Improving detection and characterisation using multi-view TFM images

Paul Wilcox[1], Anthony J. Croxford[1], Nicolas Budyn[1], Rhodri L. T. Bevan[1], Jie Zhang[1], Artem Kashubin[2], Peter Cawley[2]

[1]University of Bristol

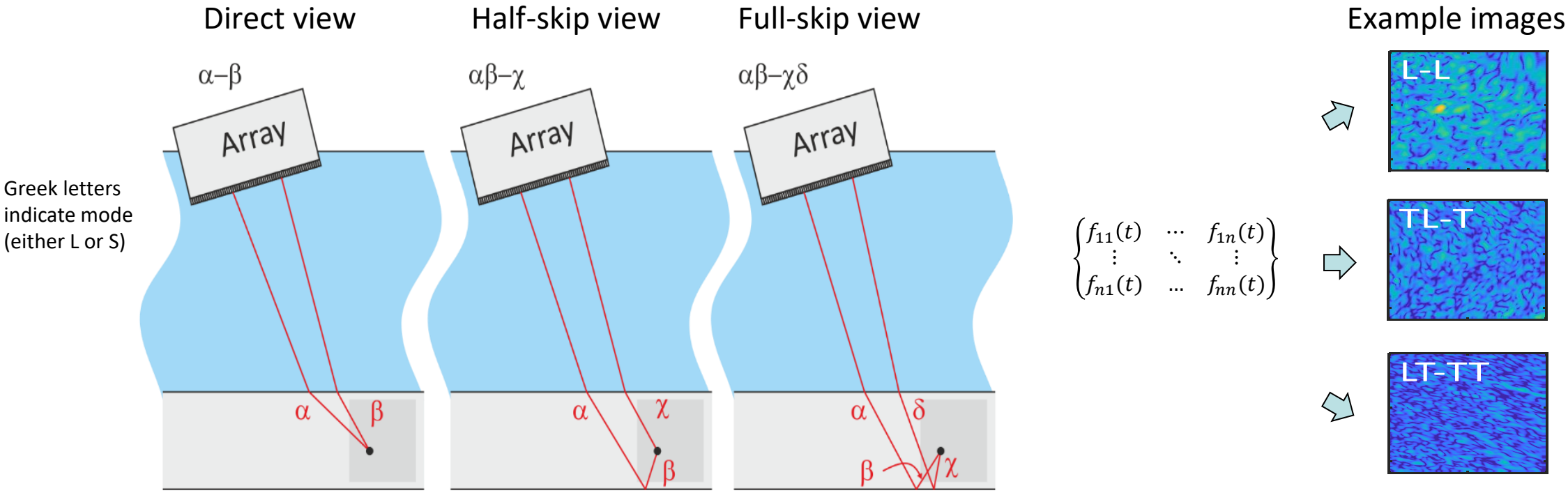
[2]Imperial College London

Outline

- Context and motivation
  - What are multi-view images and why are they useful?
- Detection
  - Artefacts, noise, signal model
  - Multi-view data fusion
  - Example results
- Characterisation
  - Fused image for large defects
  - General probabilistic approach for small defects

