Condition monitoring of composite pipes using laser shearography

Leon Lobo
Laser Optical Engineering Ltd.
Loughborough





Laser Optical
Engineering Ltd

Laser Optical Engineering

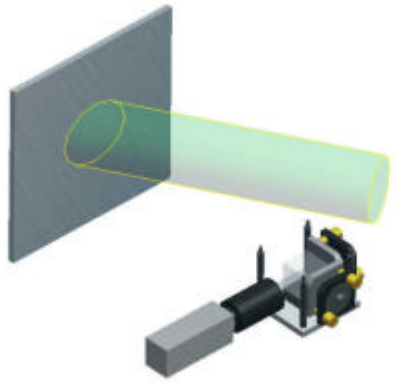
- LOE specialises in the development of innovative and bespoke laser based solutions.
- Established as an independent spin-out company from Loughborough University in 1996
- Laser Optical offer :-
  - Laser shearography & vibrometry systems
  - Custom laser metrology solutions
  - Diffractive optics for high power laser processing
  - Multispectral imaging for remote sensing – vehicle occupancy, contamination, gas leaks
  - Laser-induced fluorescence systems for trace residue and narcotics detection

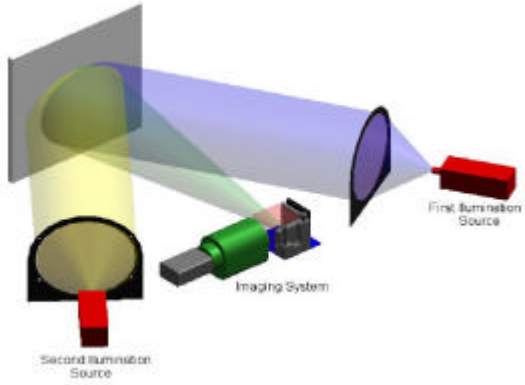




In-plane laser shearography

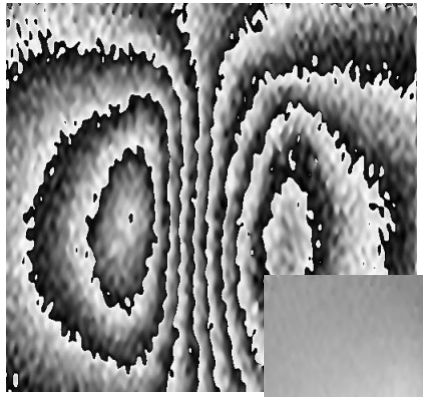
- Non-contact
- Measures structural strain
- Wholefield – f150mm ? 1m x 1m
- >1,000,000 points of measurement
- με sensitivities
- Real-time visualisation
- <10 seconds to acquire & process data

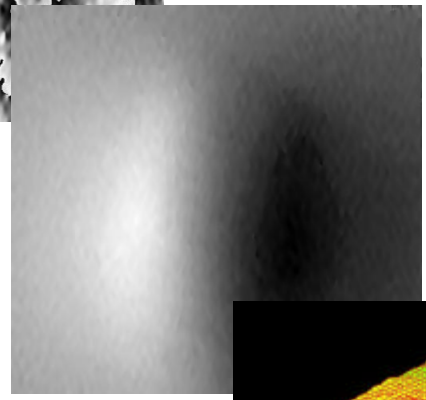


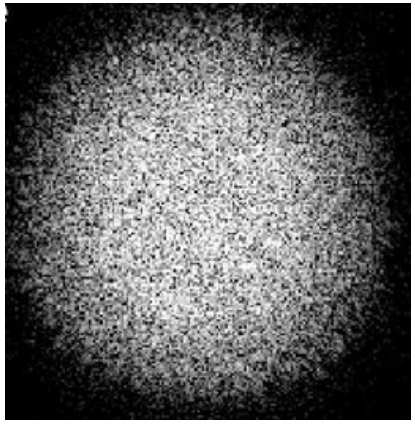


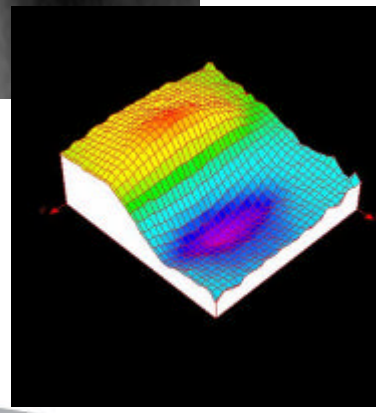
Measurement technique

- Speckle pattern
  - Optically rough
  - Coherent
  - Interference
- Reference @ unloaded/preloaded state
  - Active loading (actual operational strain field)
- Differential measurement
- Fringe formation
- Post process
  - Phase of the target surface



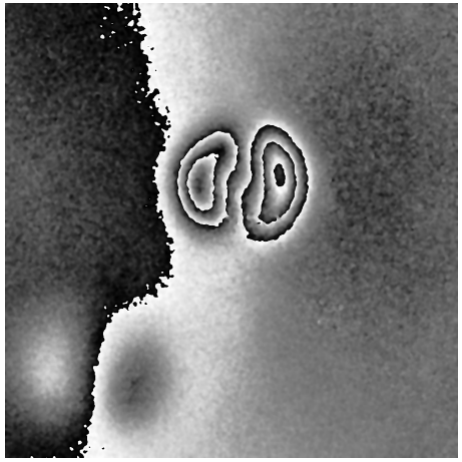


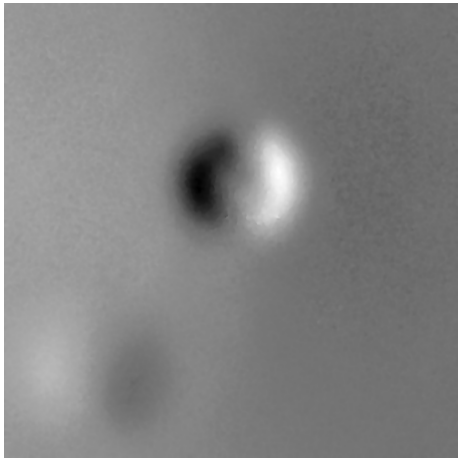


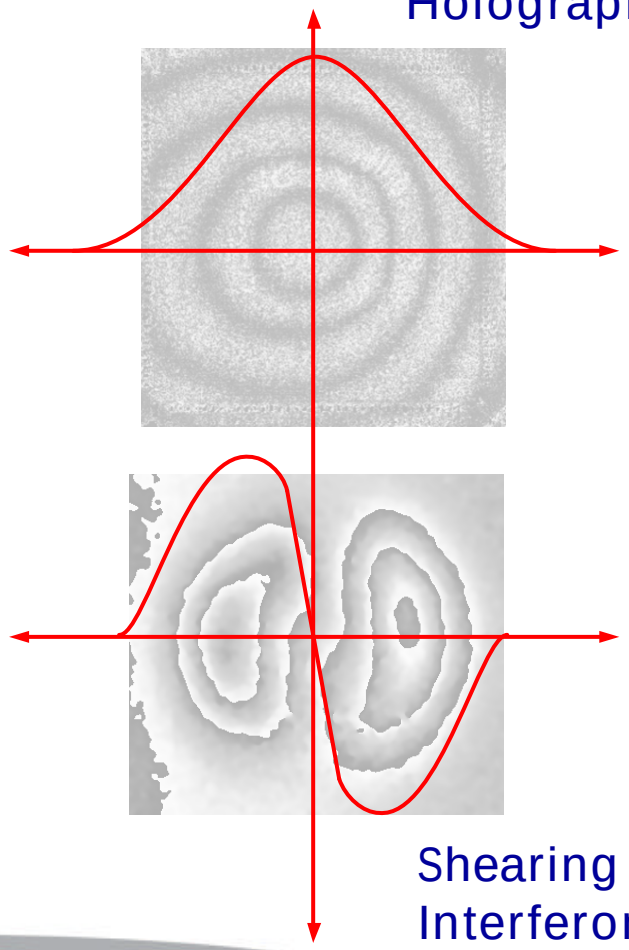


Optical differentiation δL/L

- # of fringes depends on strain
- Strain affected by sub-surface anomalies
- Structures fail at points of maximum strain NOT maximum displacement

