NDT and SHM of Carbon Composites using Acoustic Ultrasonic Methods

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AeroNDT Forum

Deutsches Zentrum
für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

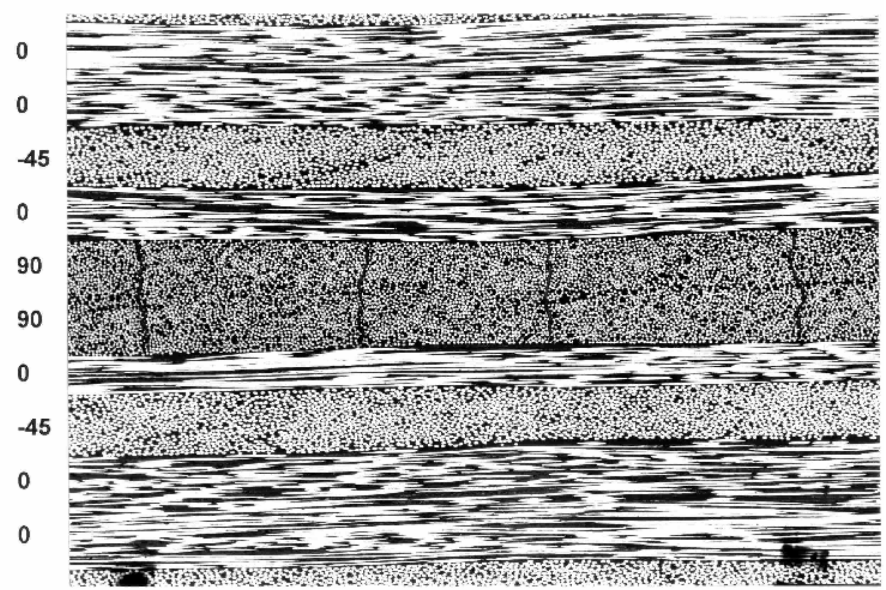
Contents

Introduction

CFRP (carbon fibre reinforced composites) provide a high specific stiffness and strength.

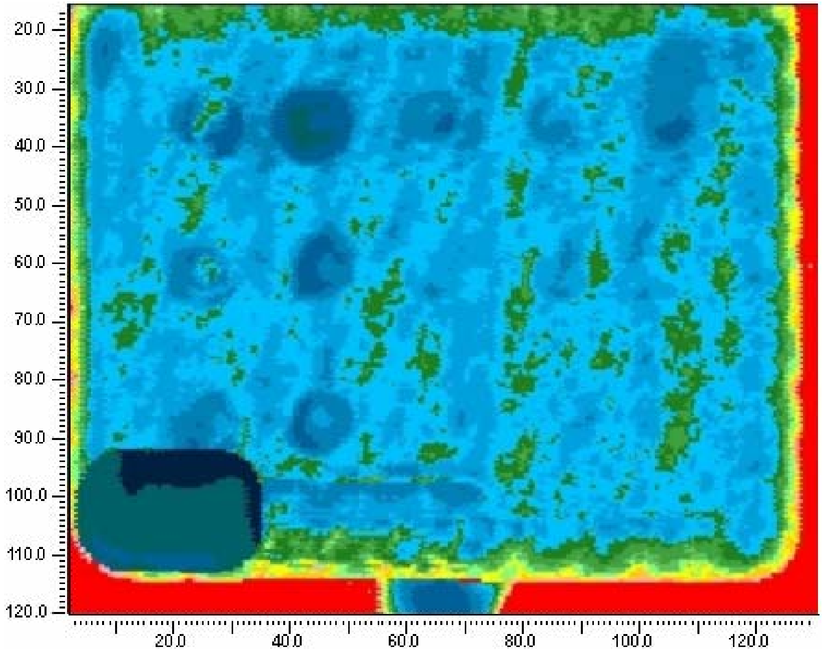
Future components like the black fuselage will be more and more complex in order to take advantage of their properties. However the NDT-methods have to be applied for the inspection after production and in service.

