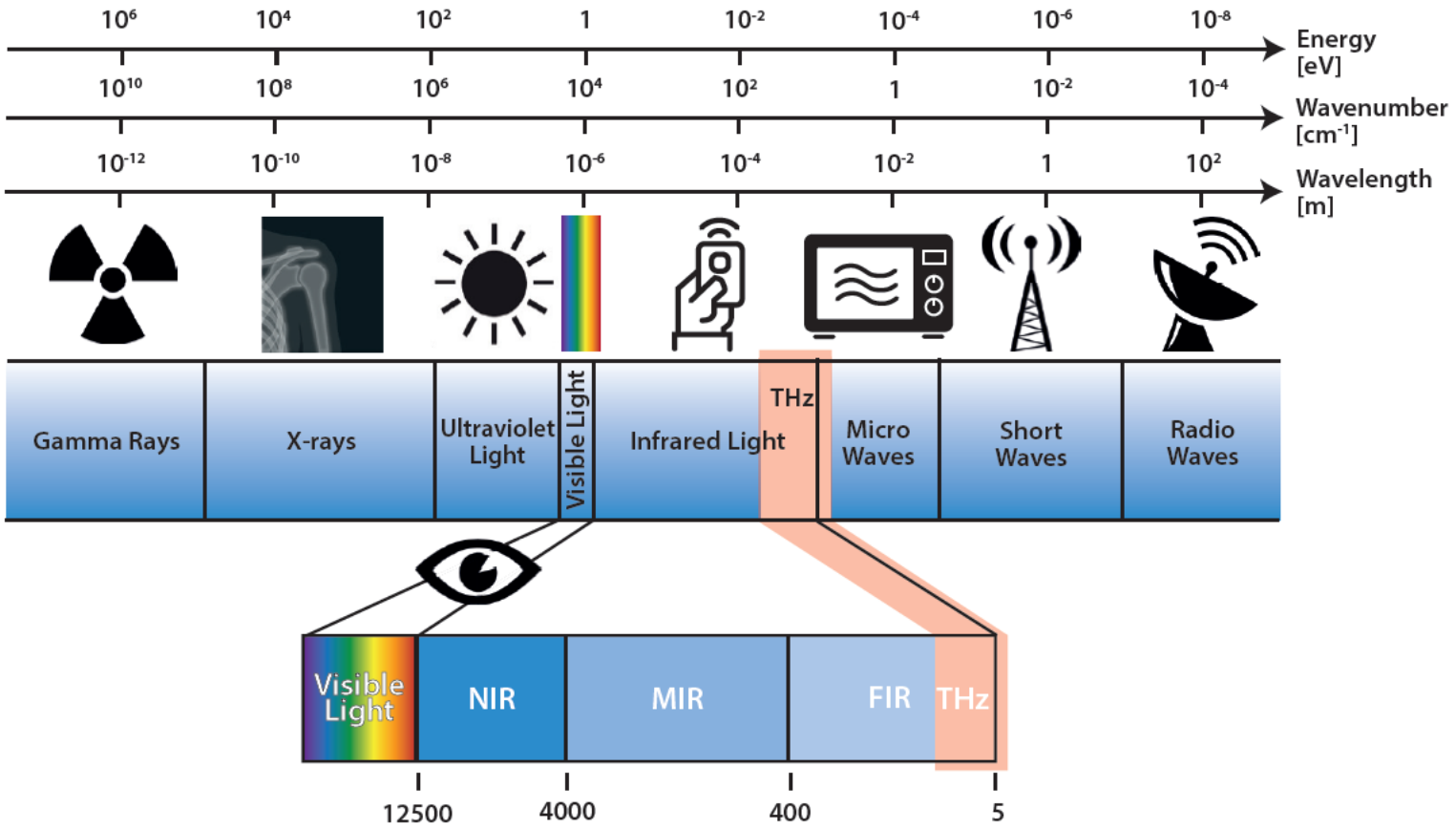

How does THz work?
Time-domain spectroscopy (TDS)

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TDS is the predominant platform for THz measurements:
∗ photonic ∗ pulsed ∗ broadband ∗ coherent

