Is the future of aircraft maintenance with automated NDT or SHM?

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Aero NDT

What is the Challenge?

- **Operating an aircraft is expensive**
  - We are looking to automate maintenance and repair to save money
  - To provide a competitive advantage to aircraft fleet operators in the Netherlands
    - Support Schiphol as a hub airport
    - Support Dutch airforce and allies in maintaining capability
  - Keep high-technology jobs in the Netherlands

Dutch Landscape

- **Aero-Space Agenda Zuid-Holland 2016-2025**
  - Composed of industry and knowledge institutes
- **Amsterdam Schiphol Airport**
  - Hub airport for KLM, many supporting MRO activities
- **Woensdrecht Airbase**
  - MRO hub for airforce, supported by companies
- **Smaller MRO hubs at Lelystad and Maastricht airports**

Outline

- Our current research topics
- Push to automation in manufacturing and maintenance
- How to automate?
  - Sensor positioning
  - Decision making
- Summary – automated NDT or SHM?

Research Vision

Engineering, Science & Industry are built upon performing well-designed experiments and accurate measurements

- Experimental testing of materials and structures for verification of models and improve design
- Process monitoring and quality control for manufacturing
- In-service health monitoring of structures and materials to guide maintenance and repair processes
- Correct decision making for cost-effective use of assets and infrastructure

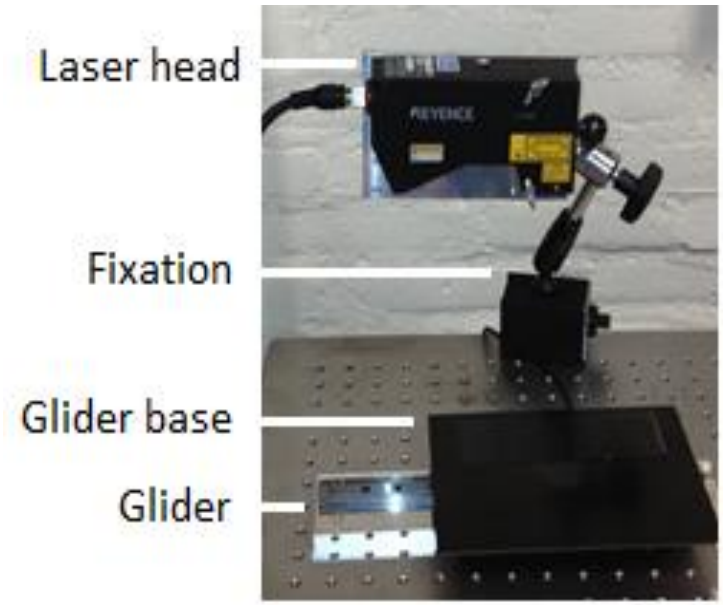
Aerospace NDT Laboratory

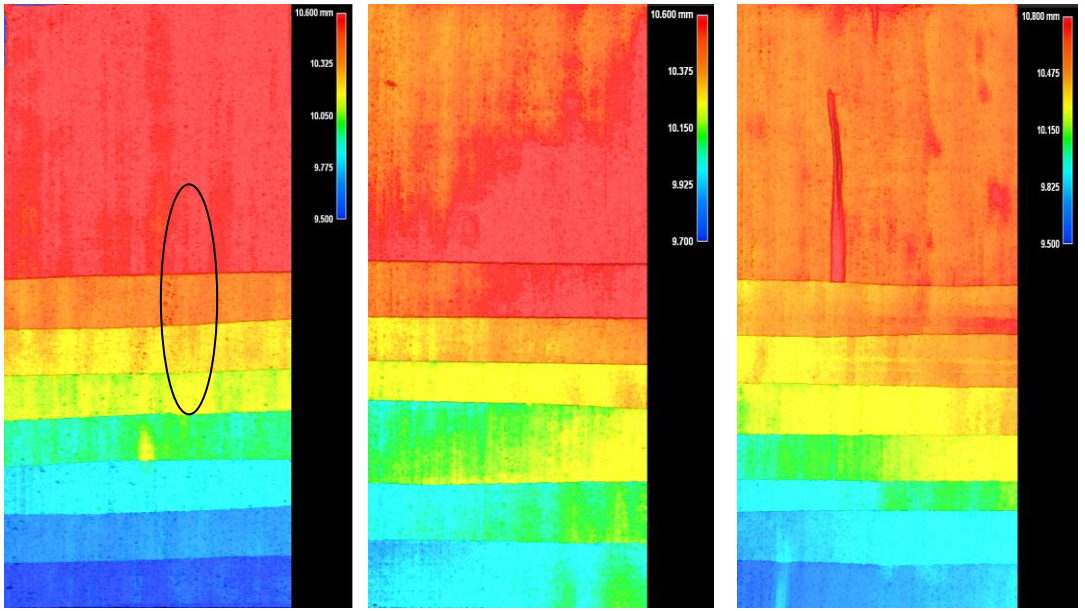
Aerospace NDT Laboratory at TU Delft

Research centre for NDT & SHM

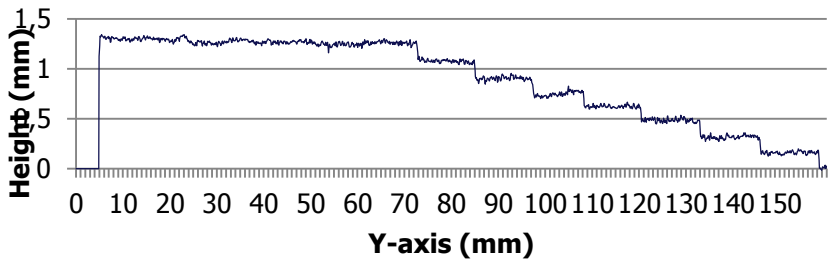
- **Our main research technologies are:**
  - **Optical Metrology:** for 3D shape & strain sensing, optical tomography
  - **Fibre Optic Sensors:** Fibre Bragg grating sensors for SHM
  - **Spectral Imaging:** Hyperspectral imaging, thermography
  - **Ultrasonics:** Guided waves and phased array