Context and Motivation

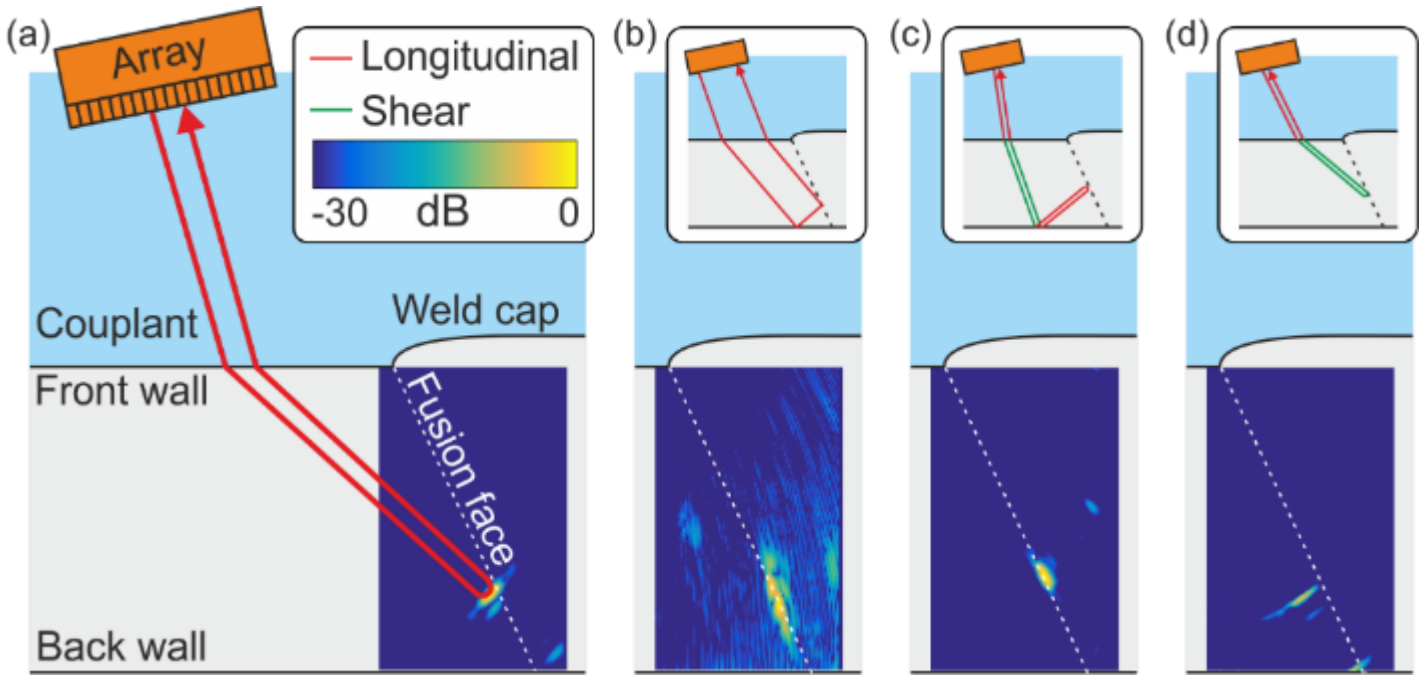
- Multi-view TFM images can be formed from same set of FMC data by exploiting mode conversions and reflections – oblique incidence example



- Multi-view images provide opportunity for improved detection and characterisation