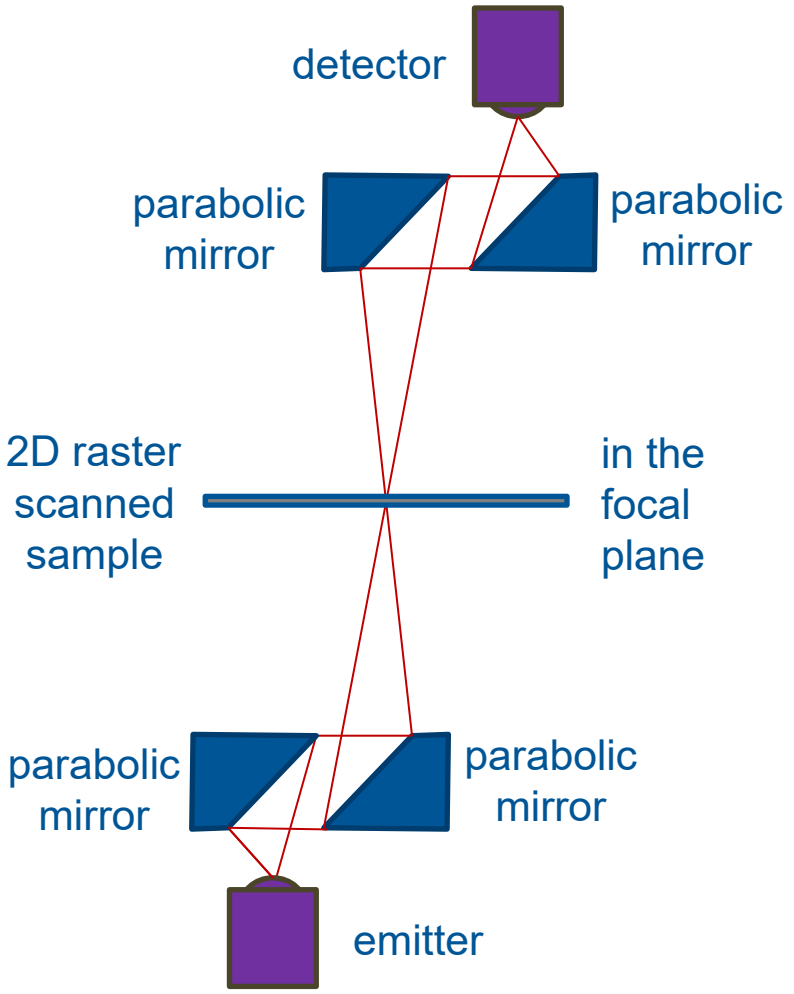
Measures

- Amplitude
- Phase
- Time-of-flight

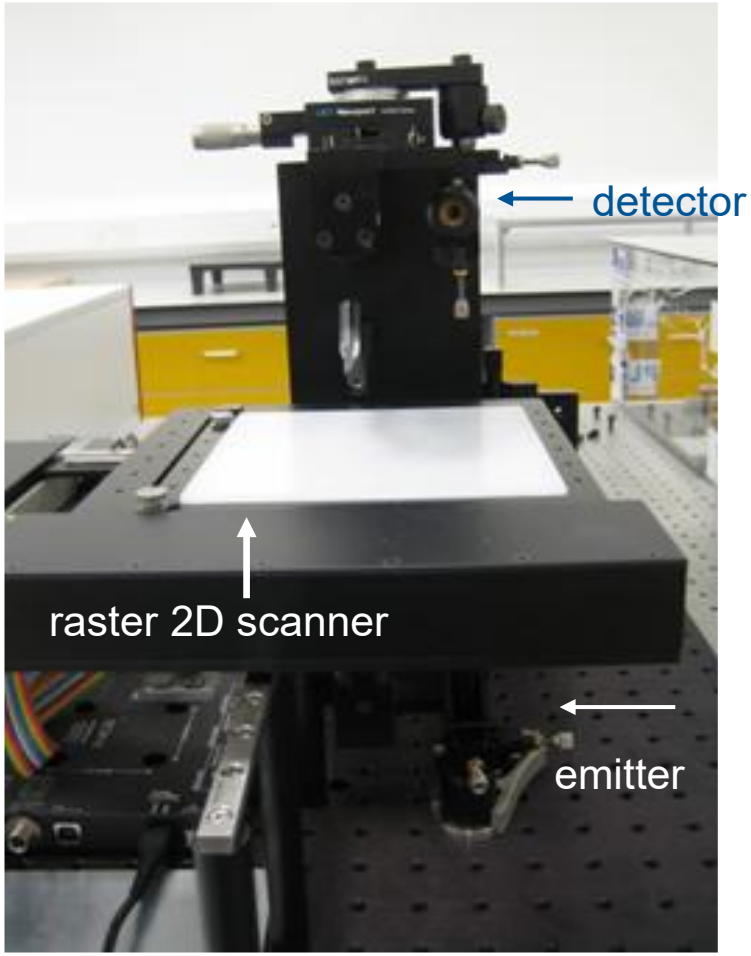
TDS performance

- Broadband operation
- One-shot spectral acquisition
- Bandwidth: 0.1 - 6 THz
- Frequency resolution 1-10 GHz
- Polarised beam and polarisation-sensitive detection