Linescan/Point Shape Sensors

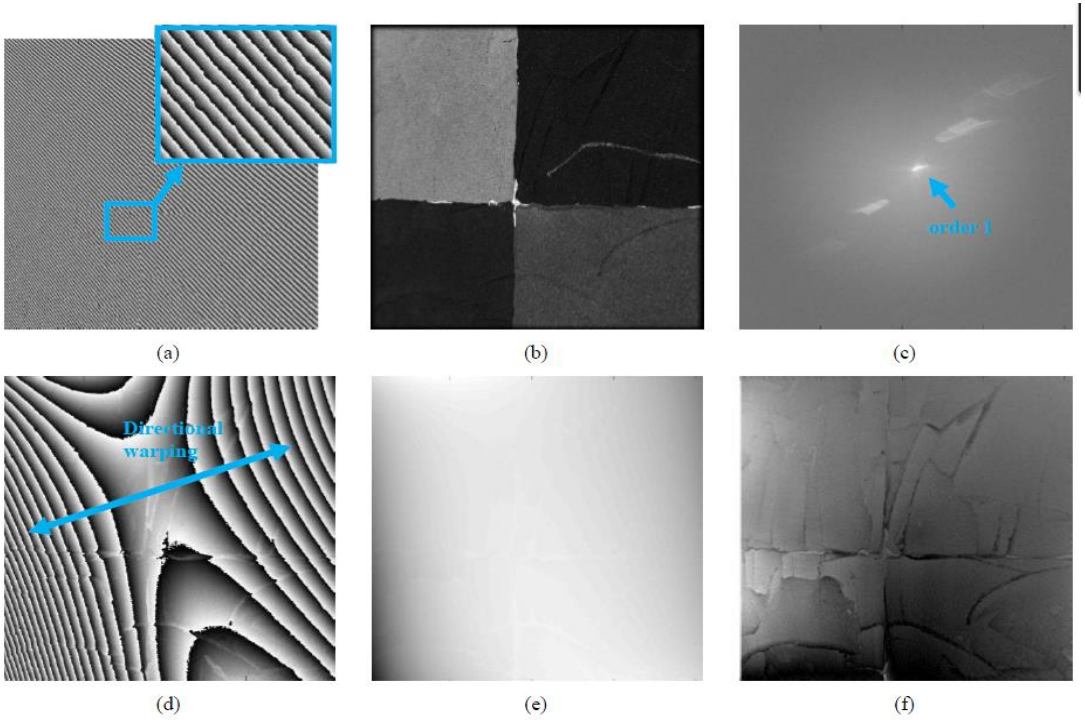


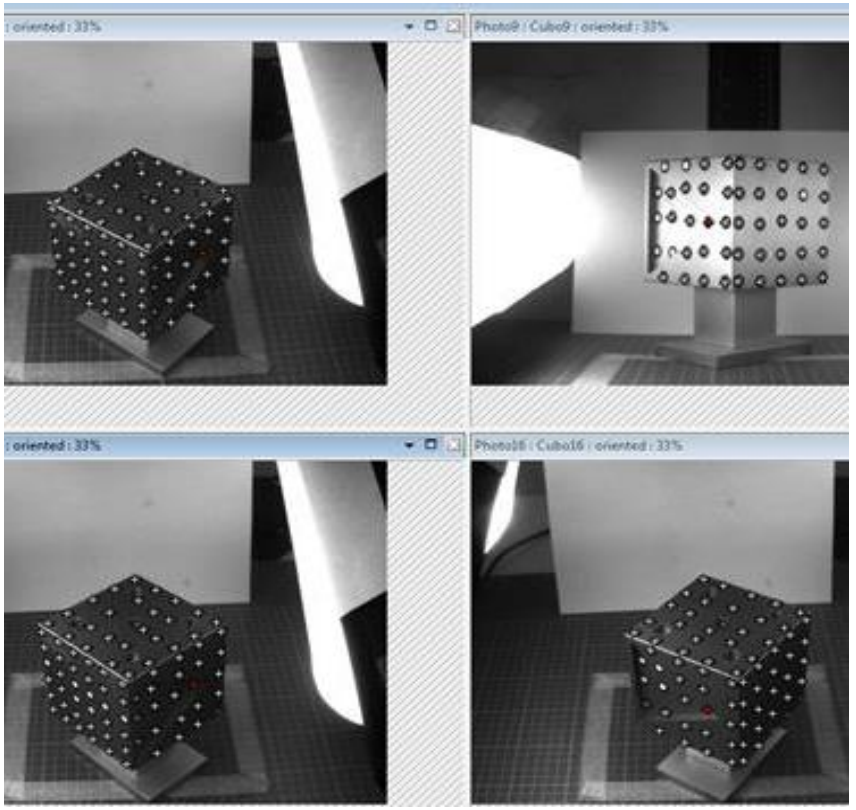


Application: manufacturing layup of composite materials
Accuracy to 2,6 µm



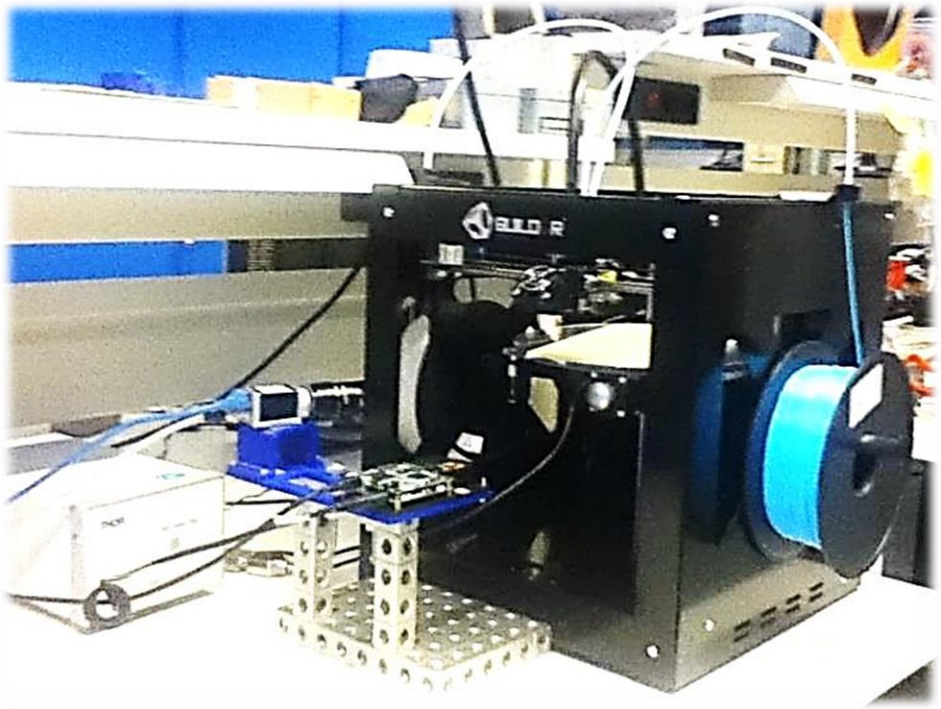
How fringe projection works?





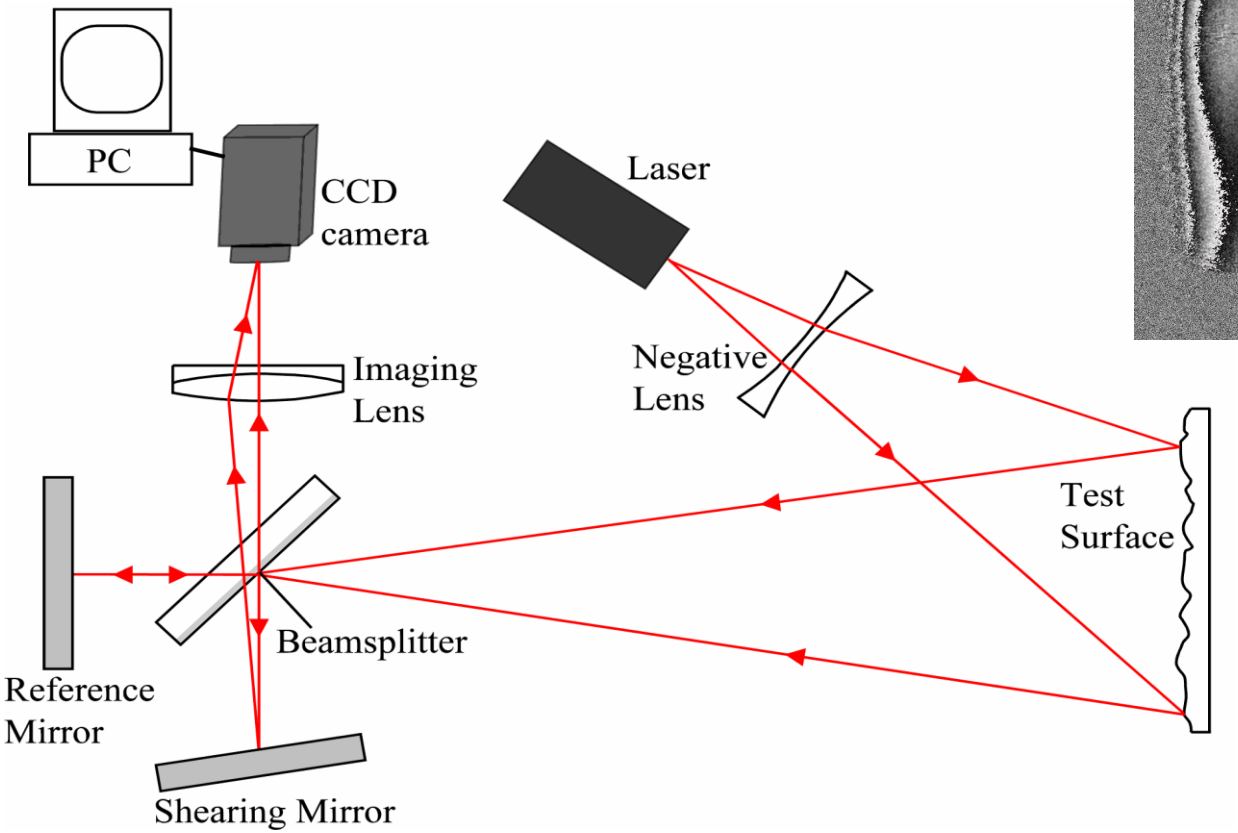
Accuracy to 50 µm

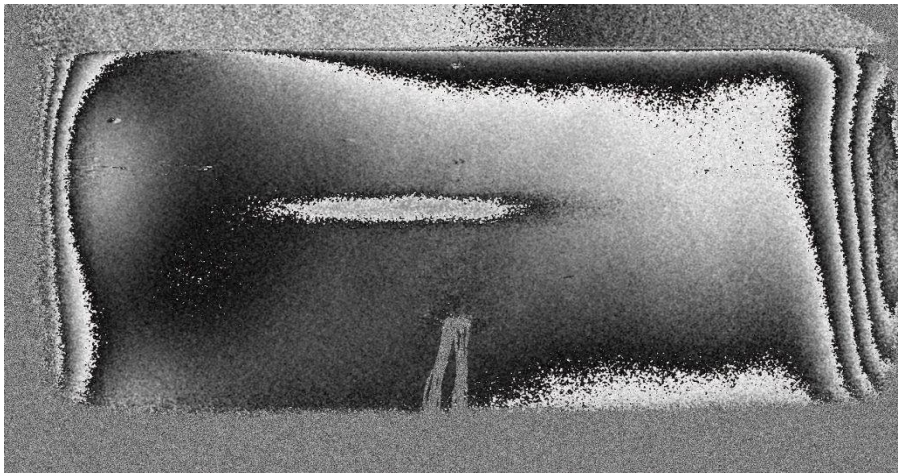
Fringe Projection for 3D Printer



Developed finger projection, camera and turntable system to monitor manufacturing on a 3D printer