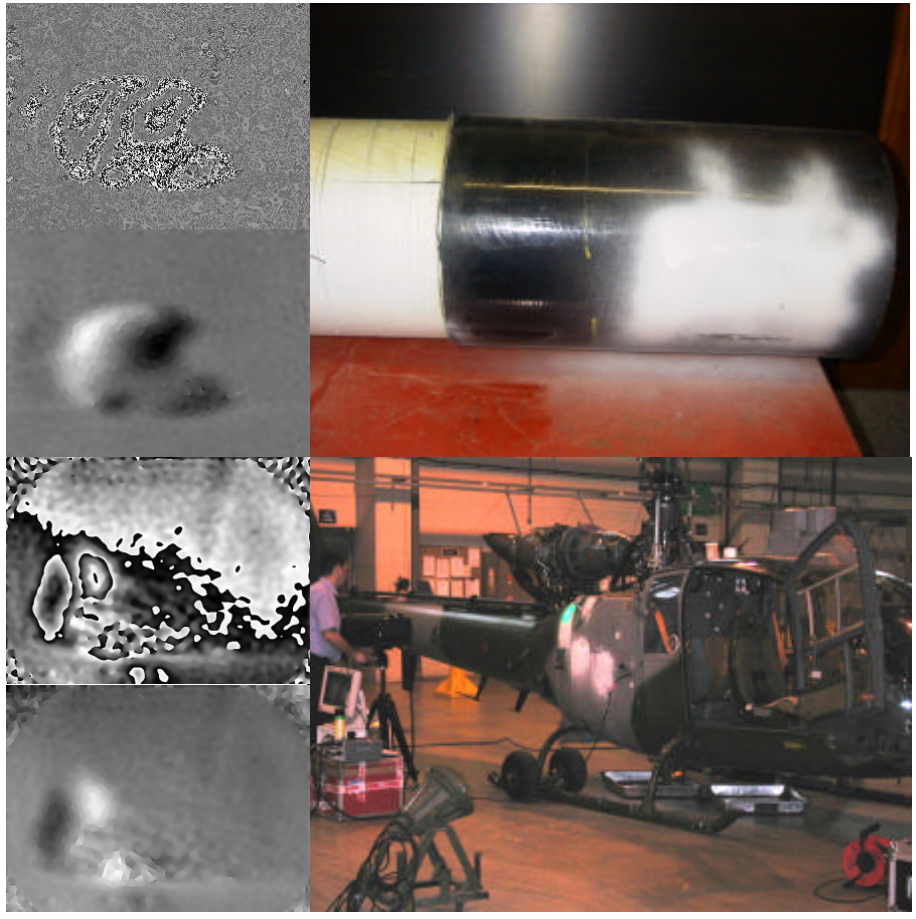






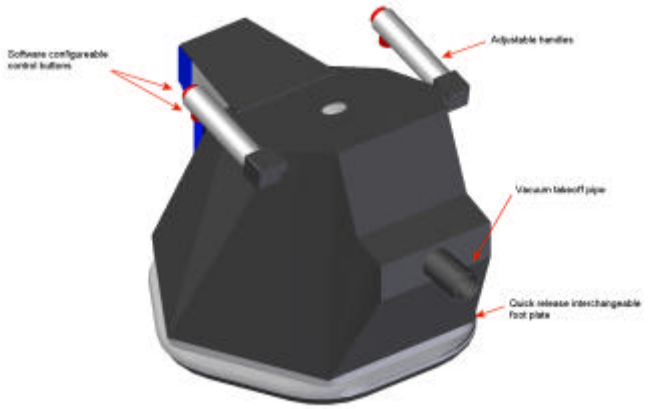
Defect detection

- Defect detection
  - Delaminations
  - Disbonds
  - Voids
  - Inclusions
  - Impact damage/BVID
  - Cracks
  - Erosion
  - Fibre breakage
  - Matrix cracking
  - Environmental

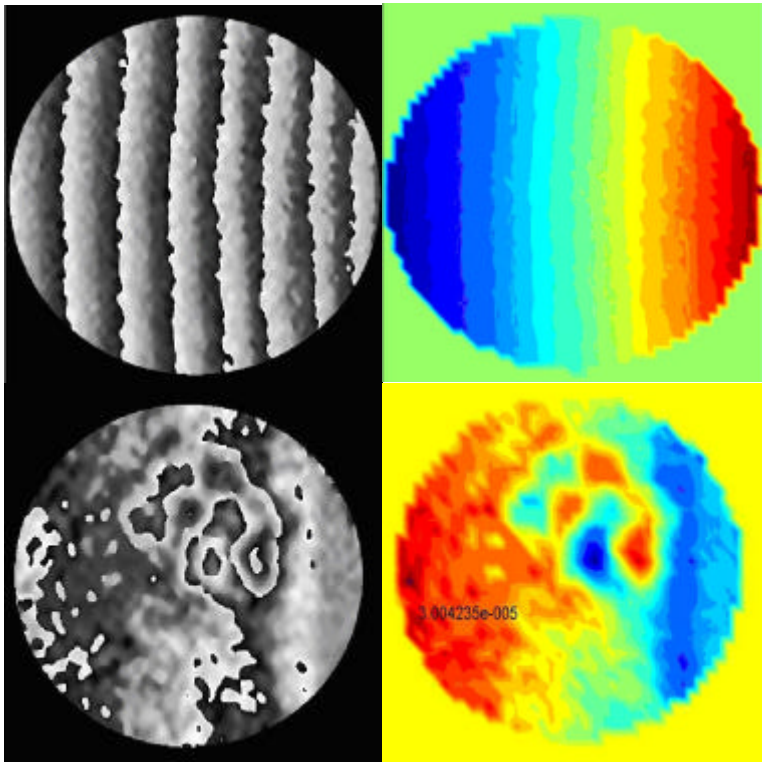


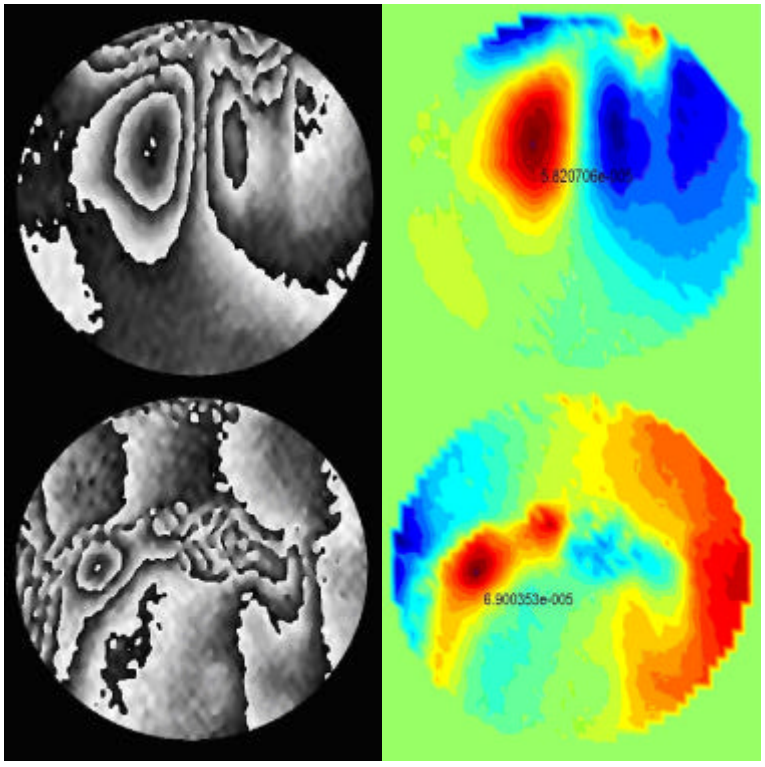
Strain measurement

- Strain measurement
  - Adhesion (bond integrity)
  - Interface stresses
  - Strain concentrations
  - Material weakness
  - Design feedback