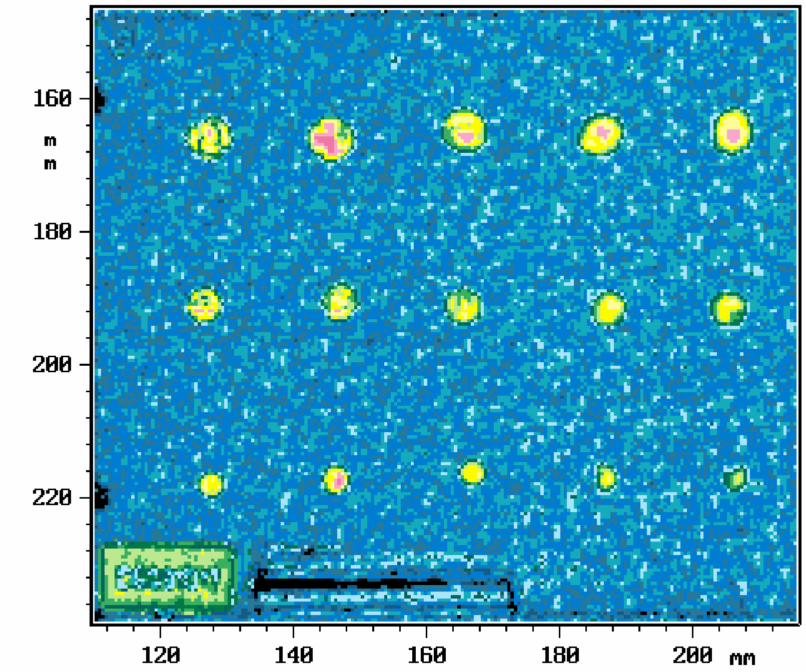
The ultrasonic technique is principally able to detect all relevant defects. The high specific attenuation and high scattering require special adjustments for these materials.



