University of BRISTOL

Future directions in NDT of composites

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15th Sept 2010

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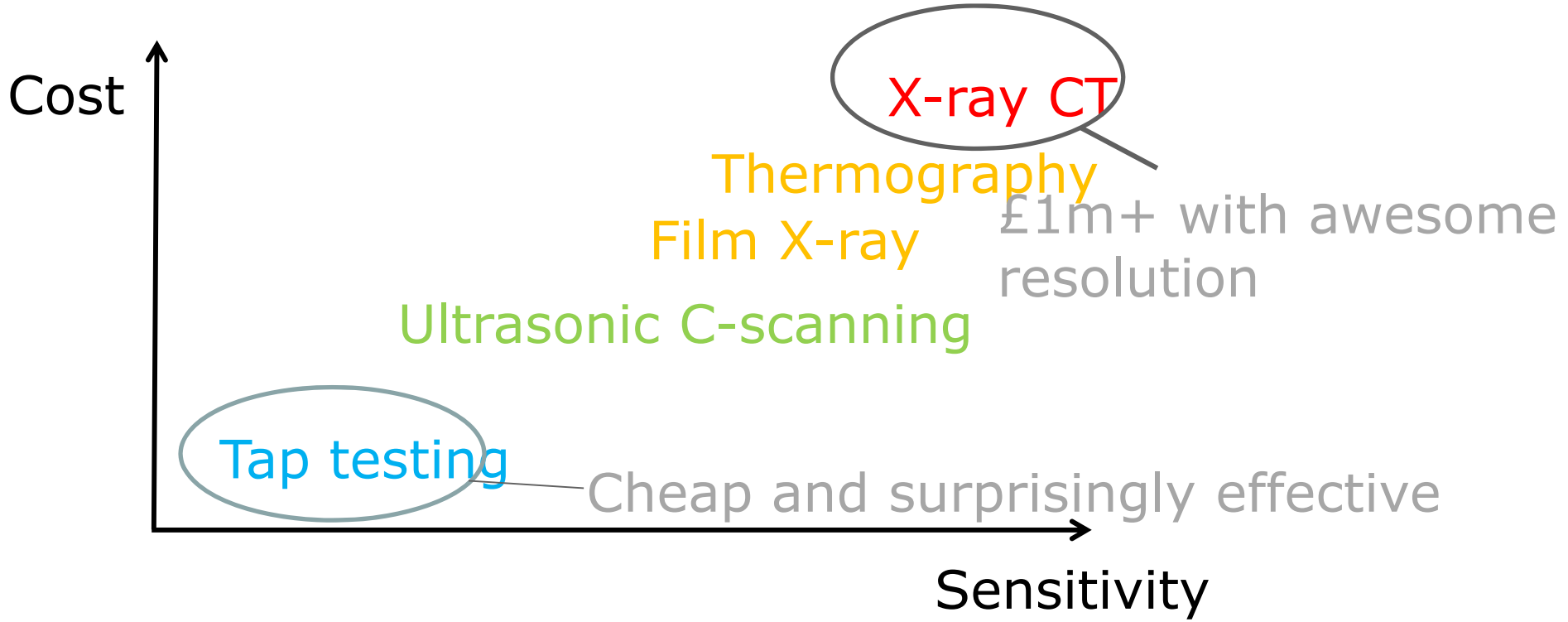
ADVANCED COMPOSITES CENTRE FOR INNOVATION & SCIENCE