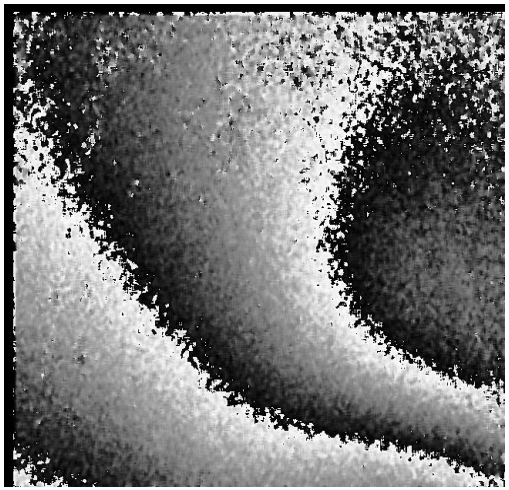
Shearography – Experimental Layout



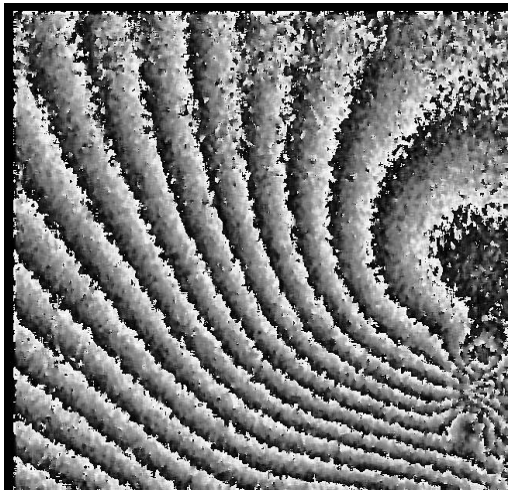


Example phase map from measurements on a cylinder

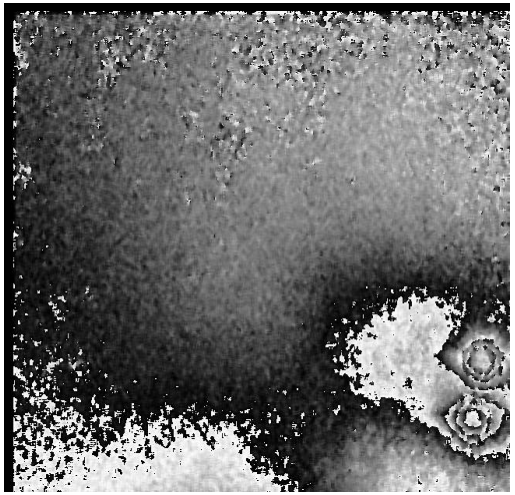
Detecting BVID in a composite panel with shearography