Laser shearography





Composite Pipes

Methods of NDT

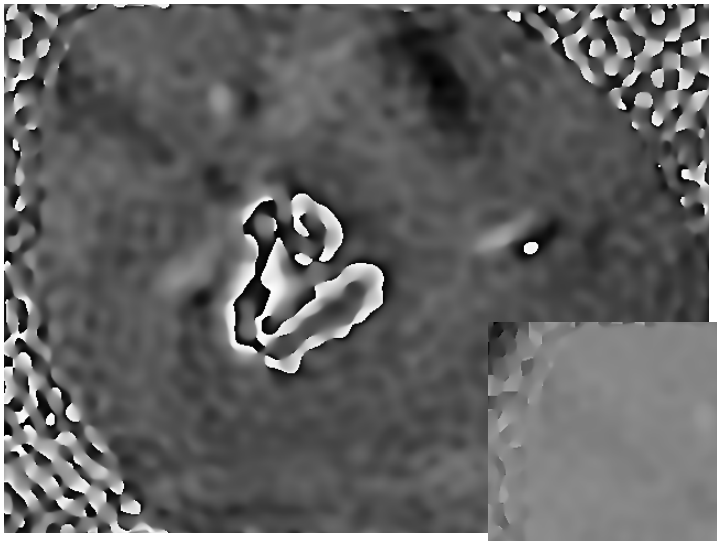
- Ultrasonics
- X-ray
- Eddy Current
- Dye Penetrant
- Mag particle
- Thermography
- Lamb waves (long range ultrasonics)

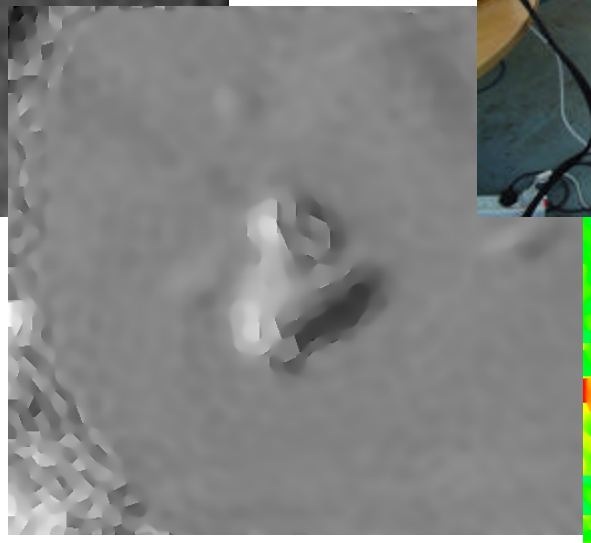
- Kissing bonds
- Most of these techniques describe changes of a signature Shearography monitors a change of state due to an impulse; eg thermally induced strain