Outline

- Standard methods and their limitations
- Promising new directions

Standard NDT methods for composites



- A number of good techniques available for BVID/delamination detection

Detection for more subtle defects

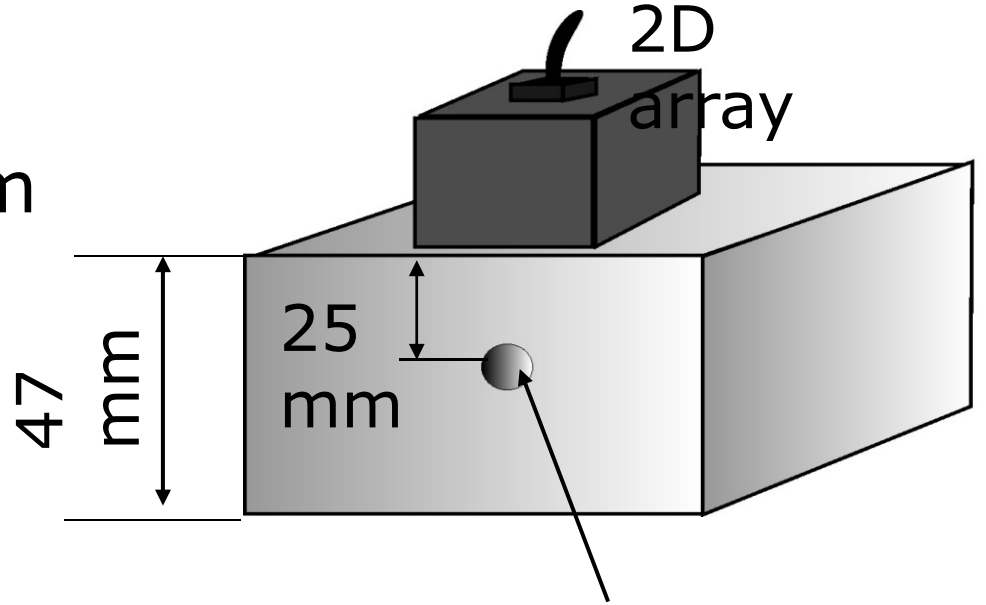
Defect	Current best options
Porosity/small inclusions	Ultrasonic velocity, CT
Matrix cracking	Ultrasonic backscatter, CT
Fibre waviness	Ultrasonic C-scan and arrays, CT
Degraded matrix	Ultrasonic velocity
Kissing bonds/weak bonding	None
Remaining fatigue life	None

- Given the expense of CT, ultrasonics offer some exciting opportunities

Ultrasonic arrays

3D TFM (for use with 2D arrays)

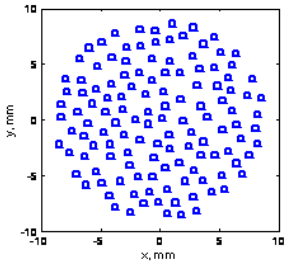
- Steel block with spherical inclusion 2.1mm diameter (provided by Rolls-Royce)
- λ = 1.9 mm



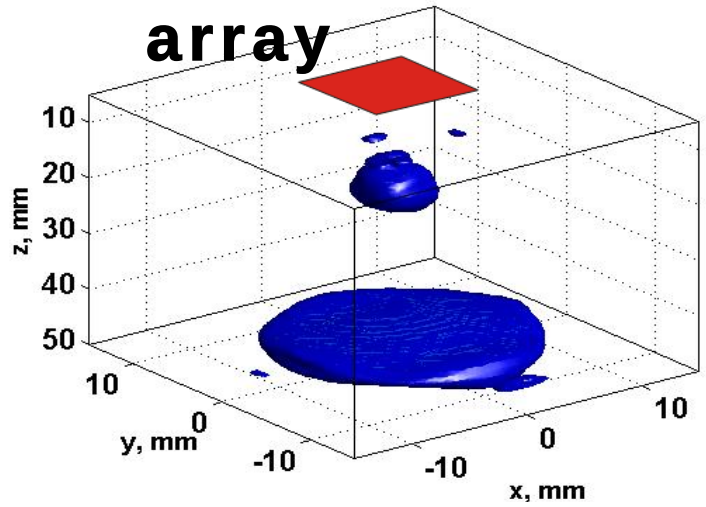
Experimental Results - spherical scatterer.