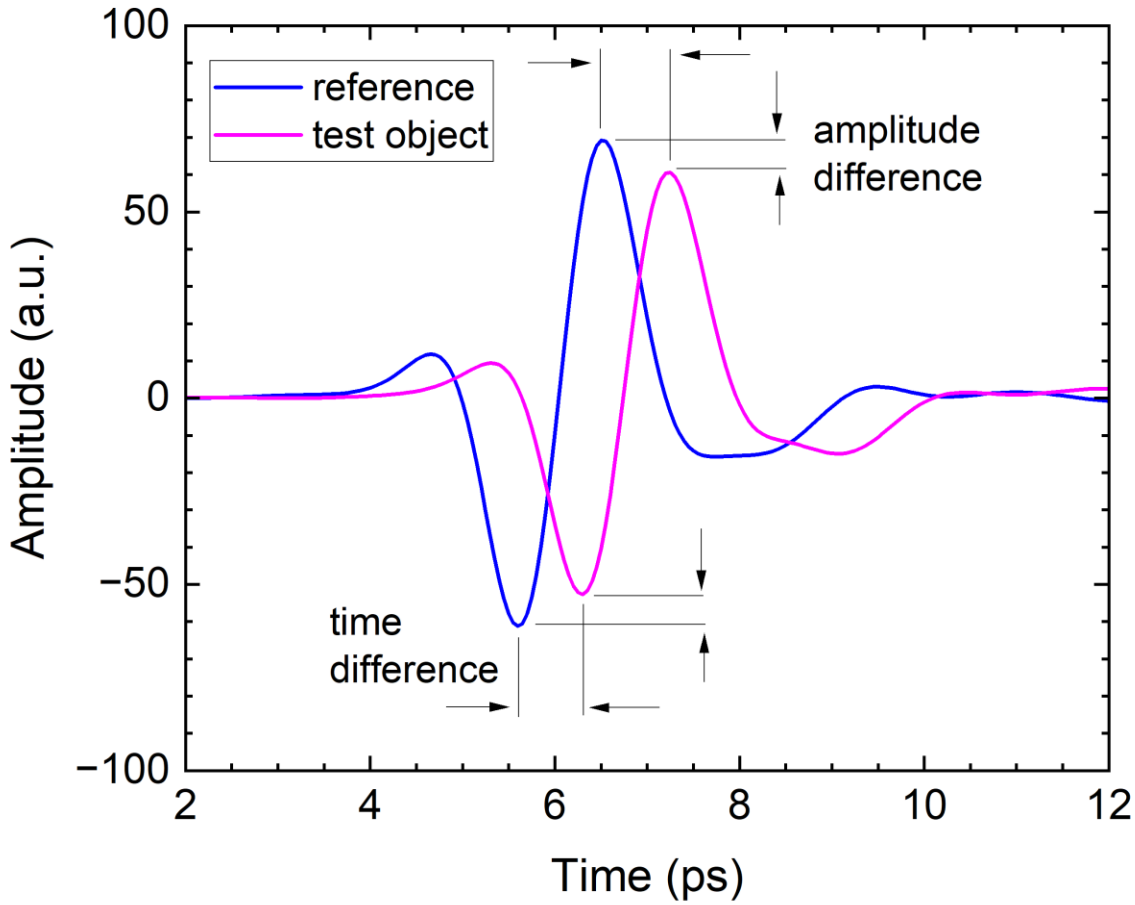
THz time-domain 2D imaging



THz imager



How does THz TDS work?



Defects in composite sheets

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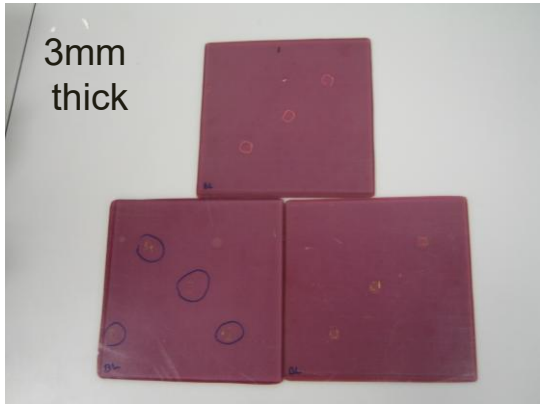
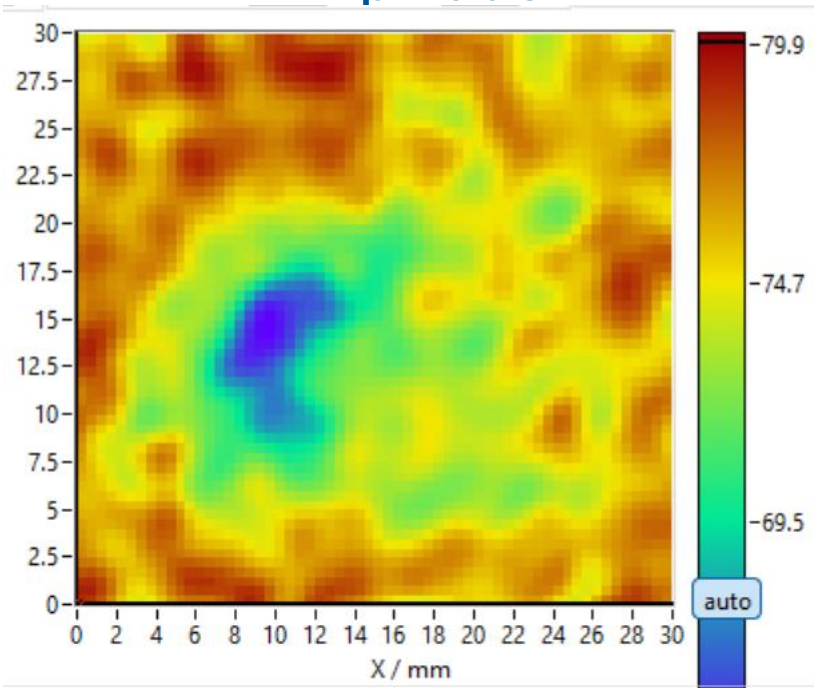
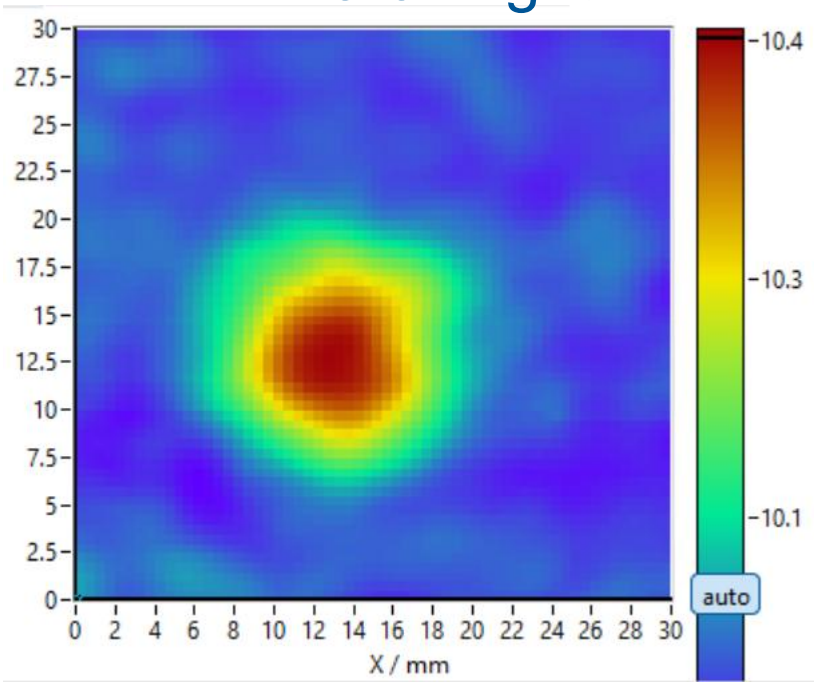
Time-of-flight measurements produce better image resolution than **amplitude** measurements