Context and Motivation

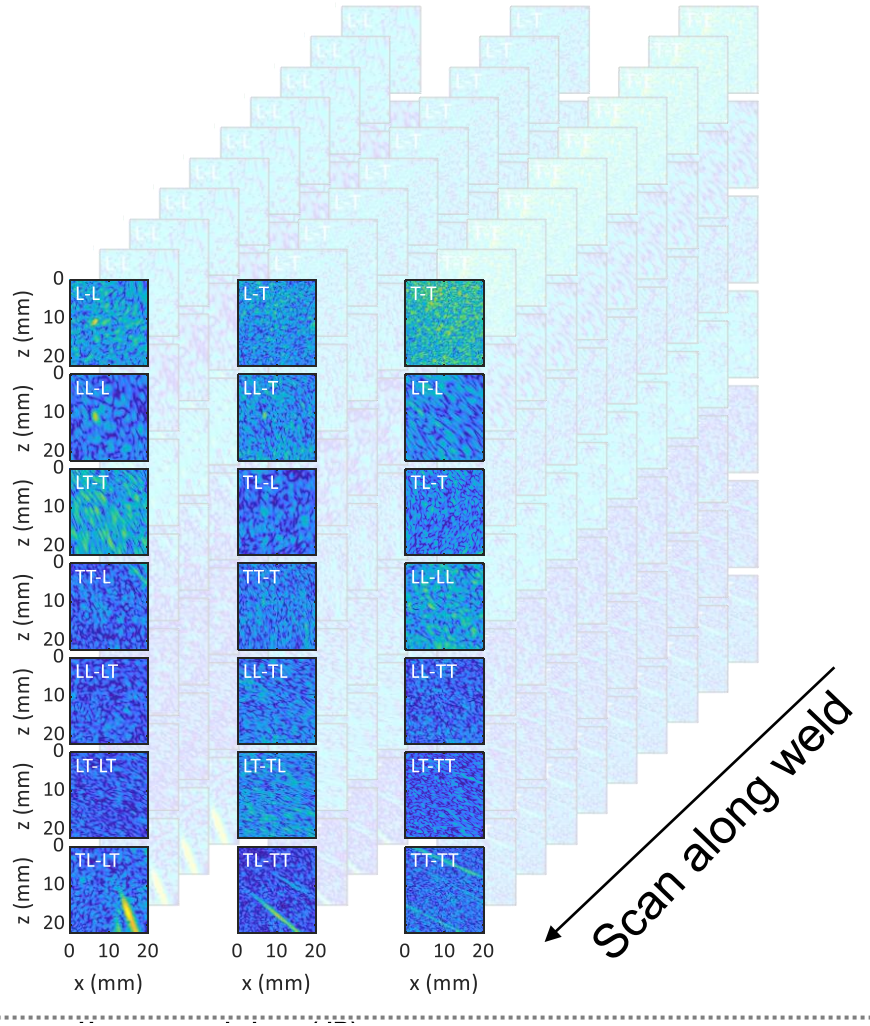
- How multi-views images help



Context and Motivation

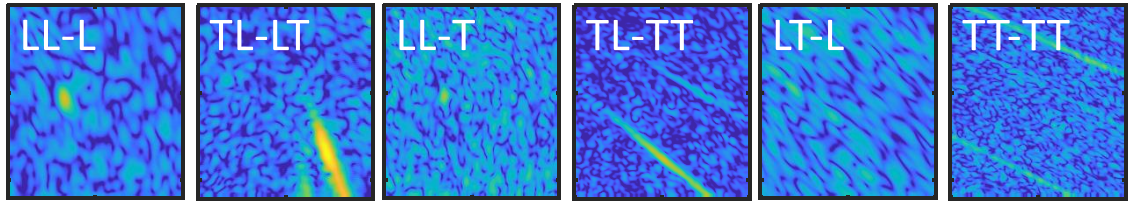
- Example raw multi-view data for oblique-incidence scan along weld
  - Each scan position generates 21 views
  - Scan positions every few mm
  - … a lot of data to analyse!

- Need tools to automate analysis

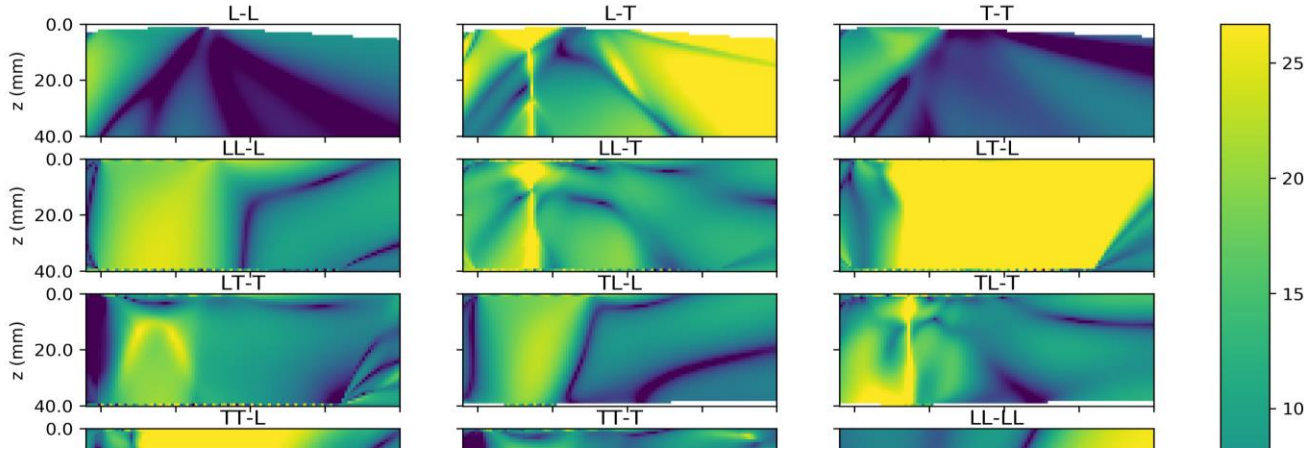


Detection

- Challenge: detectability of defect in each view depends on
  - Type, orientation and position of defect
  - Presence of geometric artefacts
  - Background image noise (e.g. microstructural)



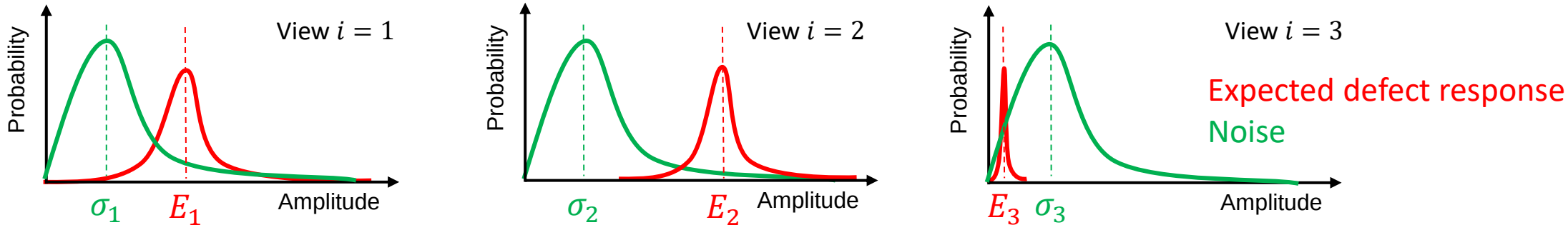
- Need systematic method of combining information from multi-view images …
  - Remove artefacts, characterise noise[1], sensitivity maps to estimate defect response[2]