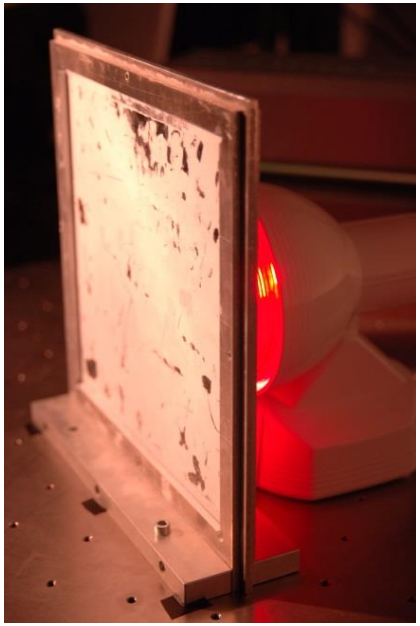
10 seconds



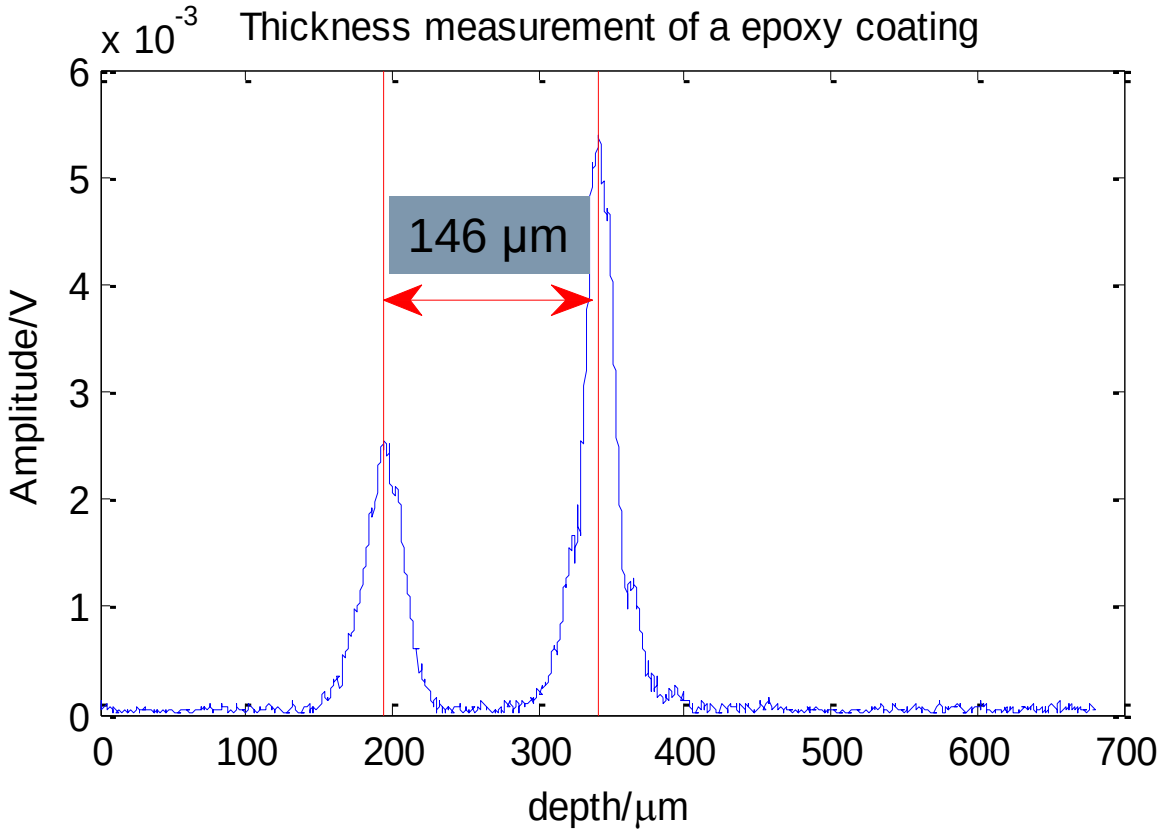
24 seconds



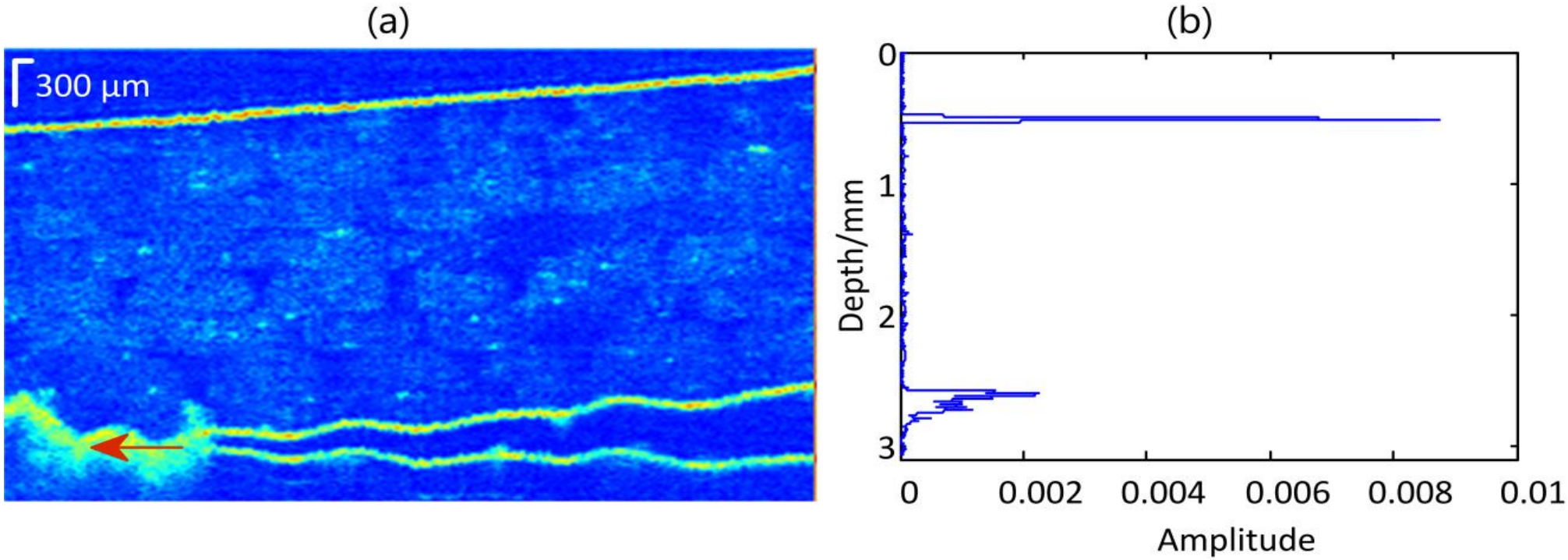
44 seconds



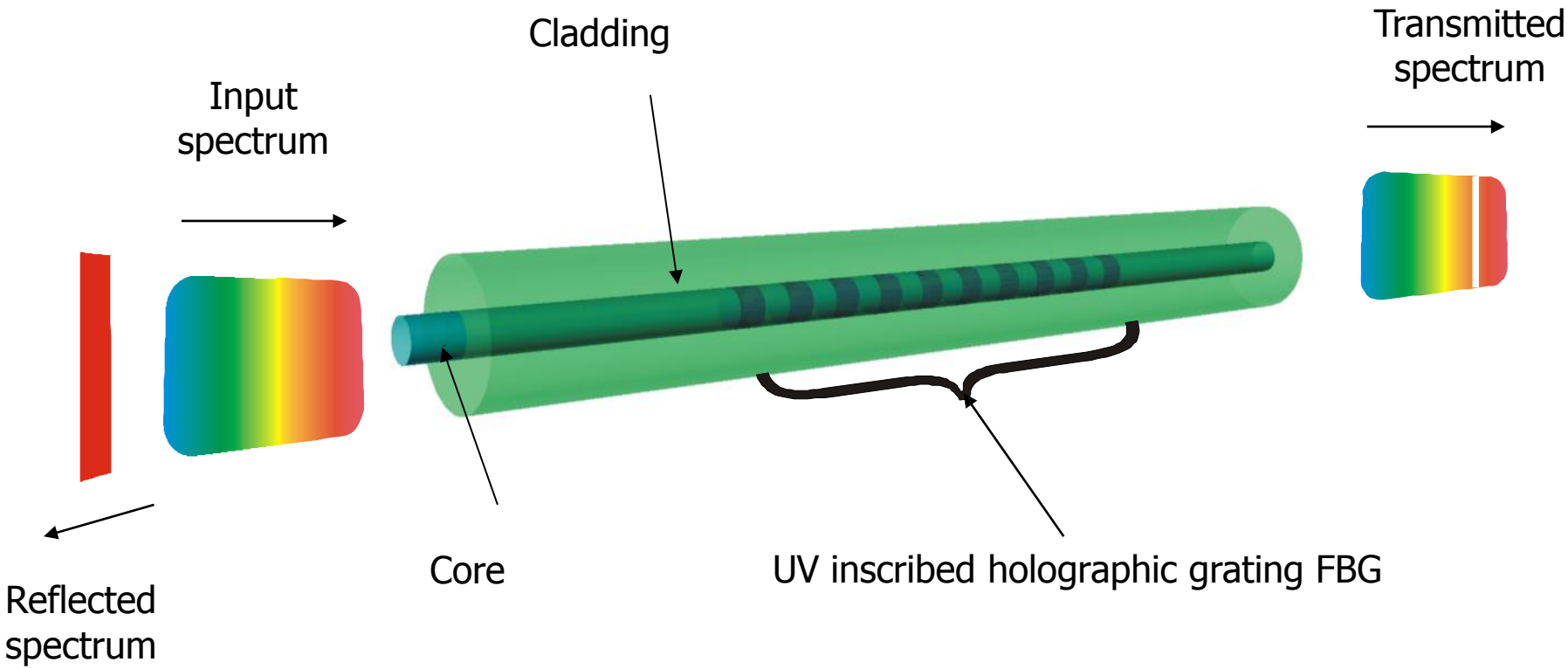
Optical Tomography for coating thickness measurement



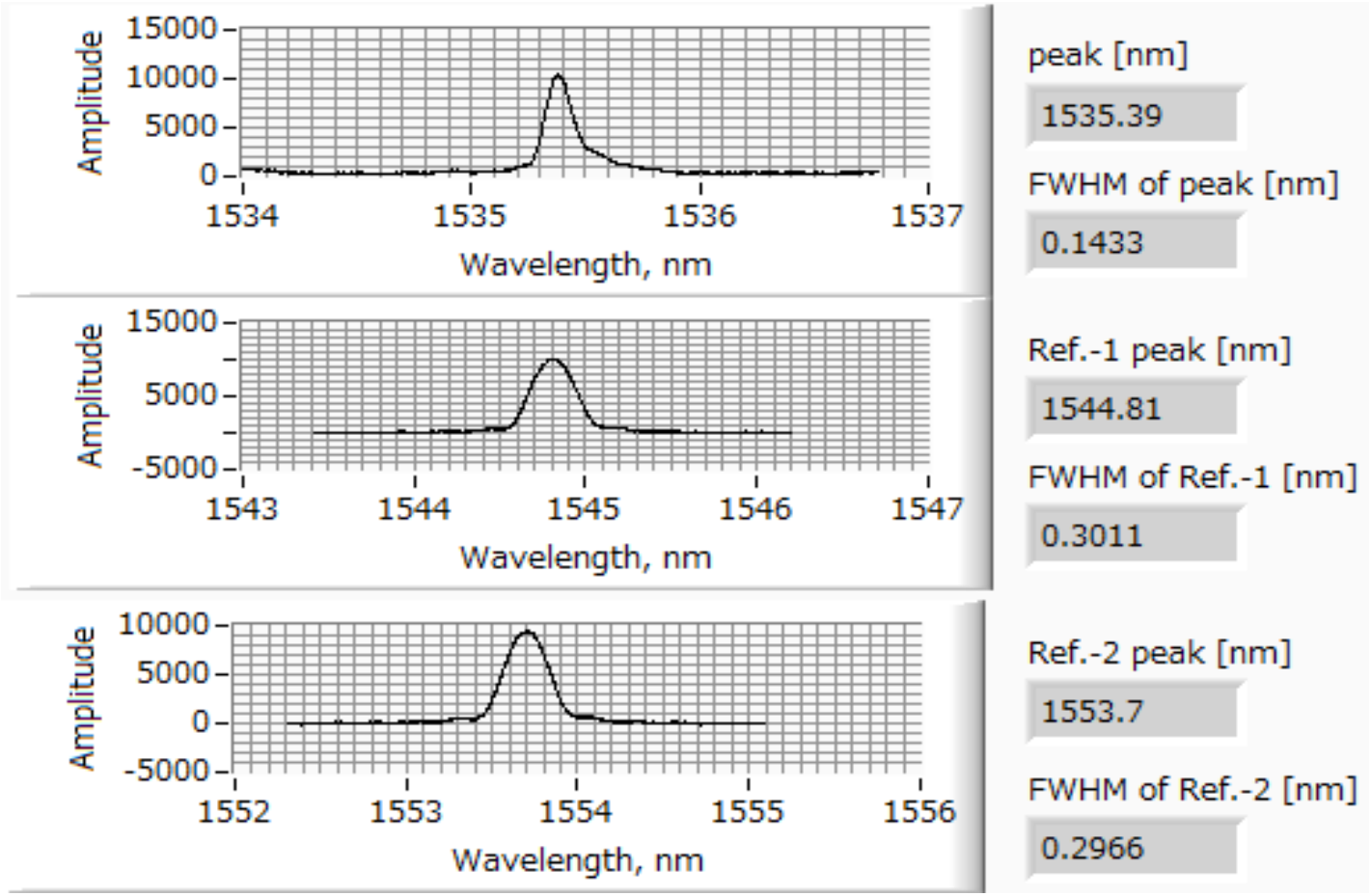
Optical Tomography for crack propagation in GFRP