Longitudinal cut of a 2 mm thick CFRP component

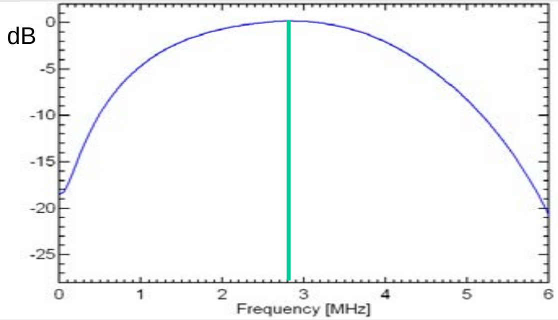
Optimization of Inspection Parameters



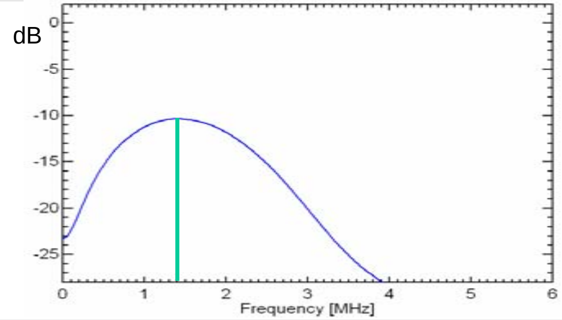


CFRP: High frequency-dependent Sound Attenuation

Transmitter

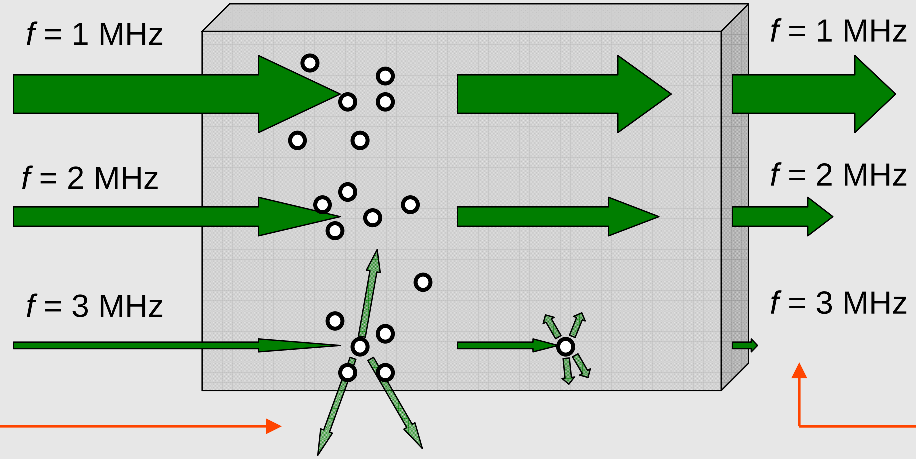


Receiver