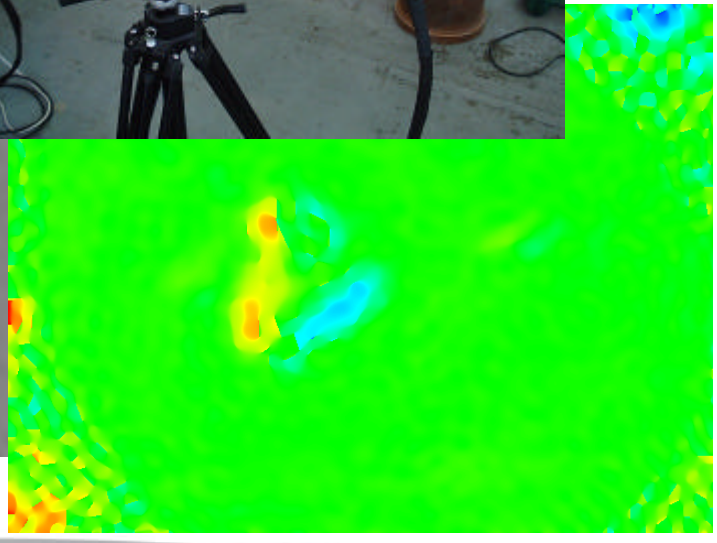




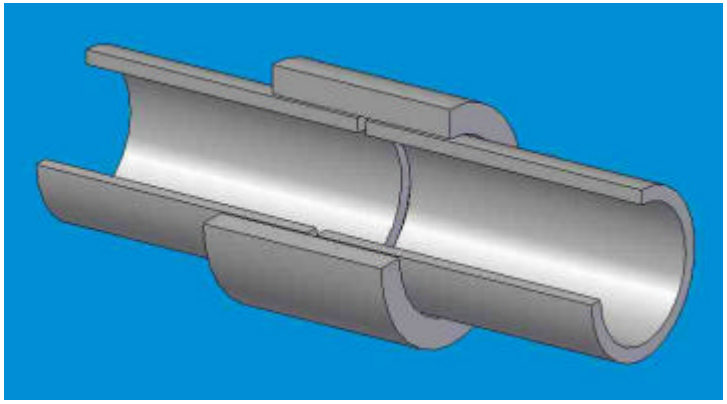
Composite wrapped pipes



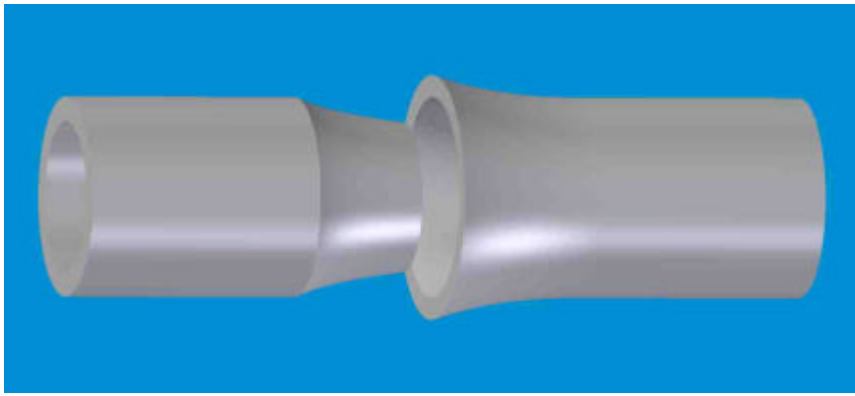




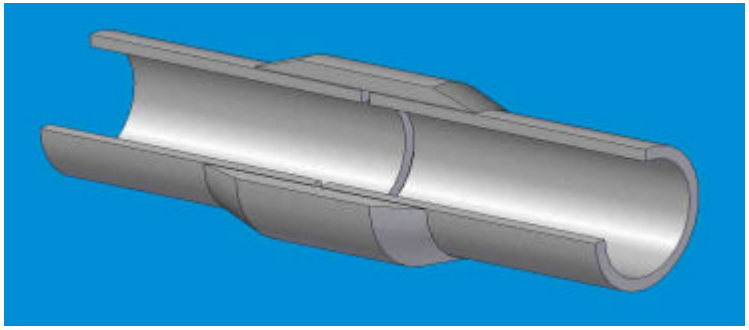
GRP Pipe Joints



Collar joint



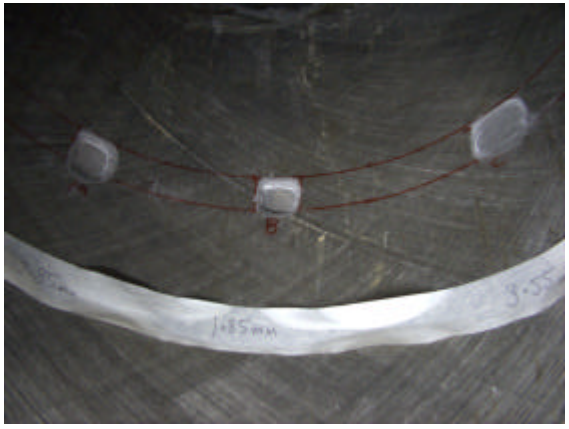
Flare – ground Cement Joint

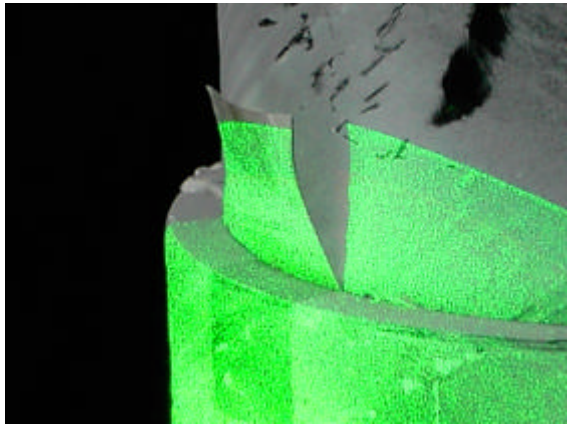


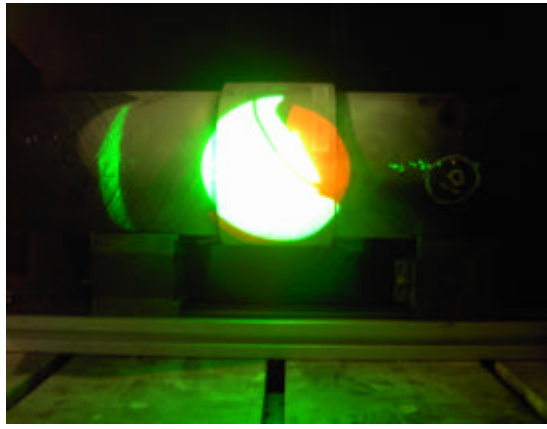
Wrapped Joint

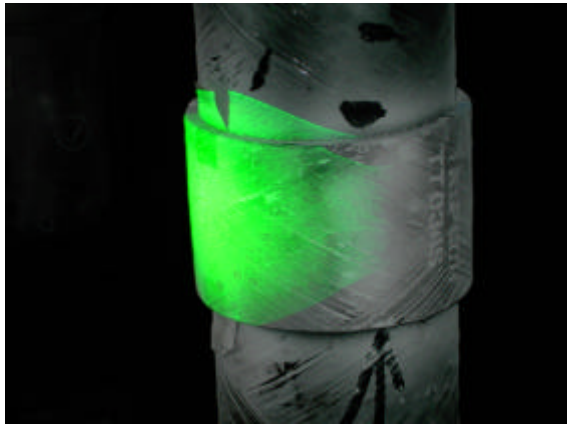
These joints are recommended in BS EN 14364:2006 as a rigid joint for non-end-load-bearing without axial loading.

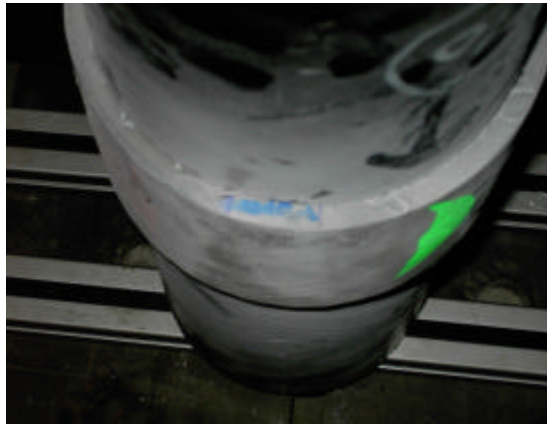
Manufactured Damage









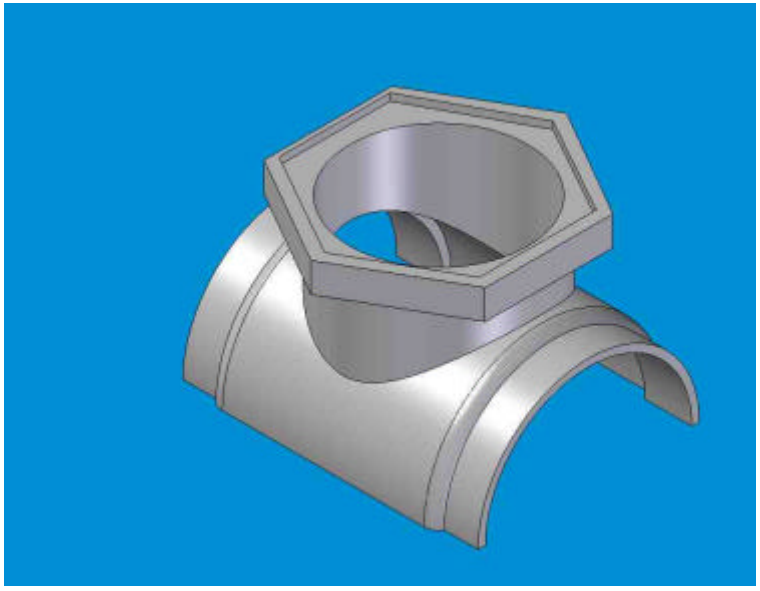


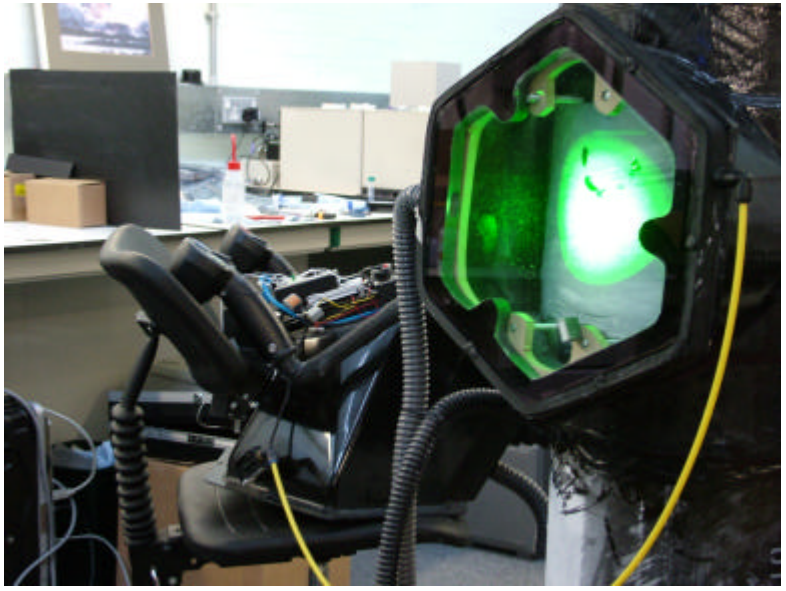
Equipment Development

- Developed an existing piece of kit used for testing boat hulls
- Allows a rigid connection to a moving or vibrating pipe
- Use pressure to load the surface