1. Bevan *et al.*, *IEEE UFFC*, **66**, 79-90, 2019
2. Budyn *et al.*, *IEEE UFFC*, **66**, 1129–1139, 2019

Detection

- Example PDFs of noise and response to certain defect at one position, $\mathbf{r}$, in different views



- Fuse individual views, $I_i(\mathbf{r})$, to single image, $I(\mathbf{r})$, using modified matched filter tuned to defect[1]

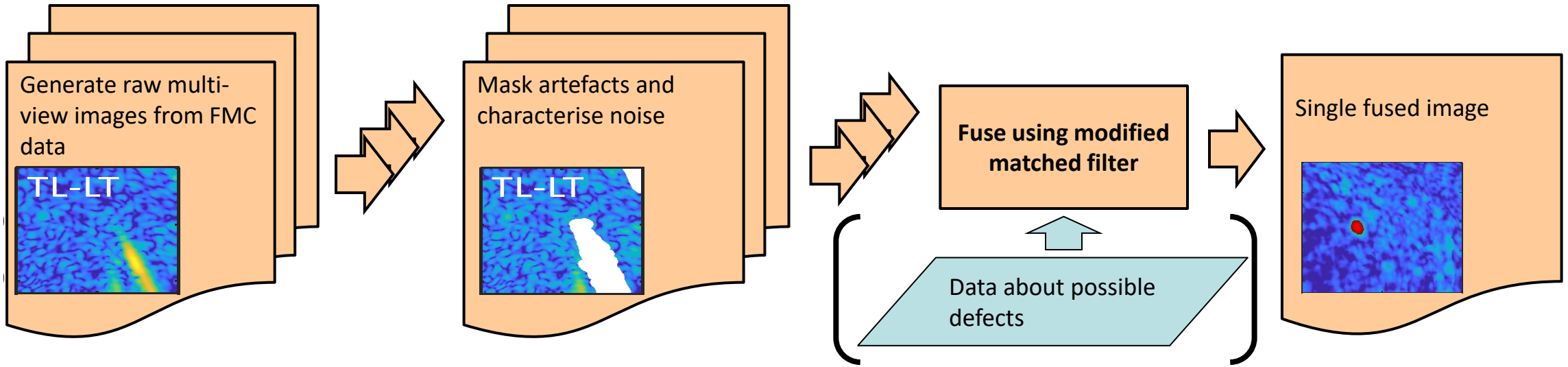
$$I(\mathbf{r}) \cong \sum_i \left[\sqrt{4 + \left(|I_i(\mathbf{r})| \frac{E_i(\mathbf{r})}{\sigma_i^2(\mathbf{r})} \right)^2} - 2 \right]$$