Amplitude

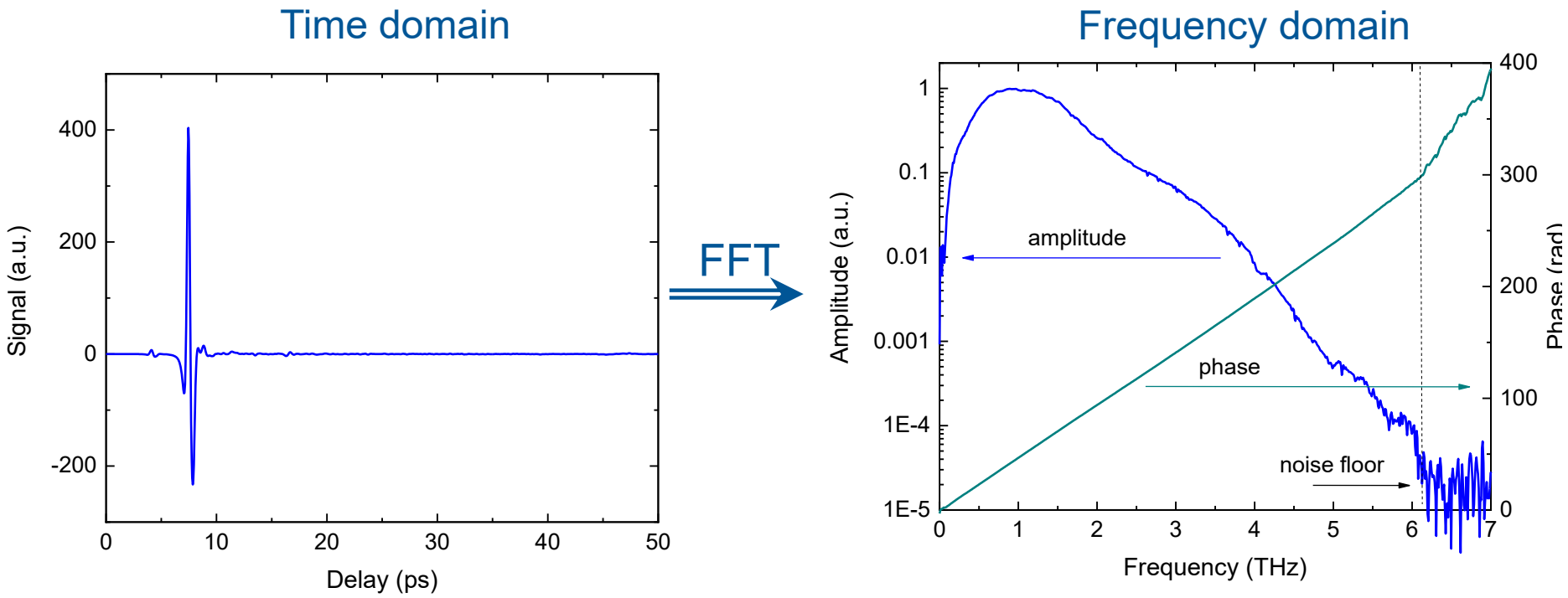


Time-of-flight

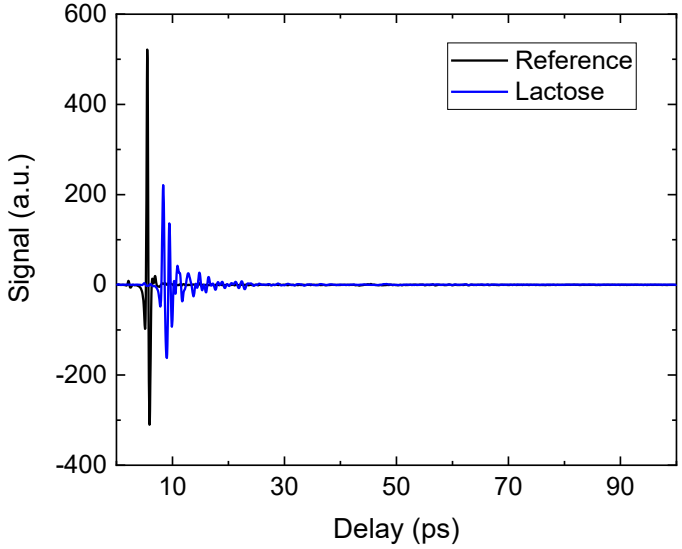


How is spectral data obtained?