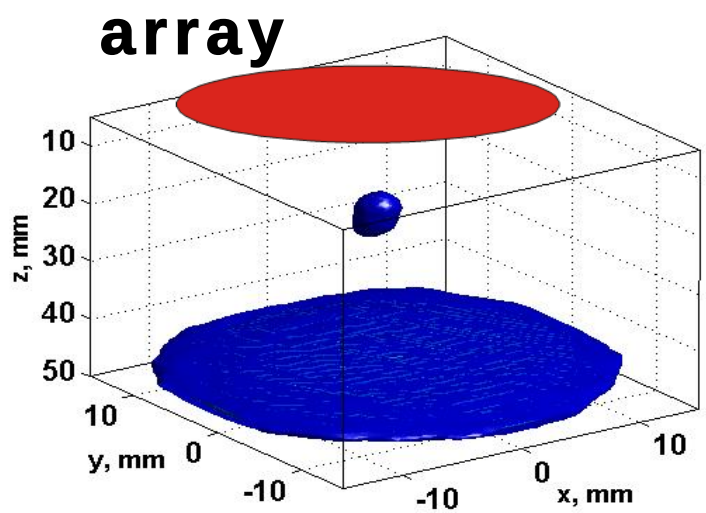
Matrix array

Poisson disk array

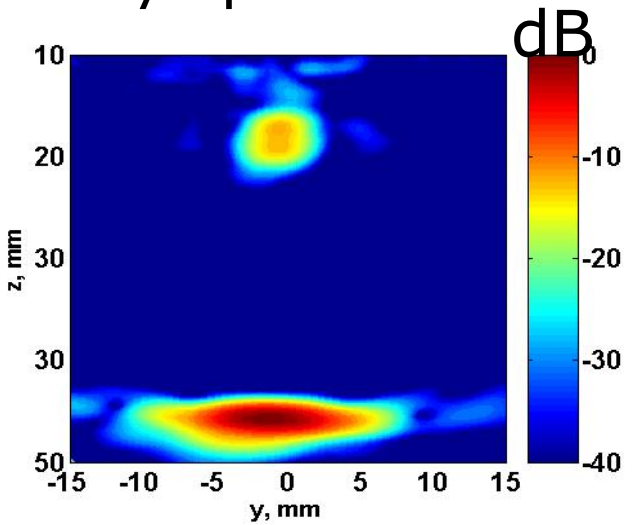


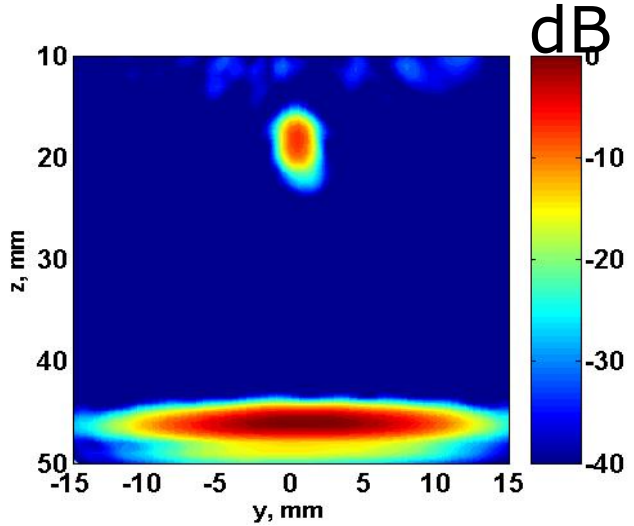
3D image, isosurfaces -30dB





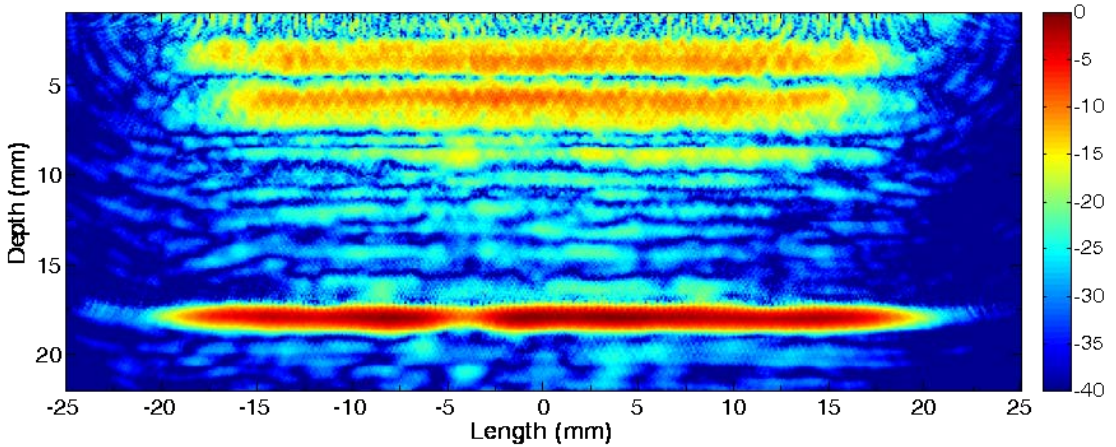
yz plane



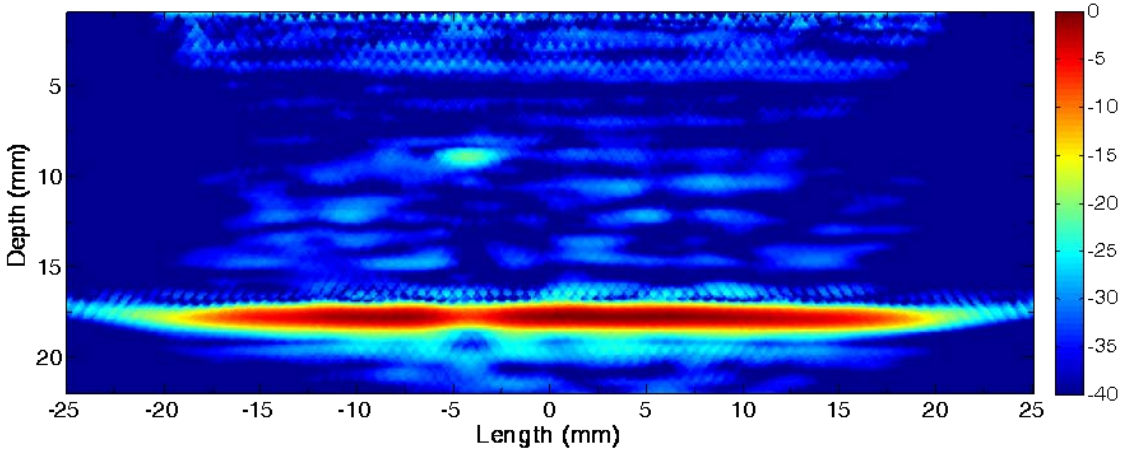


Enhanced composite imaging

'Raw' image



Corrected image