Contribution from i^{th} view

Weighting of contribution based on expected SNR

Detection

- Summary of workflow

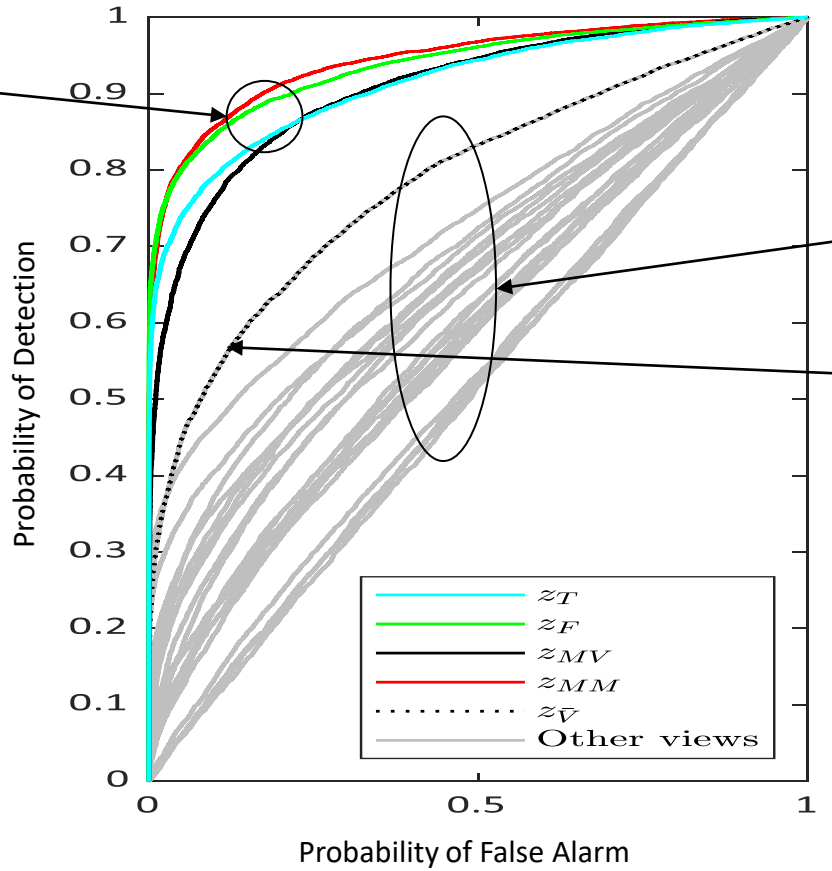


- Ultimately we will set a detection threshold, α, on the fused image

Detection

- Performance on simulated data for 49 different defects[1]

All the fusion methods do better than any individual view
Red is modified matched filter

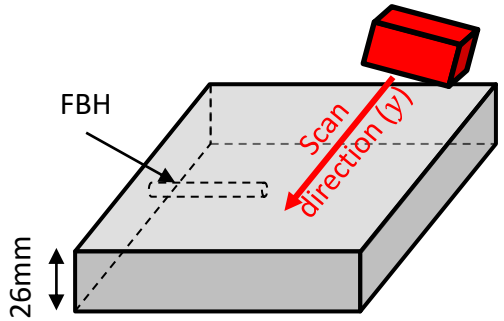


Detection performance of individual views

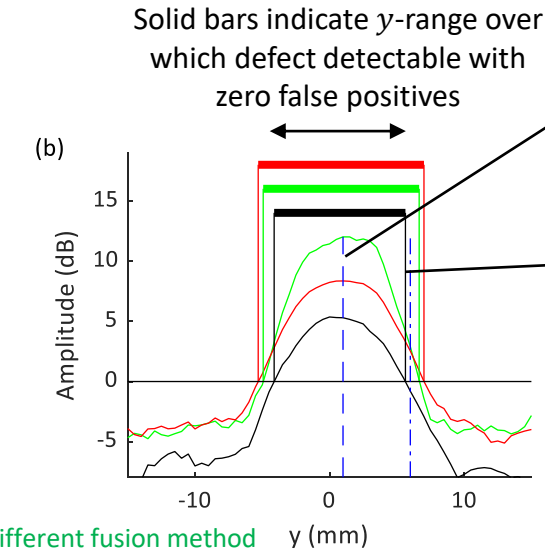
This is the individual view that has the best overall performance

Detection

- Performance on experimental data with ∅1mm FBH ‘Defect’



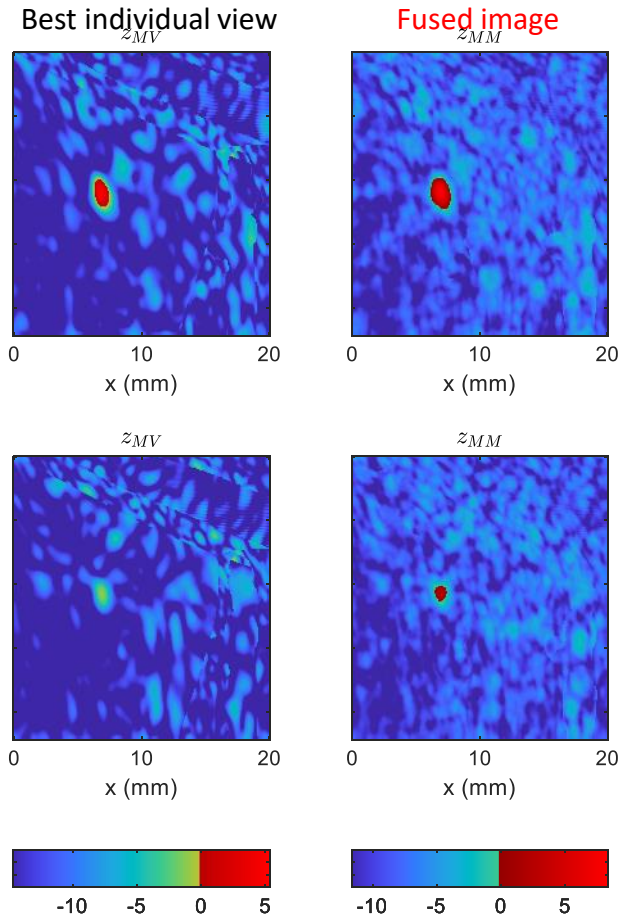
Fused image amplitude at defect location vs. y in dB relative to zero false-positive threshold