Arrow thickness ~ wavelength
Arrow length ~ amplitude
○ = *signified microstructure*

delivered signal:
E.g. same amplitude at 1, 2 and 3 MHz



Transmission:
Spectrum shifted to low frequencies

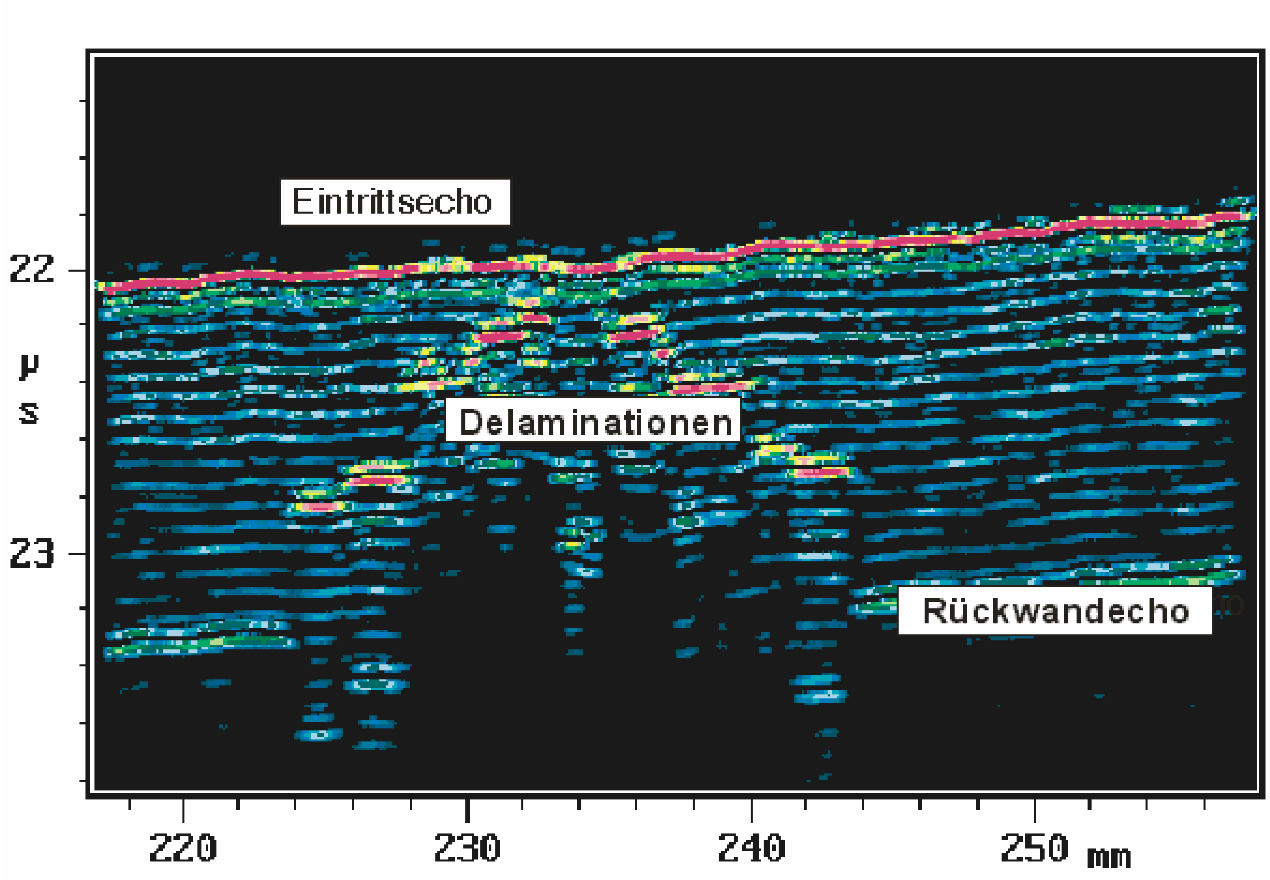
Loss by scattering is dominating at high frequencies