Amplitude and phase spectra obtained via Fourier Transform

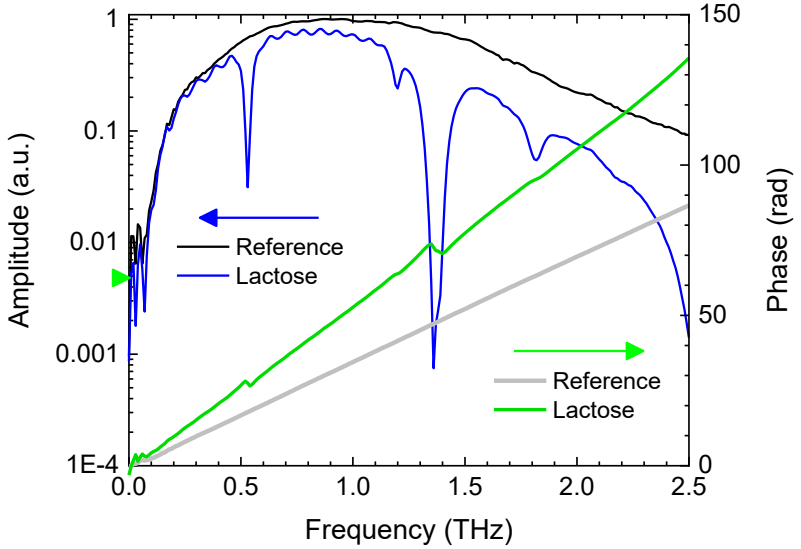


Example: lactose monohydrate

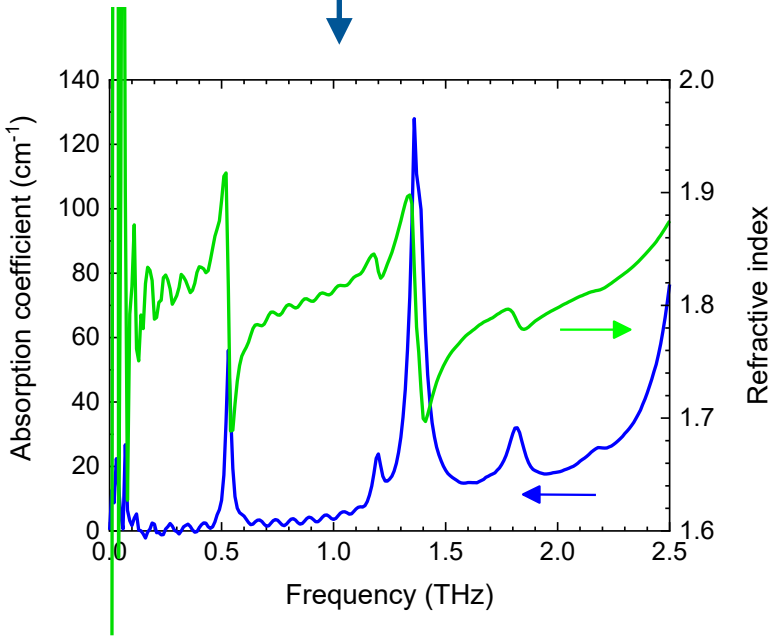


Time-domain data

Frequency-domain data (via FFT)



Calculated optical properties



Why use THz for NDT?

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- Non-contact, non-ionising, non-destructive
- Terahertz waves can penetrate through materials that are opaque in the visible and near-infrared
- Multi-layer coatings can be inspected
- Sensitive to structural inhomogeneities
- Complex internal structures can be imaged
- Hidden defects can be revealed
- Can detect corrosion under insulation
- Porosity can be accurately measured
- Moisture levels can be accurately measured, and moisture distribution can be imaged

Monitoring polymer on a roll-to-roll line

Defect detection and imaging

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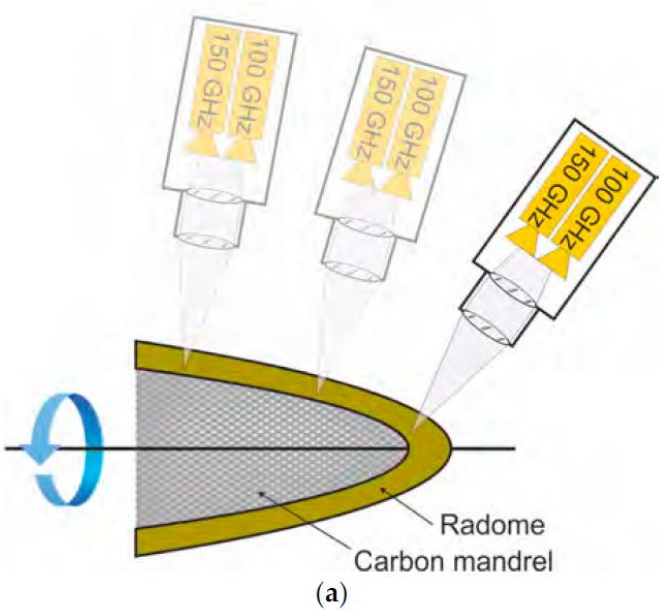
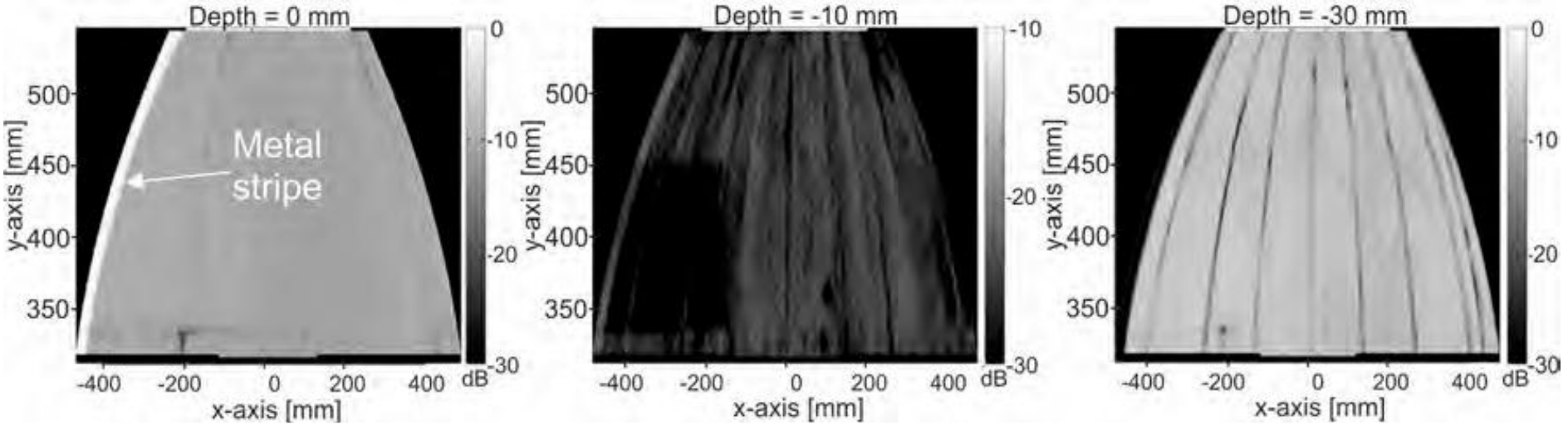
- Delamination
- Kissing bonds
- Cracks
- Inclusions
- Moisture ingress
- Compositional variations