Ignore green line – different fusion method

Images at y-position of peak defect response

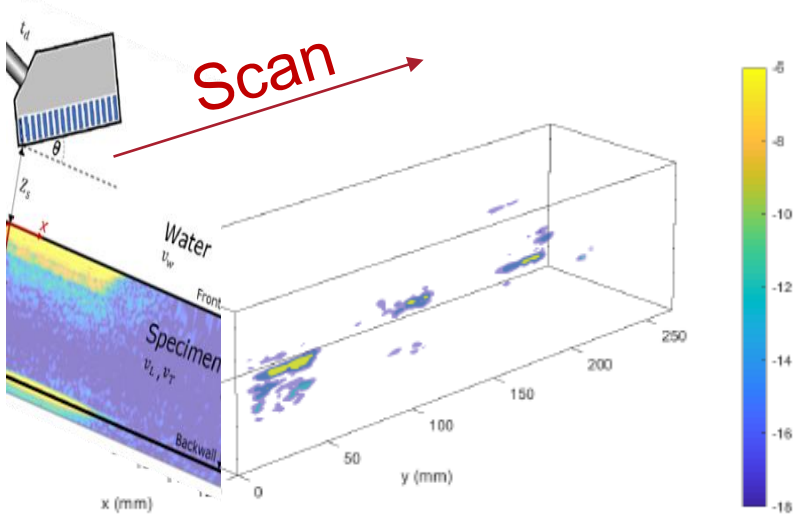
Images at y-position at limit of defect detection



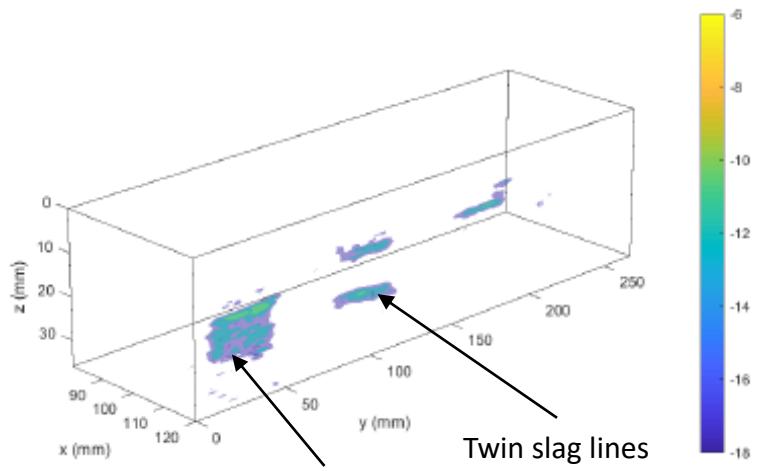
Characterisation

- For large defects, fusion of multi-views to single image can be used to obtain more complete picture[1]