The HF fraction is attenuated superproportional

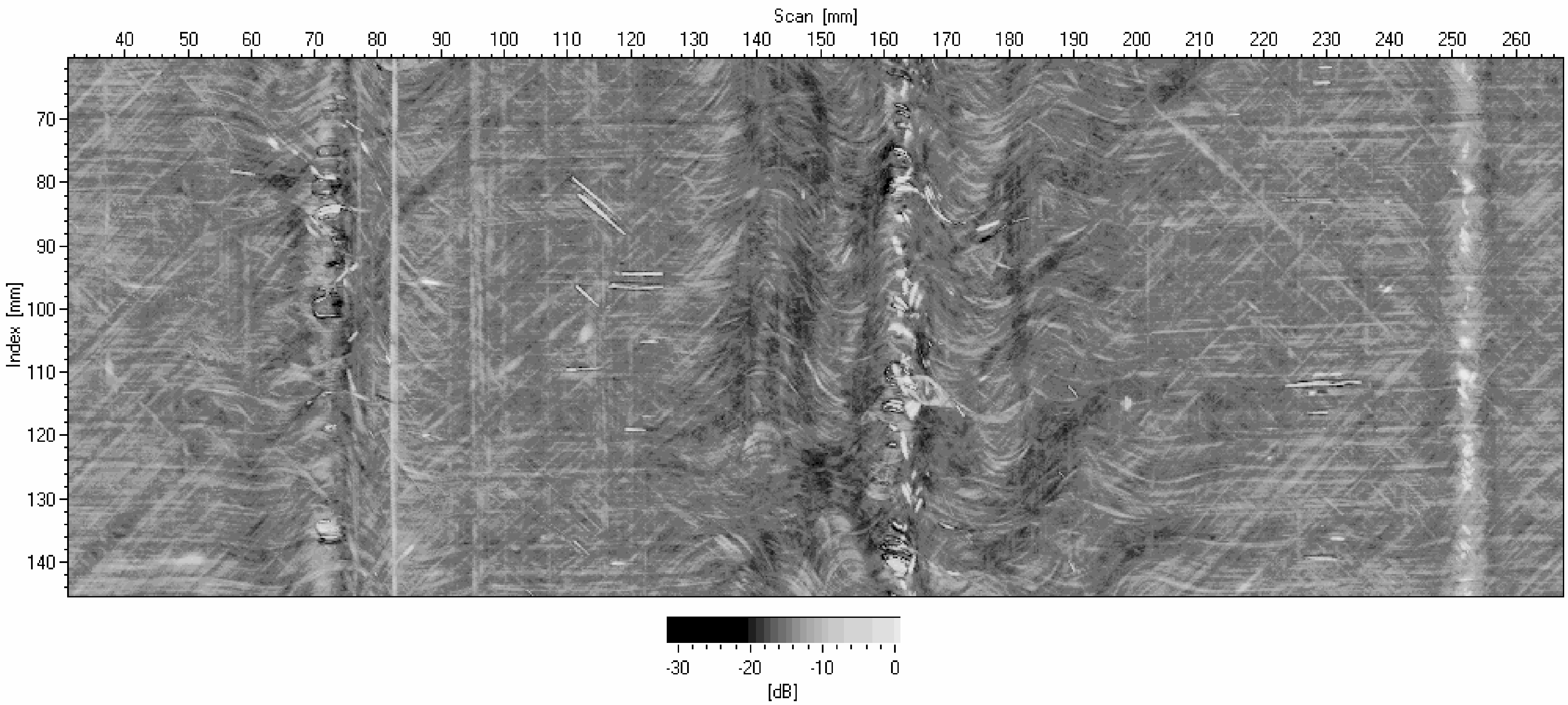
Ultrasonic Imaging Techniques at DLR

- Frequency range: 10 kHz to 120 MHz
- Coupling techniques: immersion, water split, non-contact with air