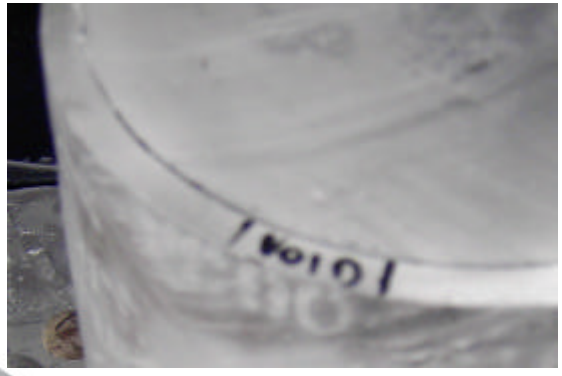
Pipe Hood

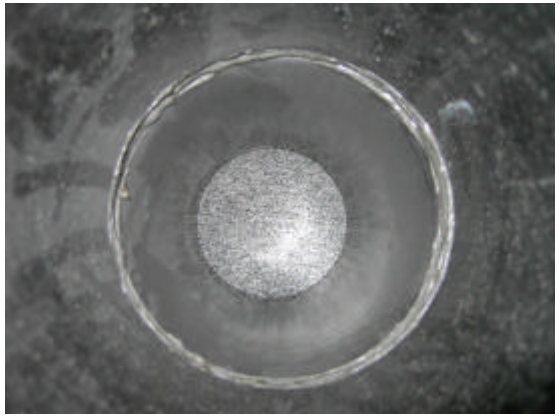
- Vacuum hood was adapted to fit pipe sections
- Consideration when examining such a curved surface
- Loading pressures of -5 to -17 kPa