FBG (Fibre Bragg Grating) - Theory



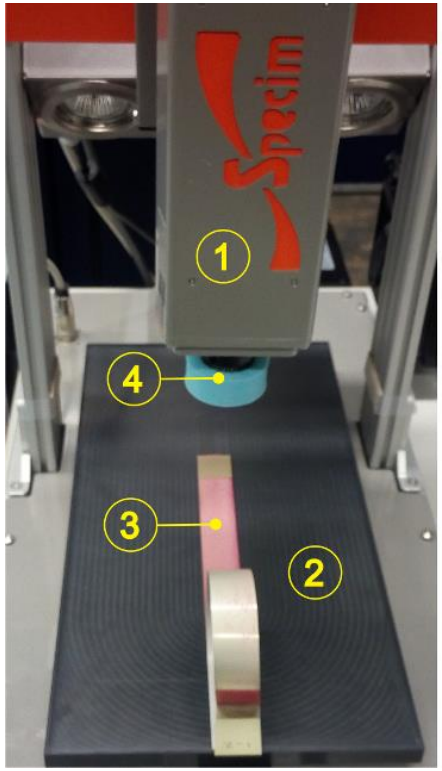
Multi-Parameter Strain and Vibration Measurement with FBGs



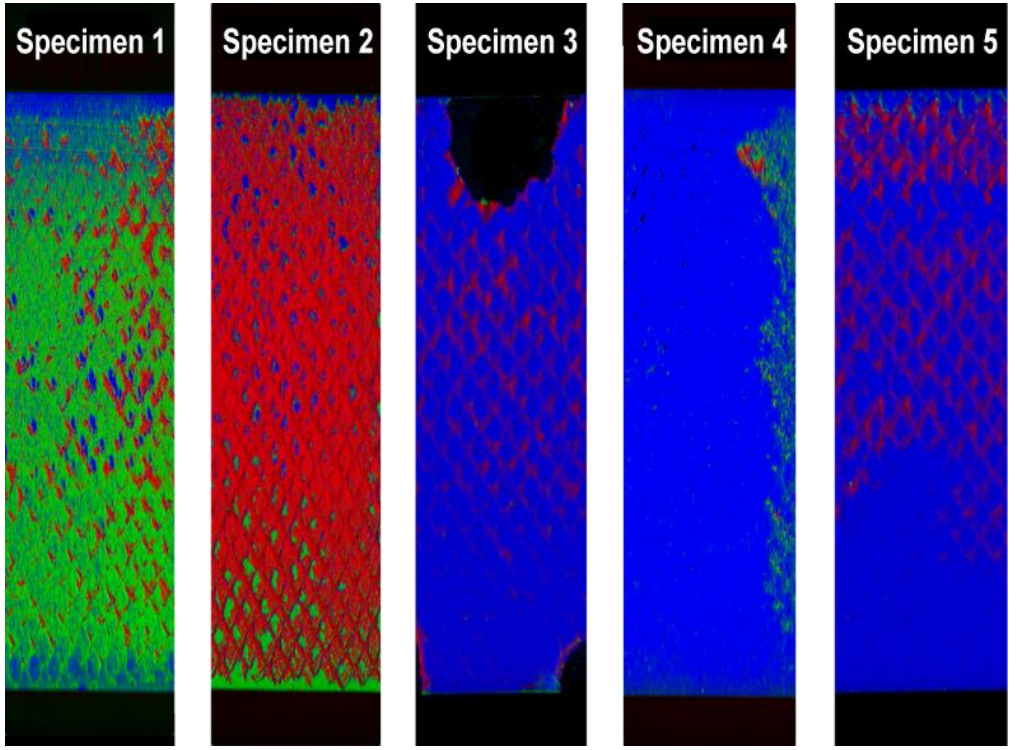
Measure

- Bending
- Tension
- Compresion
- Vibration

Hyperspectral Imaging of Adhesive Peel Test Samples



1. Hyperspectral camera
2. Scanning platform
3. Sample and calibration specimen
4. Objective lens and flattening filter



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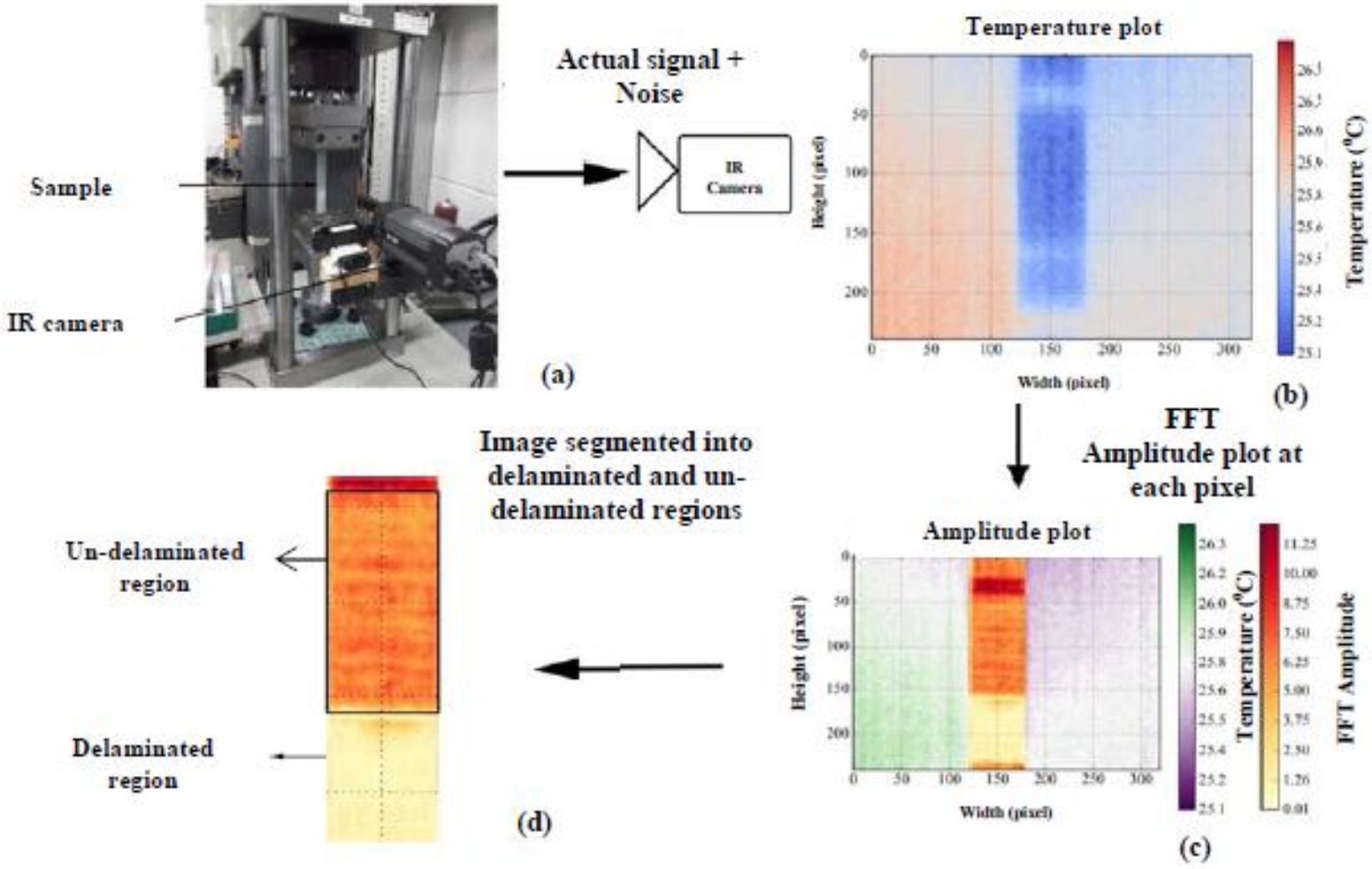
Thermal Stress analysis of GFRP under fatigue loading