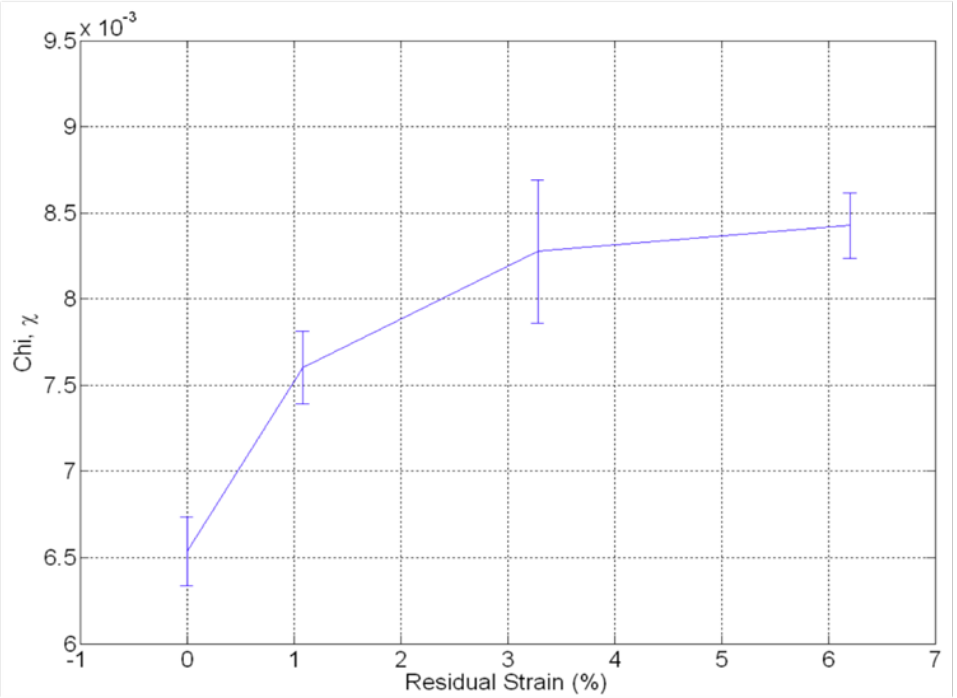


Future directions (arrays)

- Enhanced imaging resolution for thick sections
- Embedding models in the imaging process to extract features such as porosity of individual layers
- 3D imaging for in-plane and out-of-plane waviness detection/quantification
- Model based optimisation of inspection strategy

Nonlinear ultrasonics (why?)