- Imaging techniques: A-, B-, C-, D- and F-scan
- Data recording: full wave (RF-signals)
- Signal analysis, filtering, ..

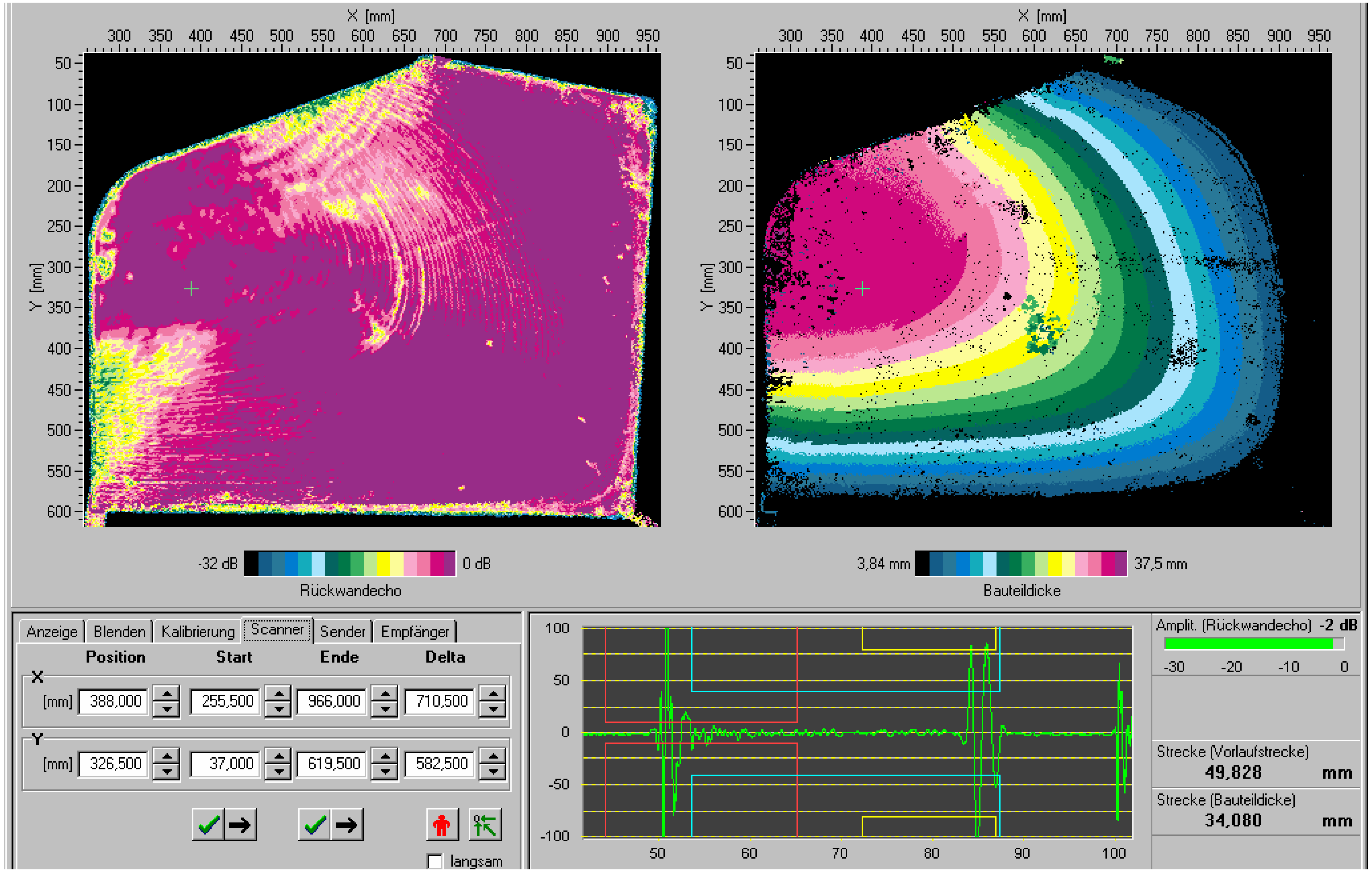
B-Scan of a 2 mm thick CFRP-Specimen with Impact