Checking pipe integrity

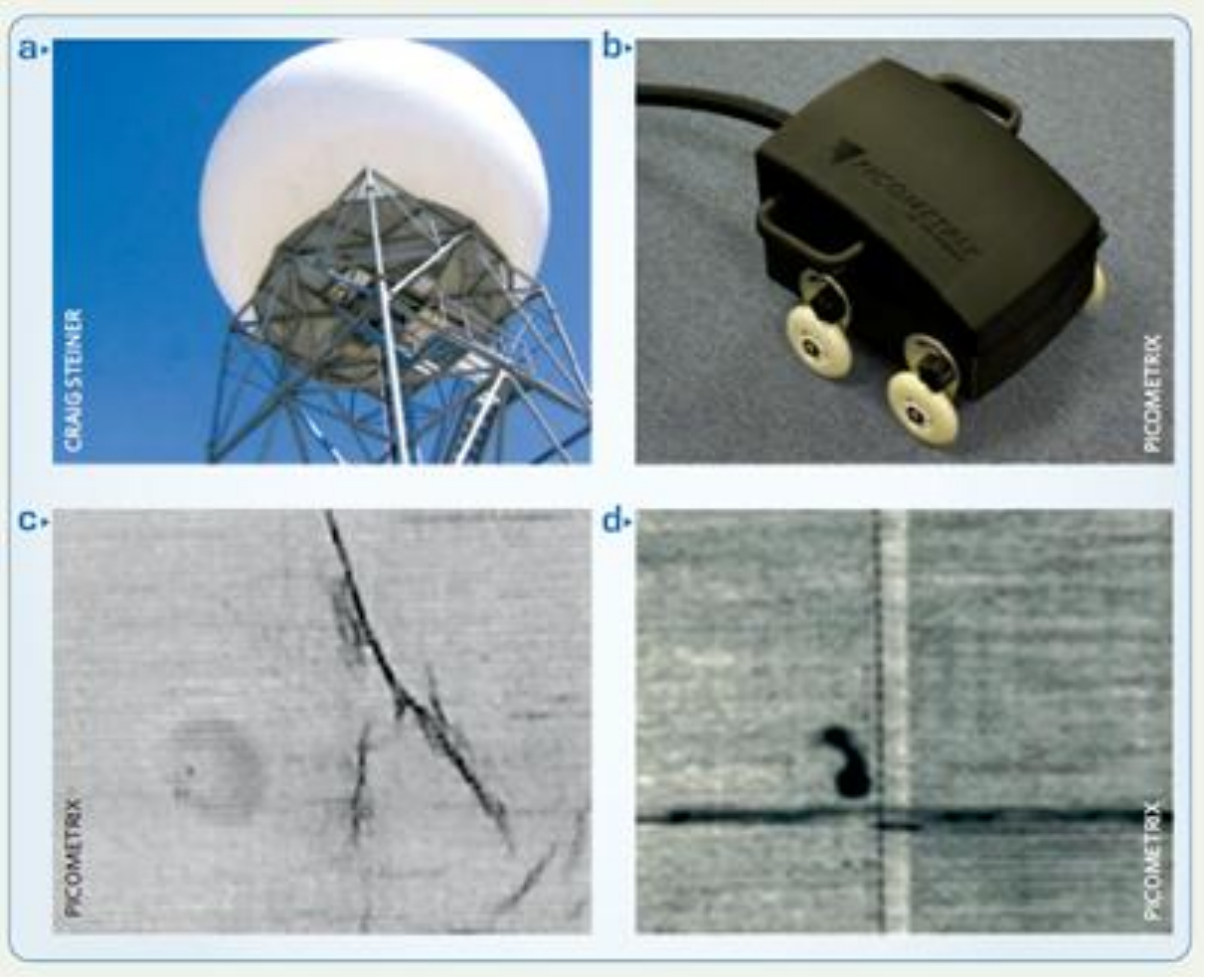
Radome inspection



Friederich, et al.
Photonics. Vol. 5. No. 1.
MDPI, 2018.

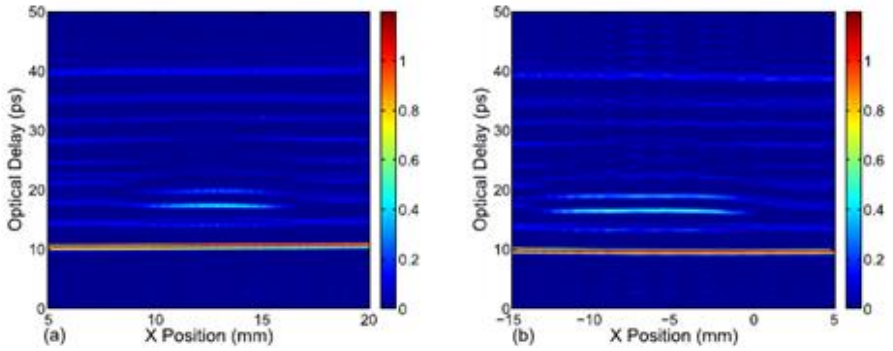


Radome inspection



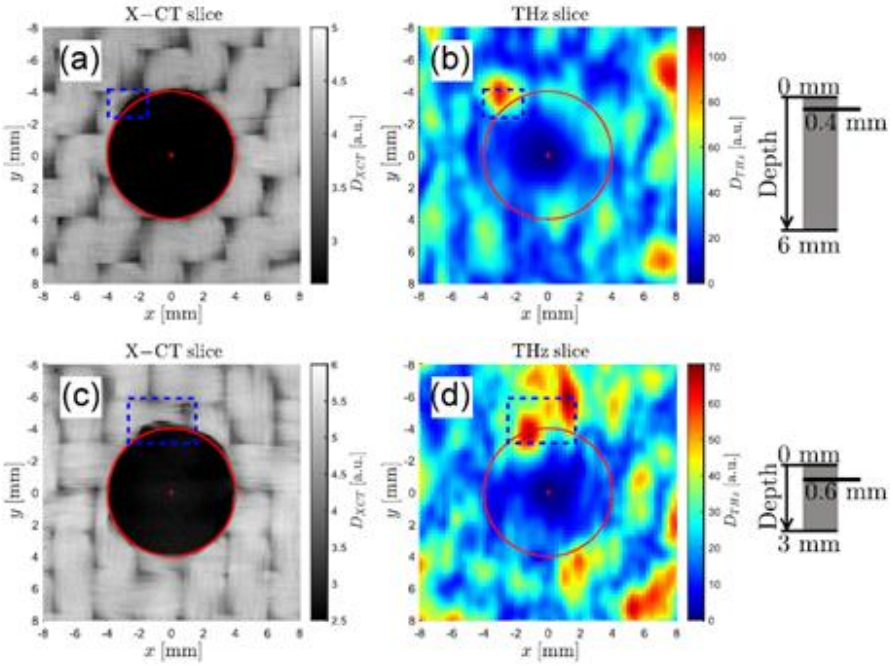
Duling, Irl, and David Zimdars. "Revealing hidden defects." *Nature Photonics* 3, no. 11 (2009): 630-632.