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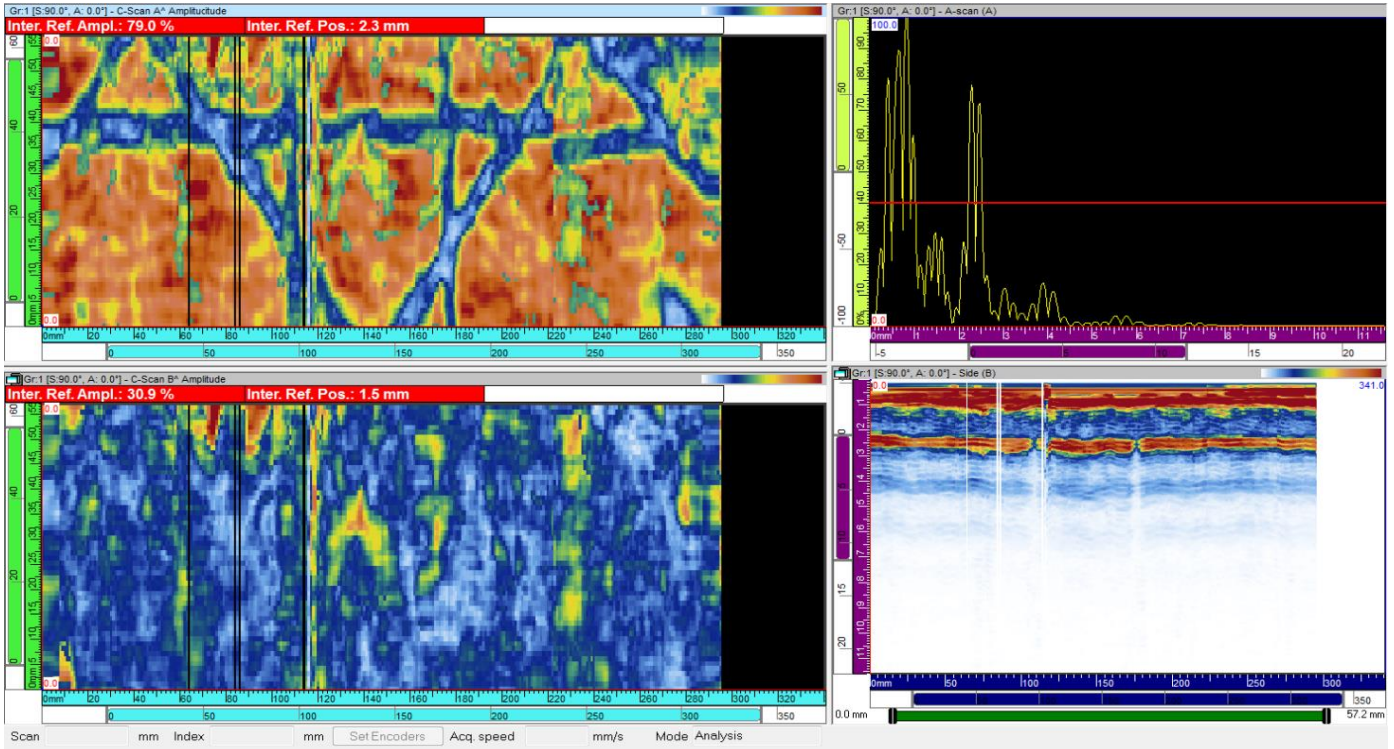
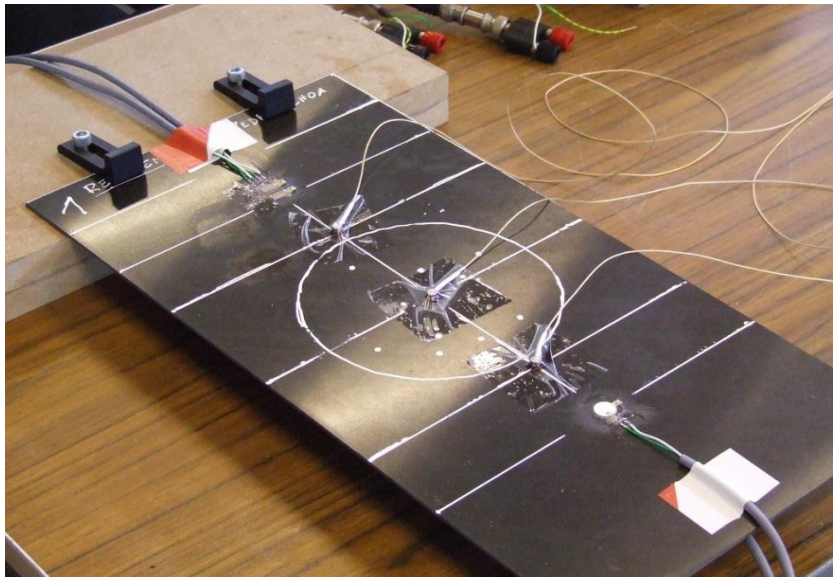
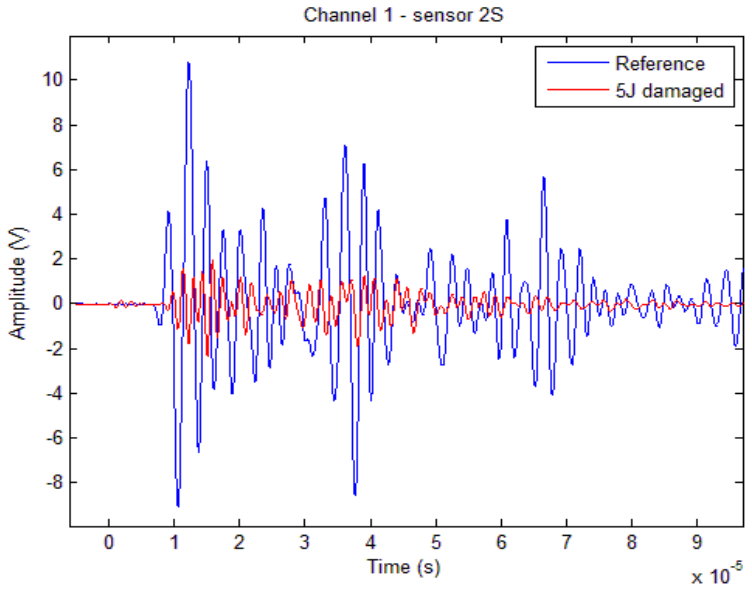
Phased Array Ultrasonics of grid-stiffened composite panel