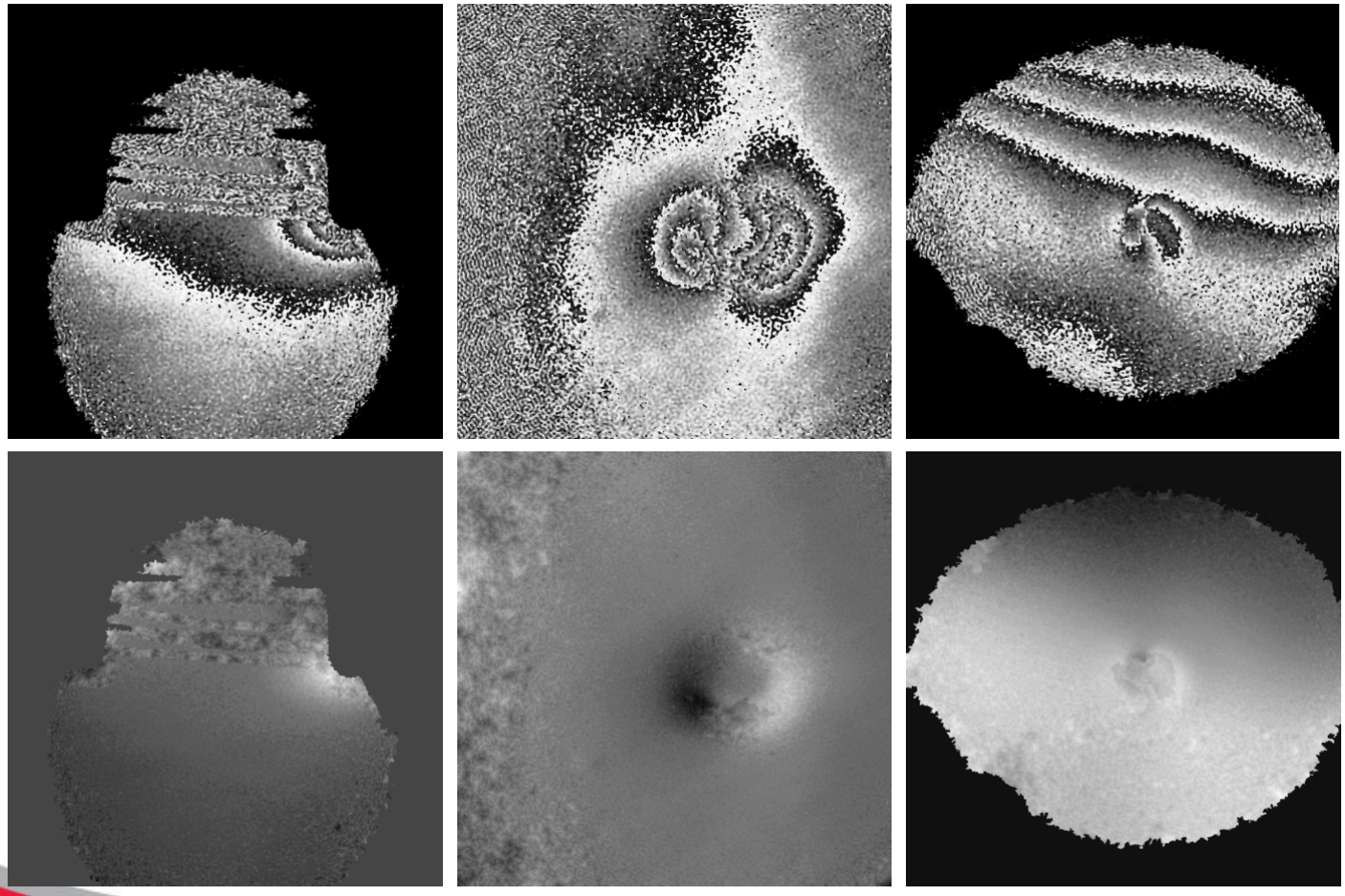


Collar Joint Pipe

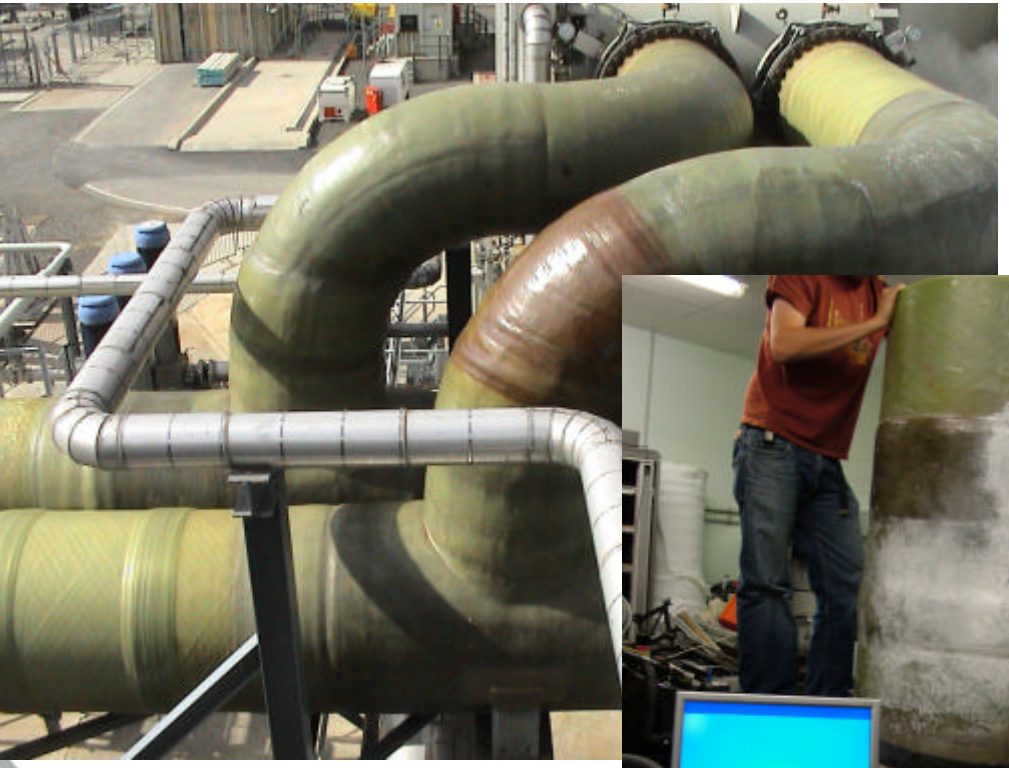


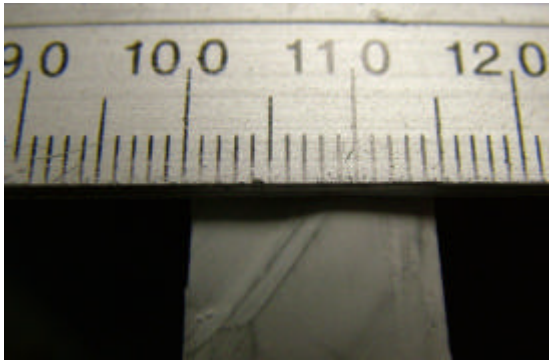


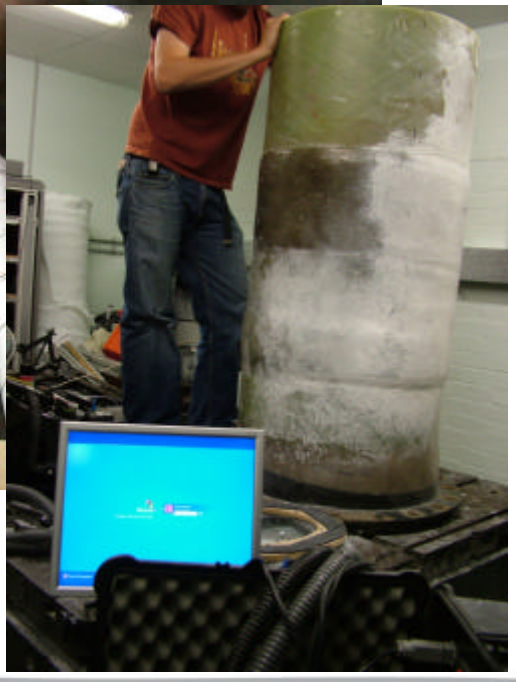
Vacuum Loading of Collar Joints

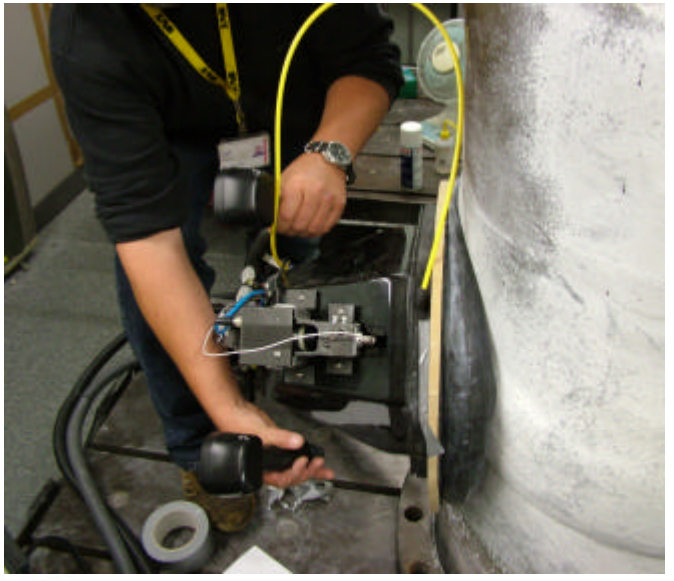