Defects in glass-fibre reinforced composites (GFRC)



Two delamination defects in GFRCs

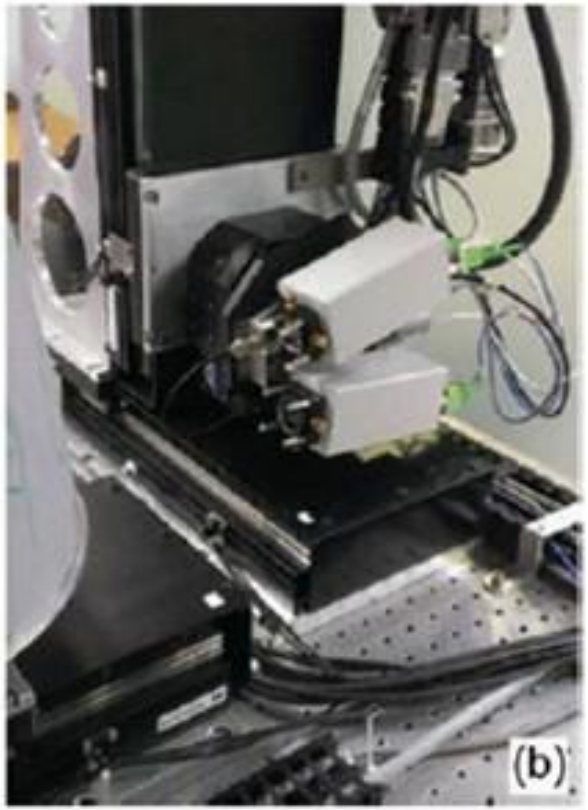
Dong *et al*., *Composites Part B: Engineering* 79 (2015): 667-675.



X-ray and THz images of two drill-induced defects in GFRC

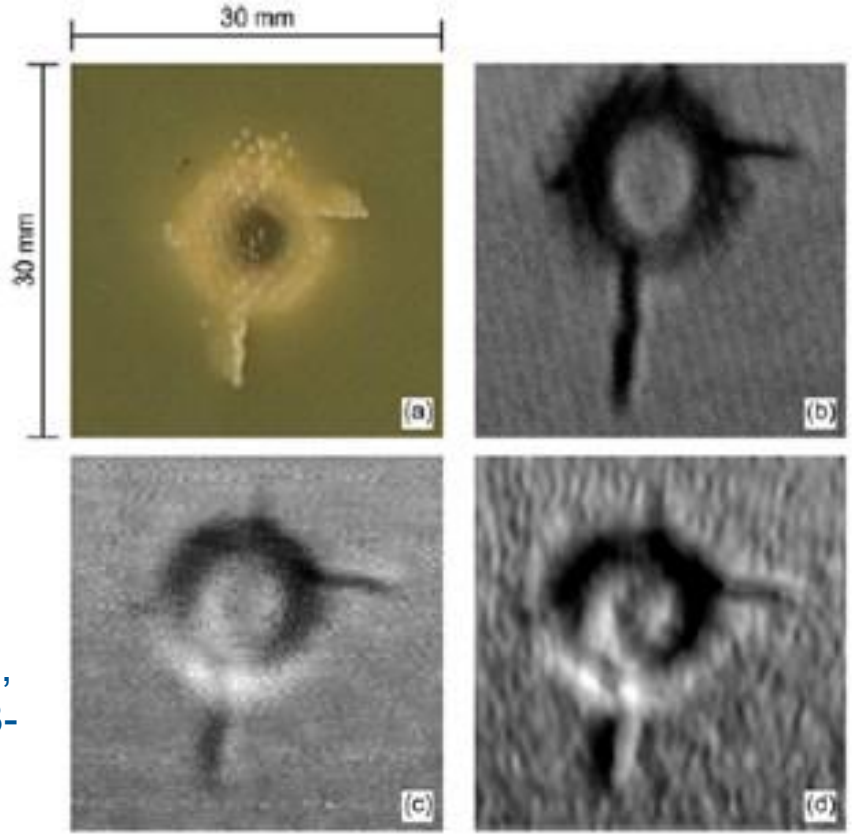
Fosodeder *et al*., *Sensors* 25, no. 3 (2025): 851.