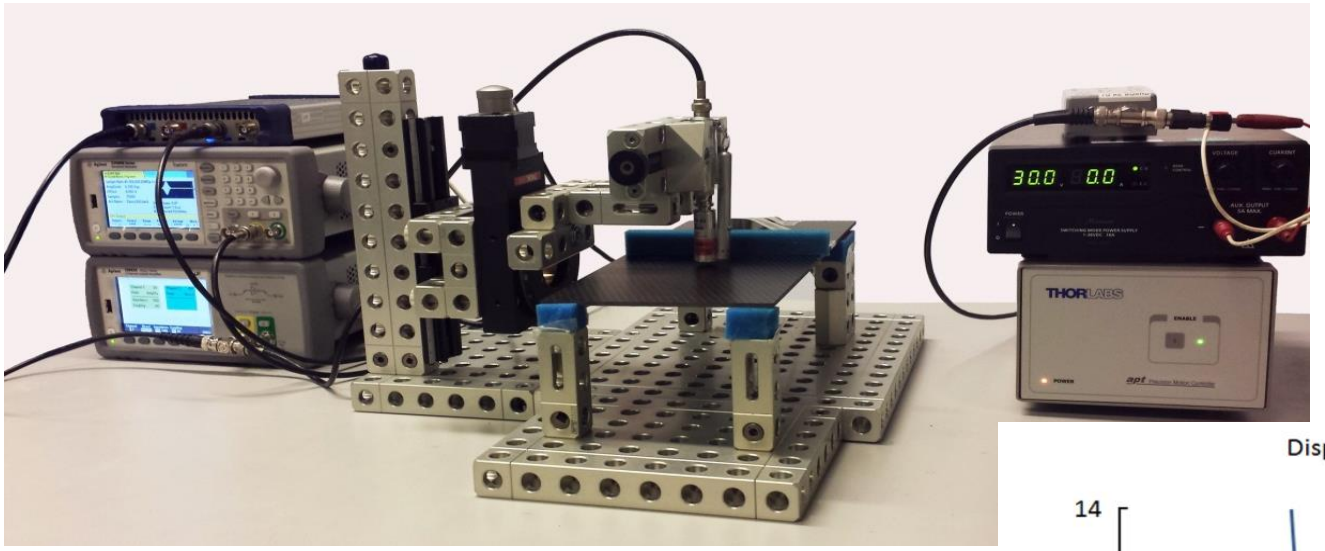


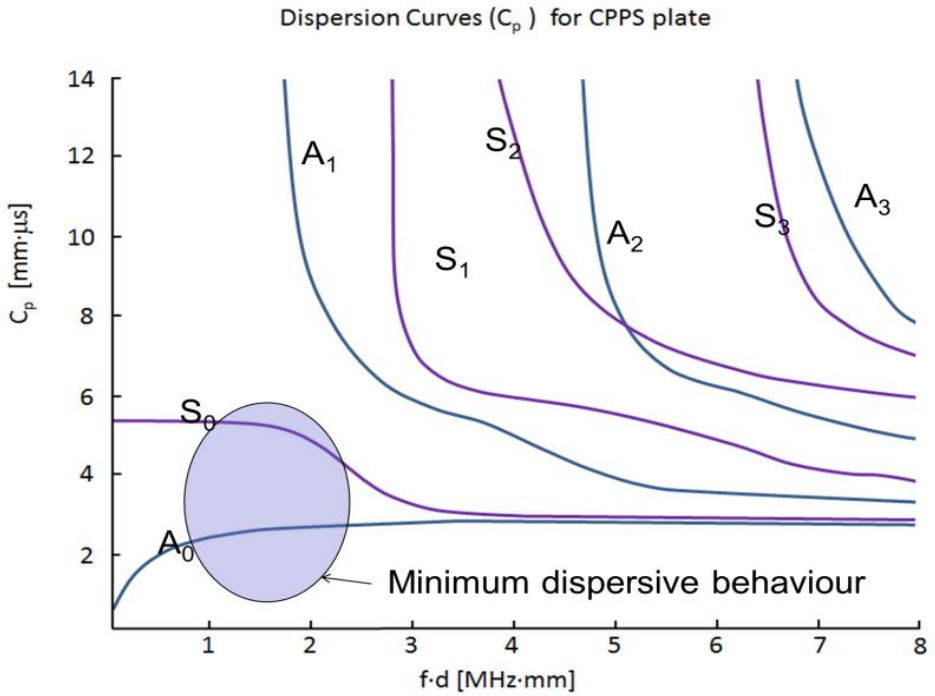
Detecting BVID in a composite panel with Lamb waves





Air coupled ultrasonics





Repairing Flaws before they Happen

Traditional approach is to test raw materials, monitor the process and check part/final product

My approach is to be proactive and continuously check the product quality in real-time during manufacture:

Preventative Non-Destructive Evaluation (PNDE)

Together with process monitoring this approach can be used to roll-back the process and correct flaws in real-time

<u>Progress so far</u>

1. *PNDE for hand layup in PhD research of Nick Miesen*
2. *PNDE for ATL in MSc research of Rik Tonnaer*

Automating NDT/SHM

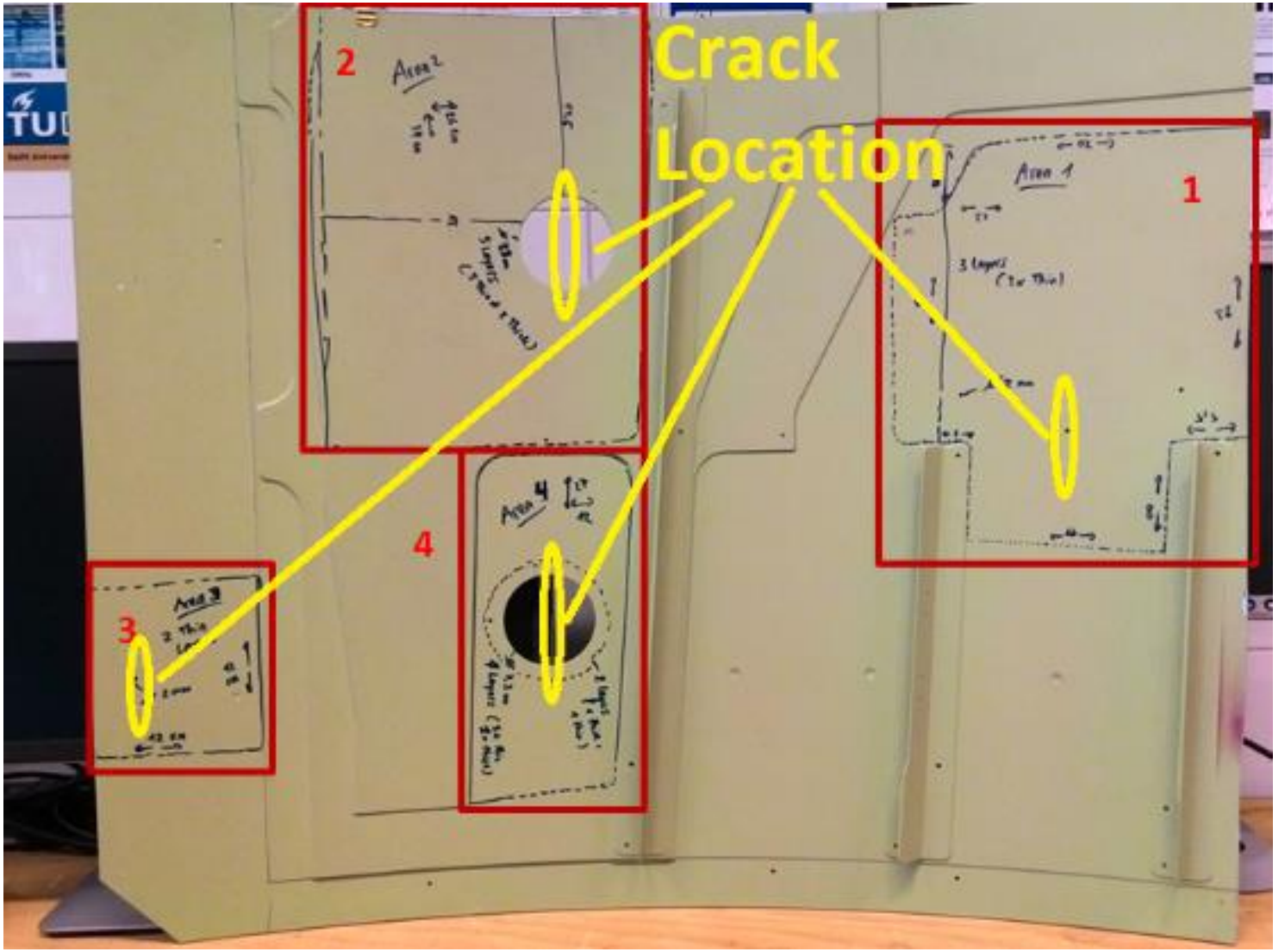
Efficient Maintenance and repair requires automated inspection & decision making. Our developments so far are:

1. Design of SHM systems and damage classification in MSc/PhD research of Vincentius Ewald
2. New computational approach for damage monitoring with FBGs in PhD research of Aydin Rajabzadehdizaji
3. Robot and 3D multi-sensor scanning in the research of Tigran Mkhoyan & Rik Tonnear
4. Integrated data fusion & processing platform (TIPP), developed by multiple researchers (lead Vassilis Papadakis)