Single (L-L) view



Fused image

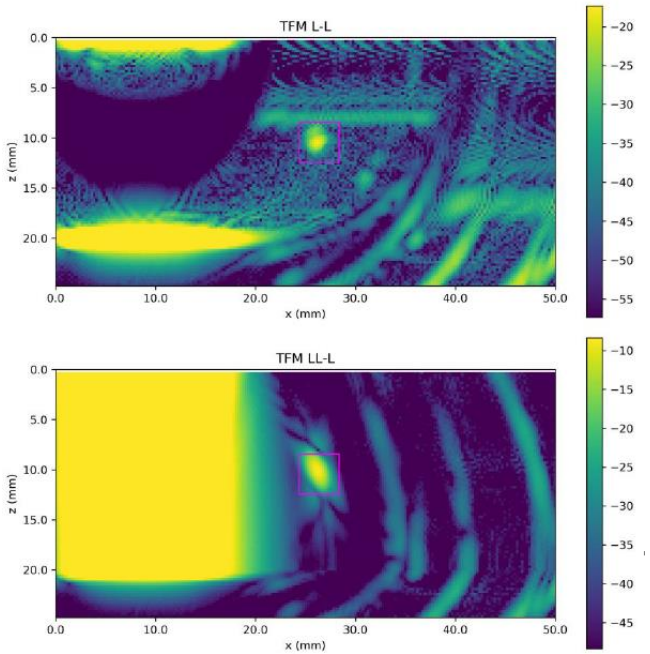


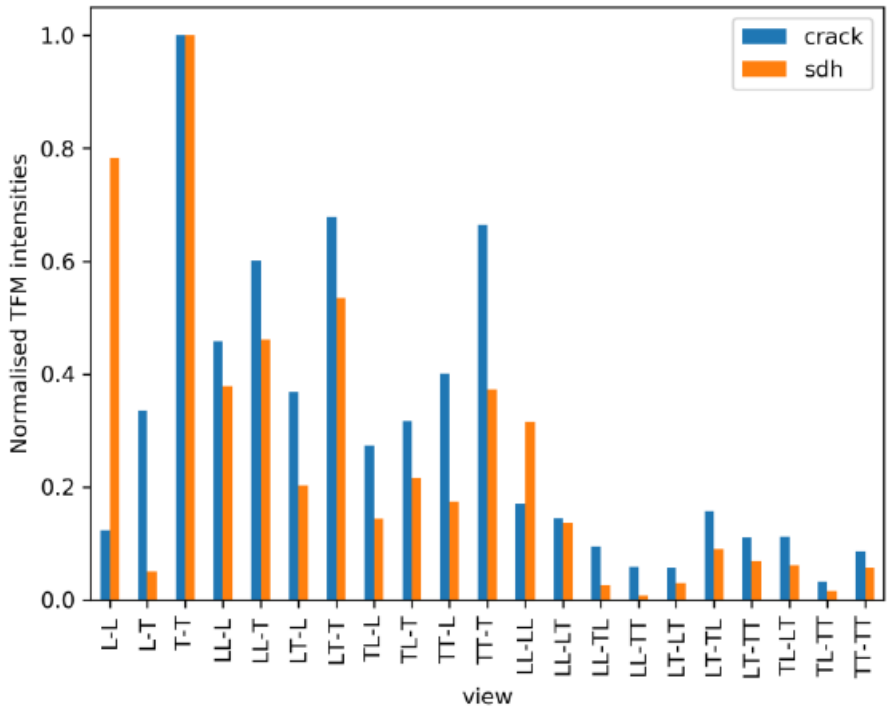
- For small defects, variation in response across views can be used to characterisation beyond diffraction limit …

1. Bevan *et al.*, *IEEE UFFC*, **67**, 2387, 2020

Characterisation

- Principle[1]
  - Defect shape may be too small to resolve in any view (diffraction limit)
  - But relative amplitude of response in different views is characteristic signature