Defects in composite panels caused by impact



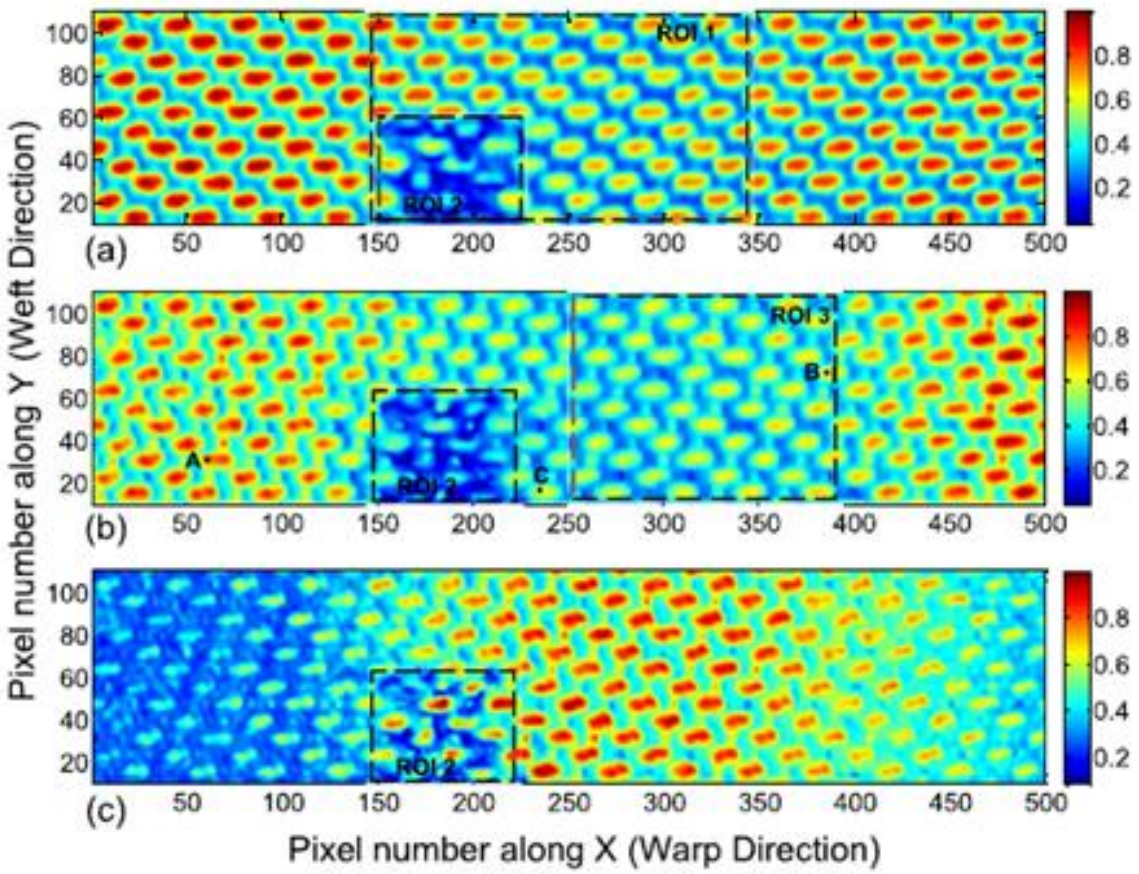
Photograph of the THz reflection scanner mounded on a 3D stage

Ospald *et al, Optical Engineering* 53, (2014): 031208-031208.



a) Photograph of a defect in composite panel caused by impact. b, c, d) THz reflection images using different types of data processing.

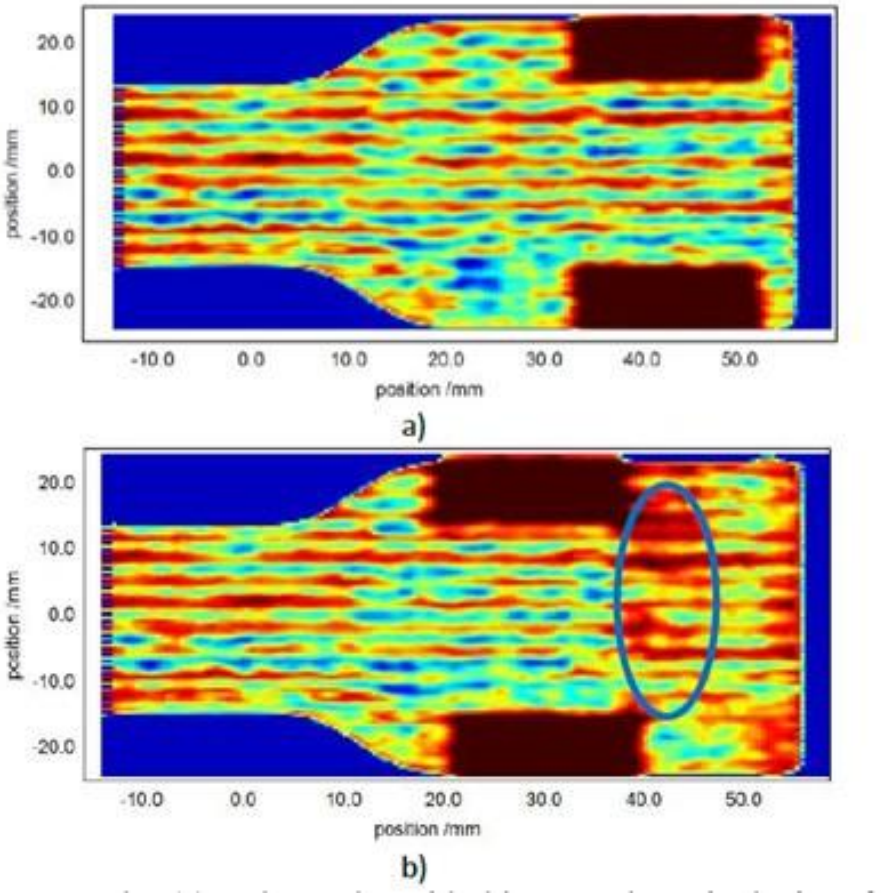
Defects in carbon-fibre woven composite materials



THz c-scan images:
(a) THz polarization parallel to the warp direction
(b) THz polarization parallel to the weft direction
(c) subsurface signals with THz polarization parallel to the weft direction.

Dong et al., *NDT & E International* 99 (2018): 72-79

Moisture ingress



Moisture ingress in fibre-reinforced composite

Malinowski *et al.*, *Journal of Physics: Conference Series*, vol. 628, no. 1, p. 012100. IOP Publishing, 2015.

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Thank you

To learn more
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Measurement for Business - NPL