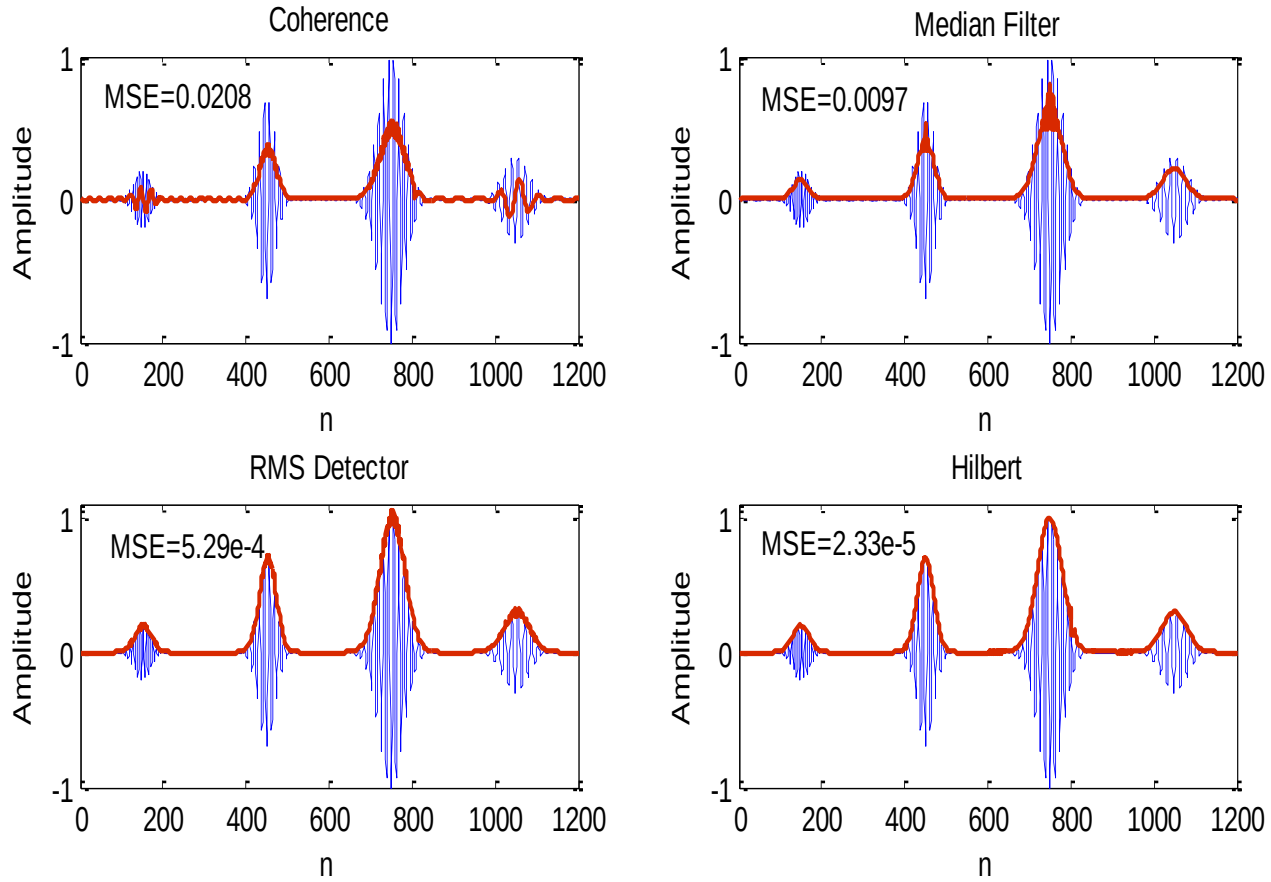
Automating the sensor position

Automating the sensor position

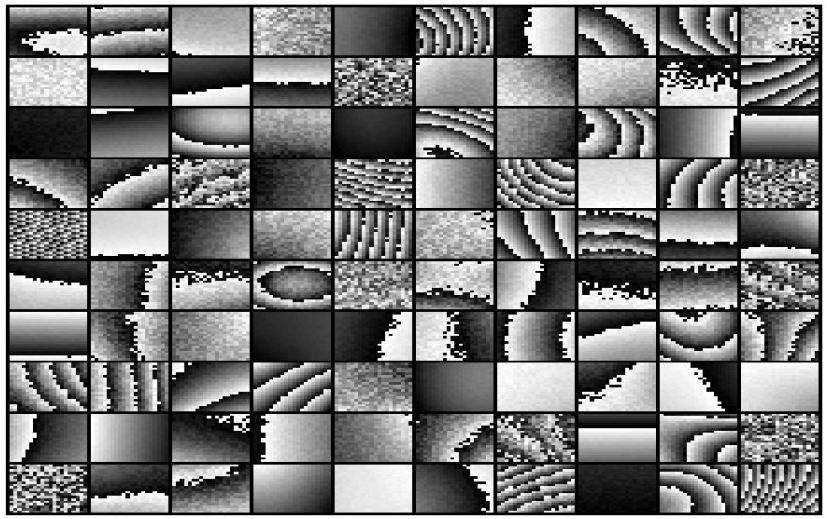
SHM system design



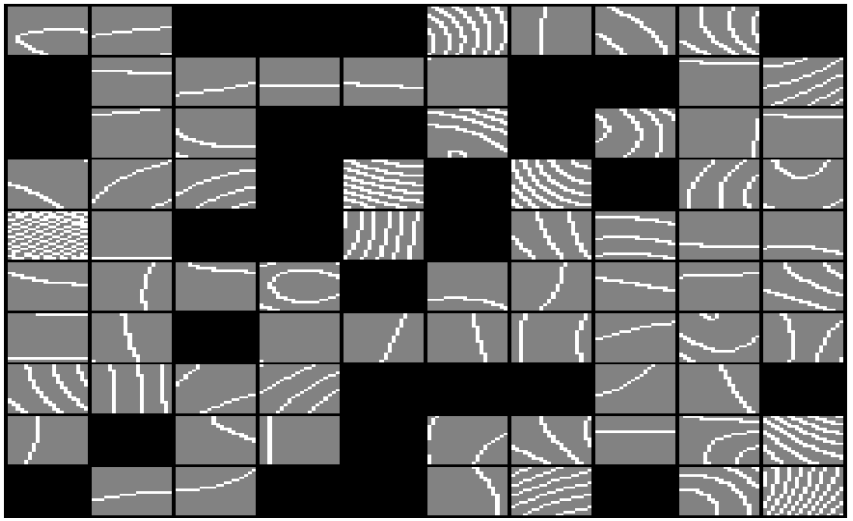
Automated processing & decision making – signal demodulation



Automated processing & decision making – fringe unwrapping

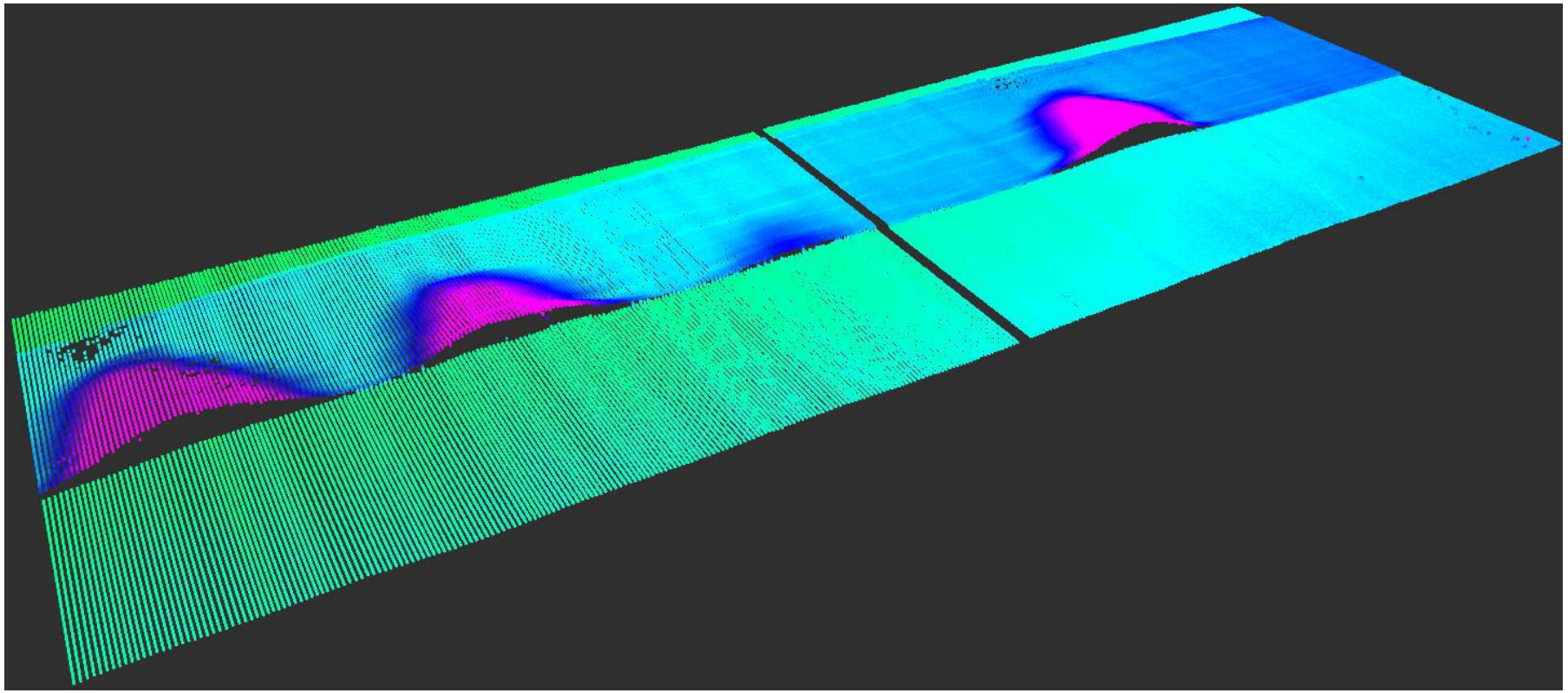


a. 20X20 pixel random portions of computer generated noisy wrapped phase map



b. Actual fringe locations, computer generate from corresponding non-noisy versions of wrapped phase map

Automated processing & decision making – defect detection in ATL



Summary - Automated NDT or SHM?

We need to consider and optimise the complete MRO system. All these are welcome:

1. Automated positioning of NDT sensors using robots, UAVs or 3D scanning systems

2. Installing SHM sensors is an option for new aircraft. Many challenges for retrofit for older aircraft

3. Consider hybrid approach, e.g. embedding markers in aircraft for NDT detection

4. **Most important is to speed up the data handling and decision making with smart algorithms**

Thank you for your attention!

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