Large Scale Wrapped Joints









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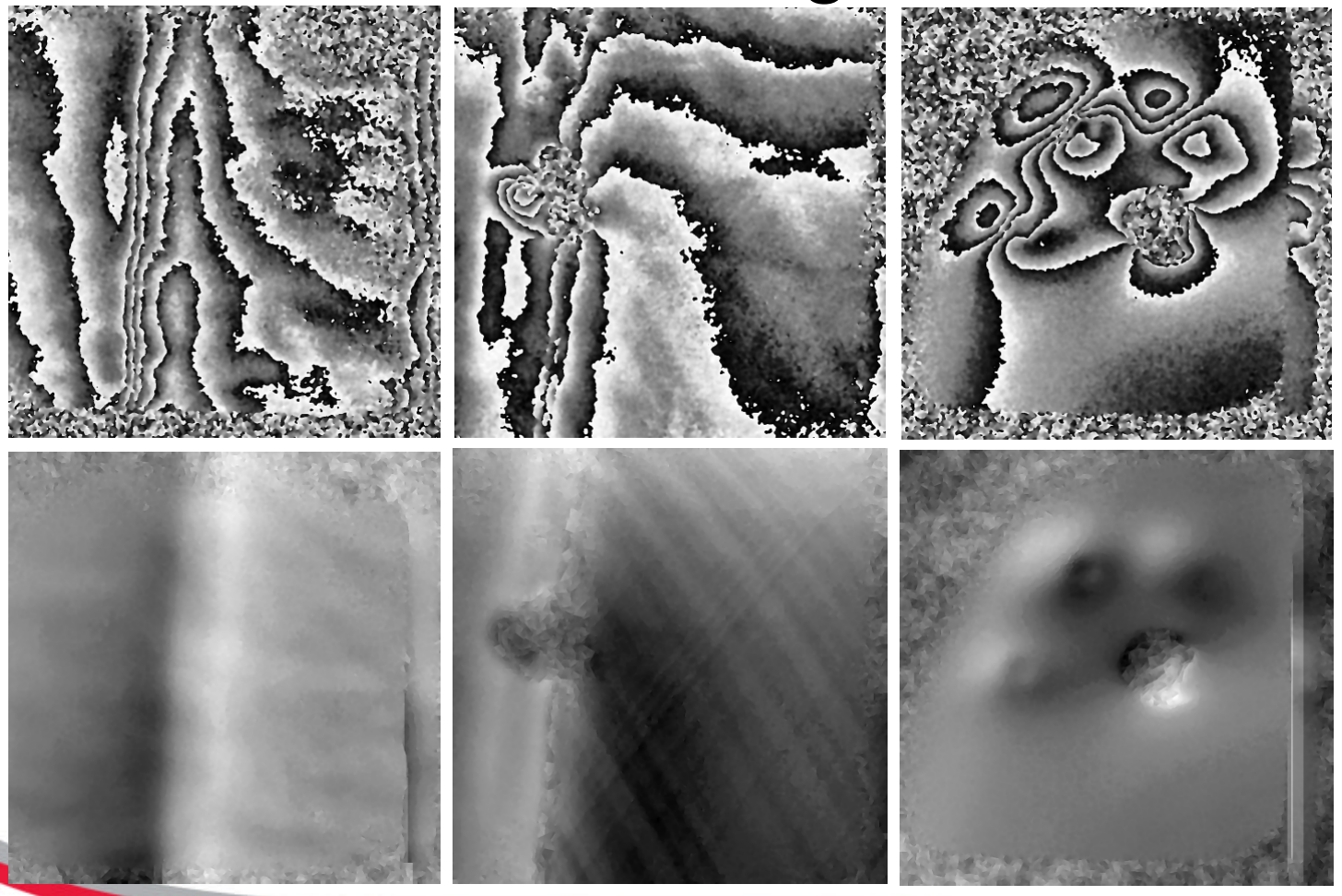
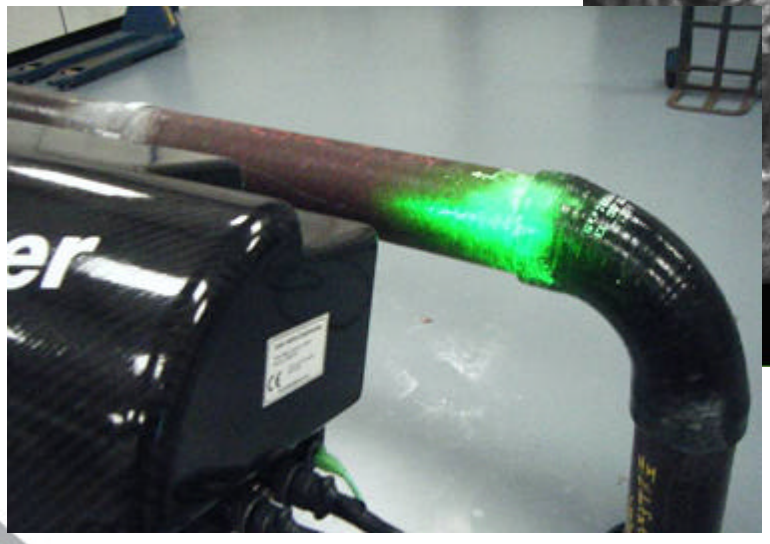
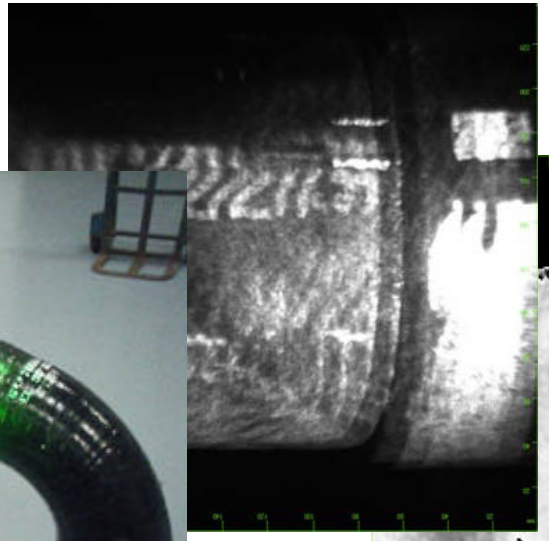
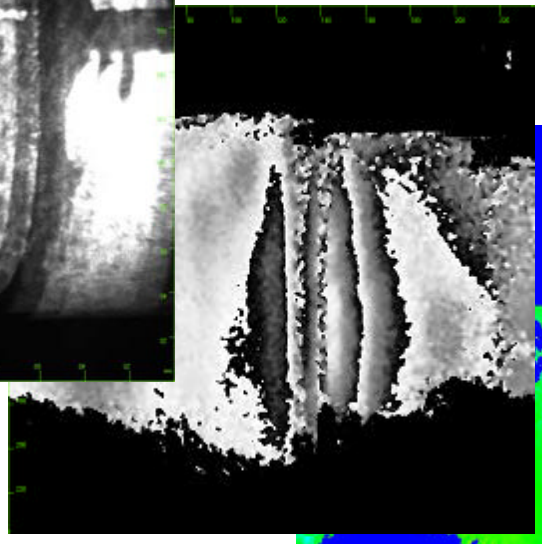
Vacuum Loading Results