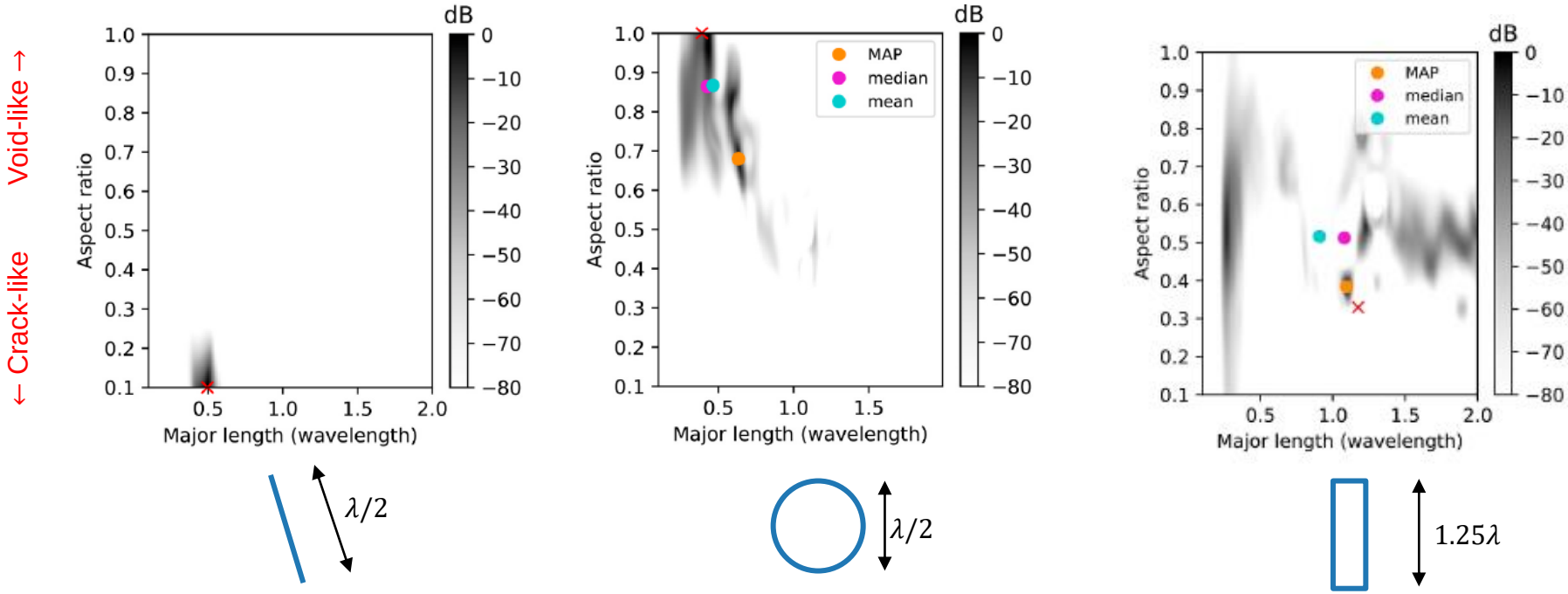




1. Budyn *et al.*, *NDT&E Int.*, **119**, 102413, 2021

Characterisation

- Method[1]
  - Build library of expected responses for idealised defects of interest (e.g. elliptical voids)
  - Compare measured response with library and estimate probability of matching measurement



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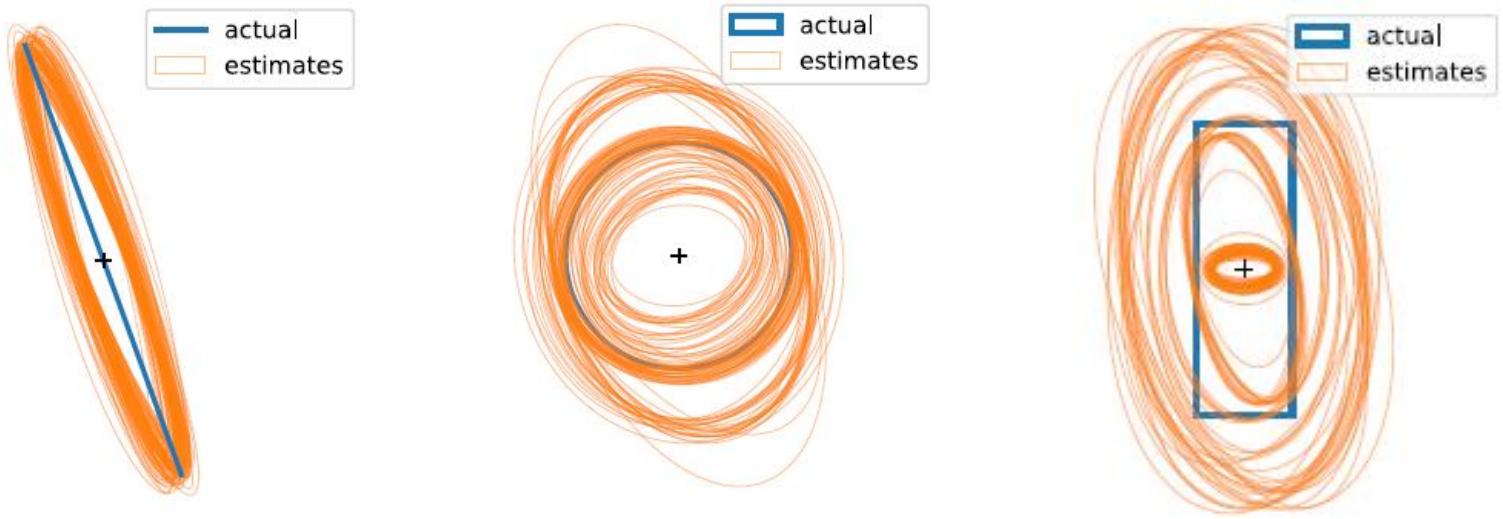

1. Budyn *et al.*, *NDT&E Int.*, **119**, 102413, 2021

Concluding Remarks

- Full matrix capture data offers potential to generate multiple views of same region
- Potential for enhanced detection and defect characterisation
- Methodology for fusion of multi-view images into a single image
  - Reduced operator burden
  - Automation of detection
  - Improved visualisation of large defects if not wholly visible in individual views
- Multi-views provide another route for characterisation of defects beyond diffraction limit