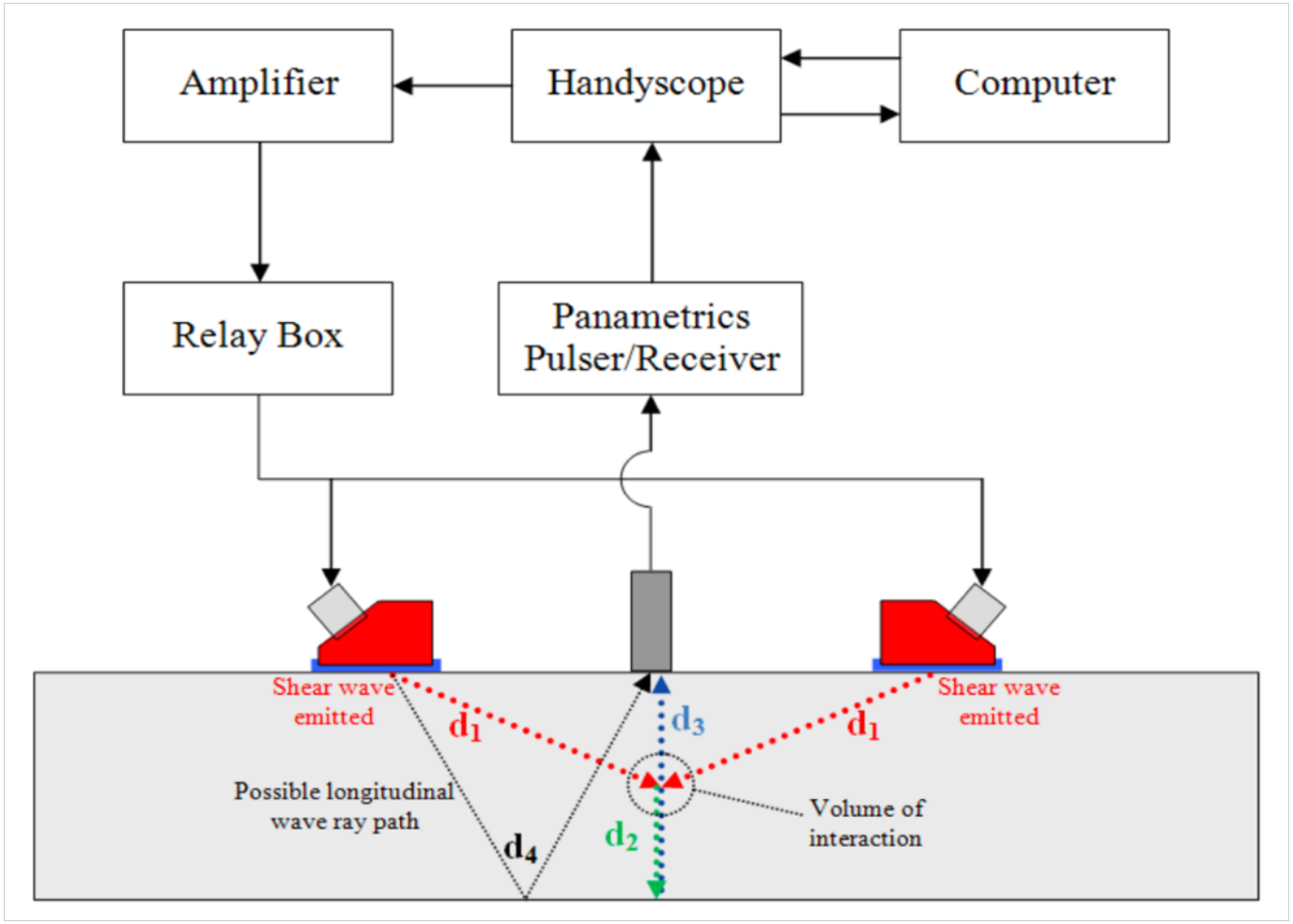
Measure of Ultrasonic Nonlinearity



Measure of plasticity

- This type of result suggests remaining life can be quantified

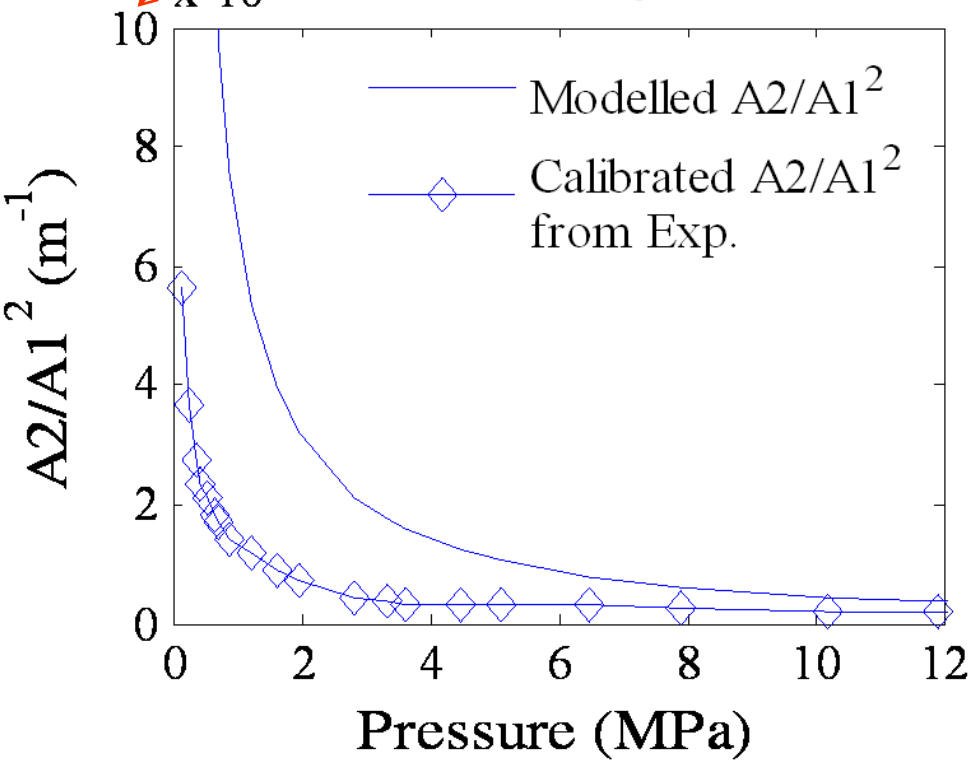
Nonlinear ultrasonics (how?)



Kissing bond detection

Al-epoxy-Al joint in compression

Measure of Ultrasonic Nonlinearity



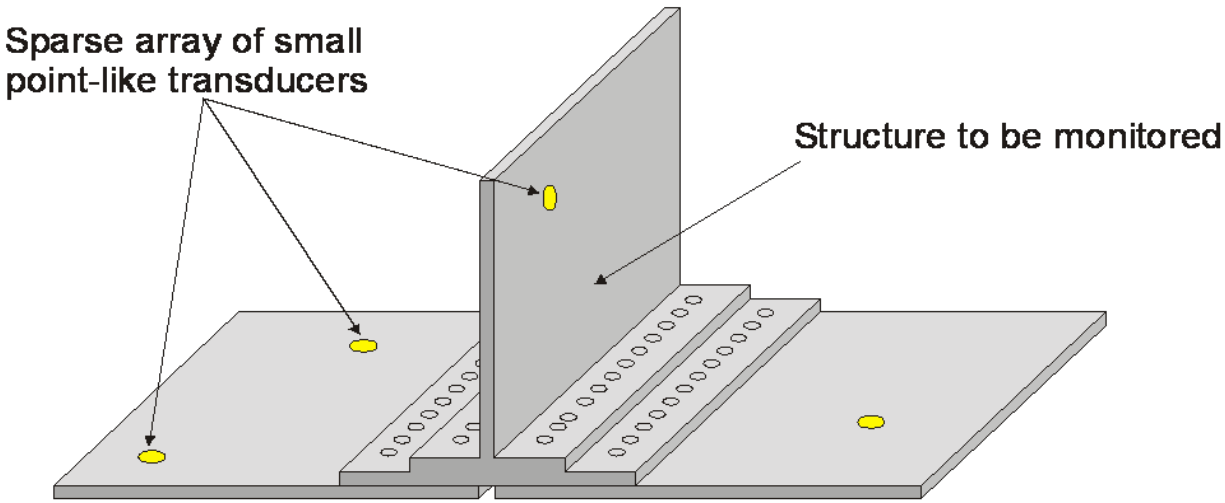
Future directions (nonlinear)

- Can the link between remaining fatigue life and nonlinearity be established for composites?
- Do kissing bonds (and other more subtle defects) exhibit increased nonlinearity in composites?
- Can this technique be robustly implemented (i.e. made suitable for field use)?

Faster NDT

- Rapid arrays

- SHM



Conclusions

- Existing techniques have good capabilities for detection of ‘gross’ defects
- Ultrasonic arrays can produce 3D images at a fraction of the cost of CT
- Arrays offer good potential for waviness and improved porosity detection
- Nonlinear ultrasonics an emerging technique with exciting capabilities for kissing bonds