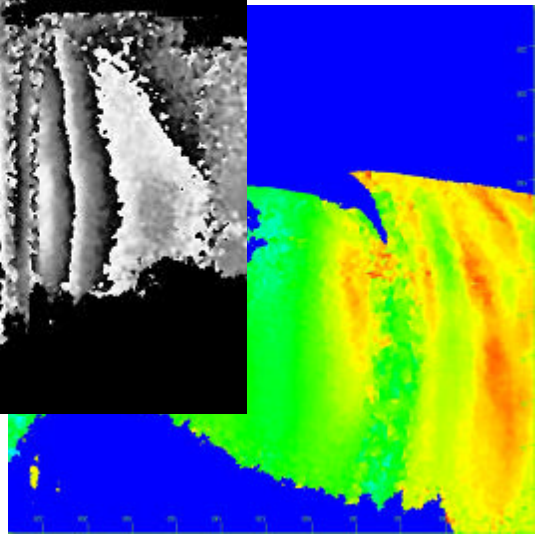


U-Tube – adhesive bond integrity

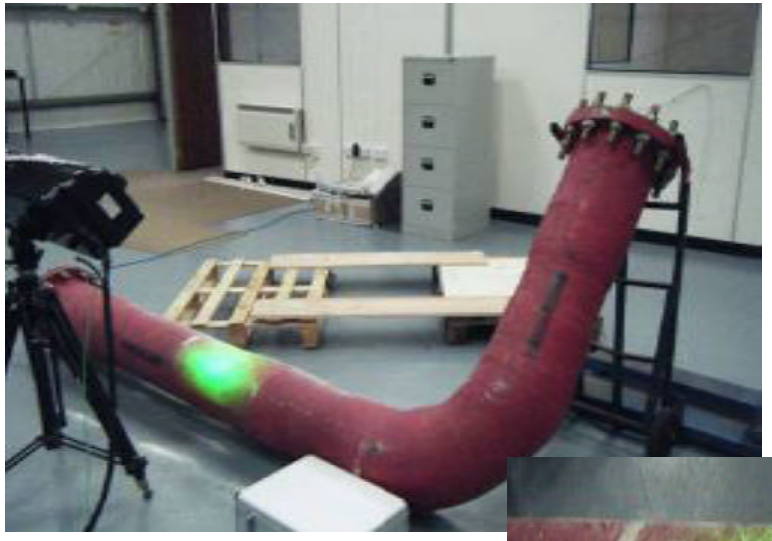


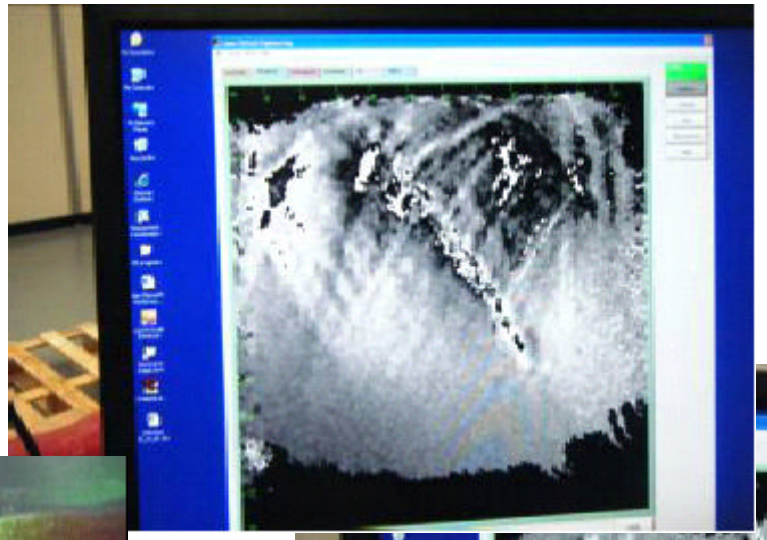


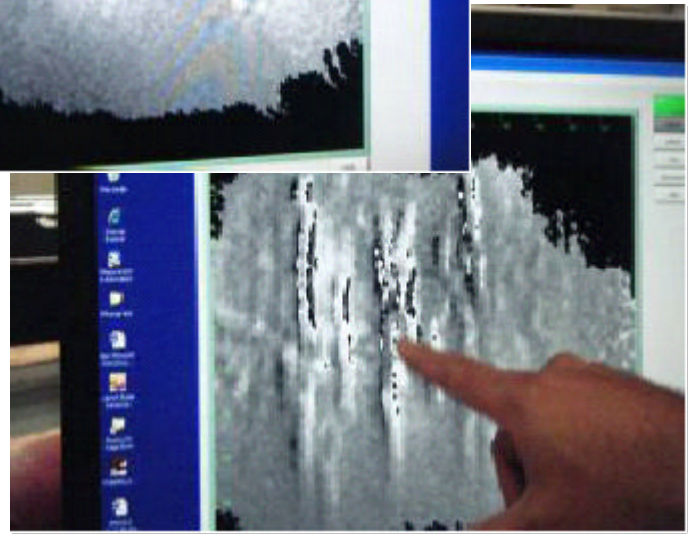




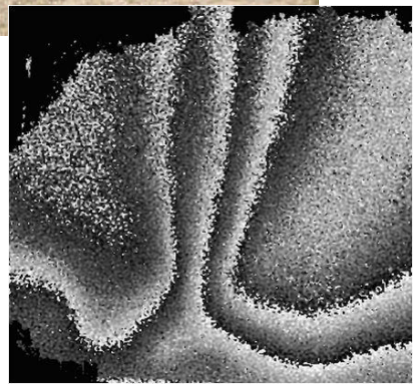
J Tube – crack imaging and associated damage

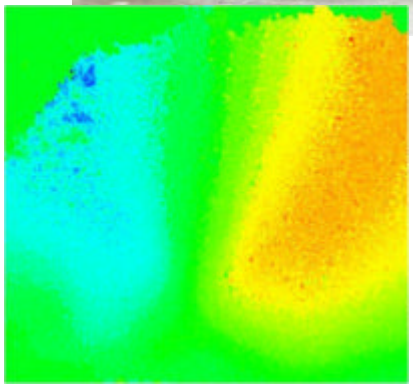






Bridges

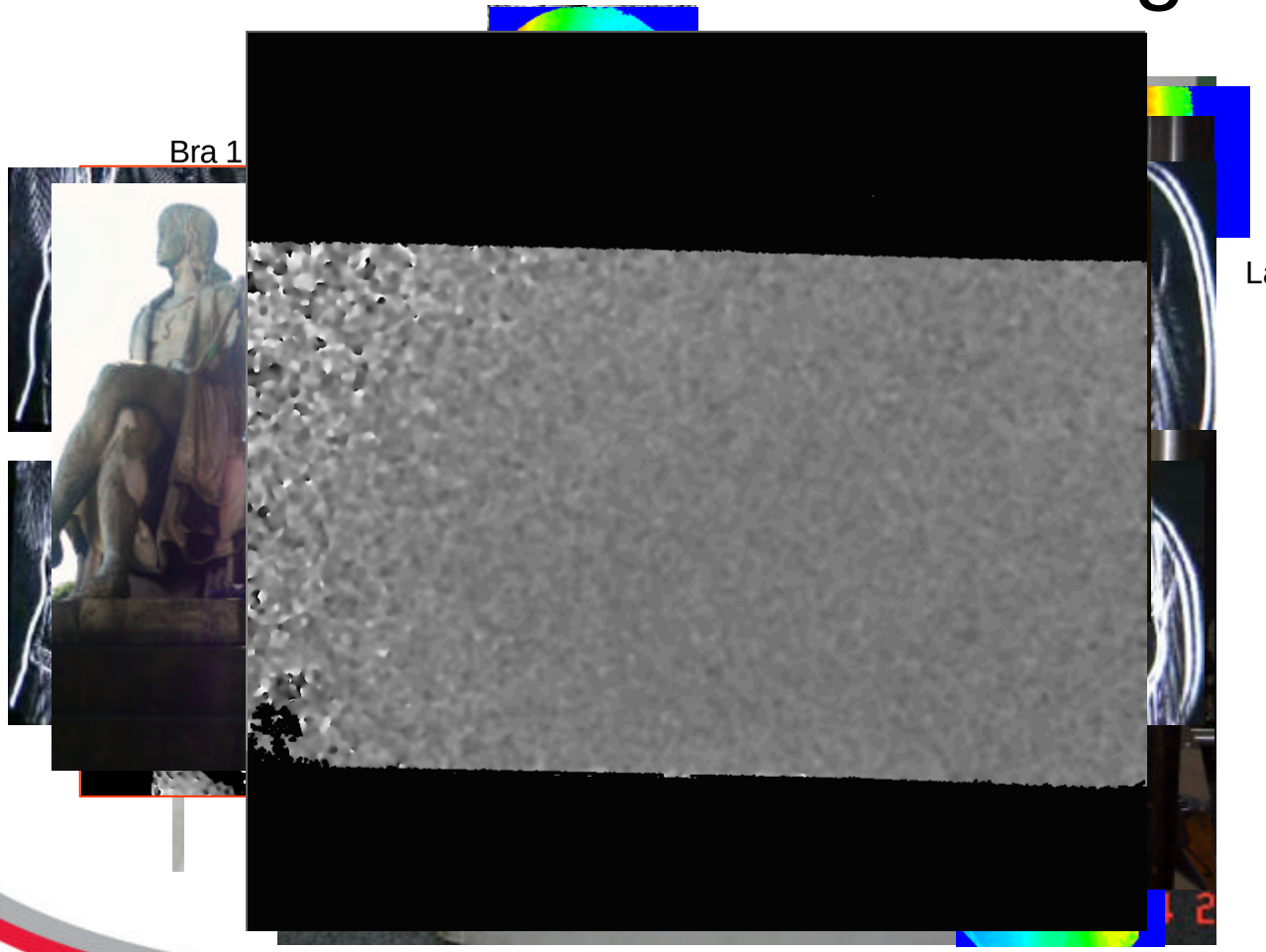




Conclusions

- Non contact
- Live visual results
- Wholefield
- Rapid turnaround
- System effective at
  - Design - feedback & verification
  - Manufacture – defect free
  - In-service inspection
  - Repairs – verification
  - In the field – transport/assembly damage
  - Annual audits – defect propagation/RLP
  - *in situ*

Thanks for listening



Dr Leon Lobo
Laser Optical Engineering Ltd.
Innovation Centre
Loughborough University
Loughborough
LE11 3EH

+44 1509 228733

leonlobo@laseroptical.co.uk