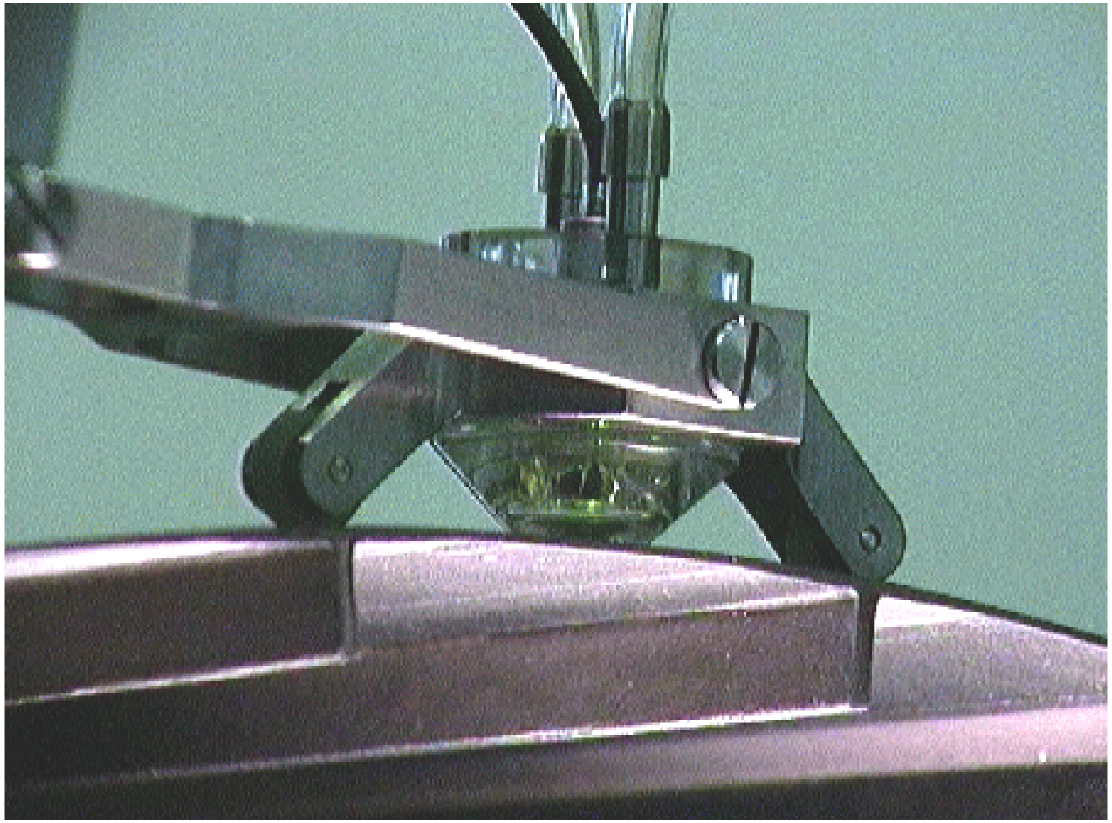
Indication of Waviness of Fibres

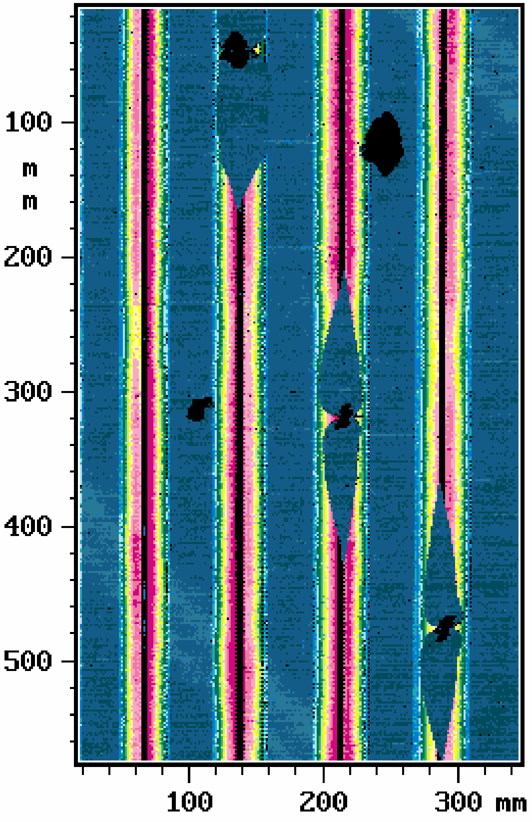


Ultrasonic Inspection of an Airbus CFRP-Component

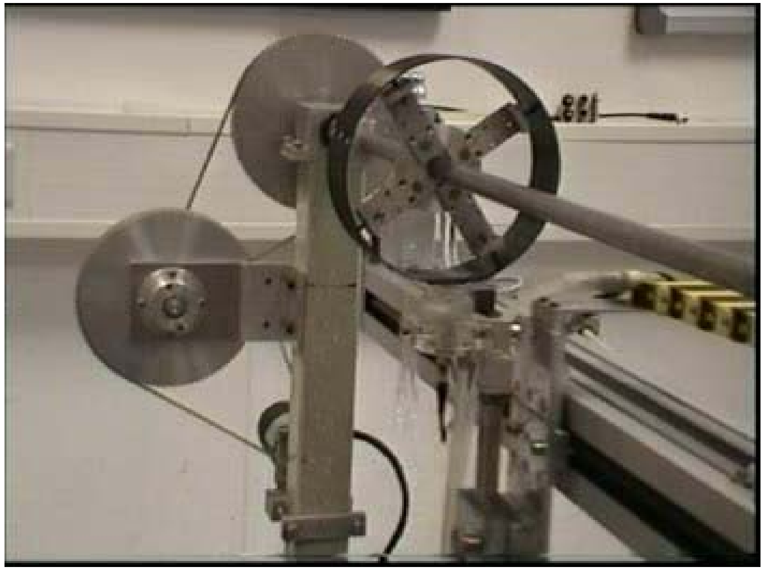


Inspection of a curved CFRP-Panel





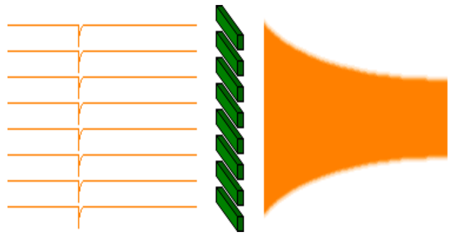
Testing of a CFRP-Cylinders (up to a diameter of 800mm)

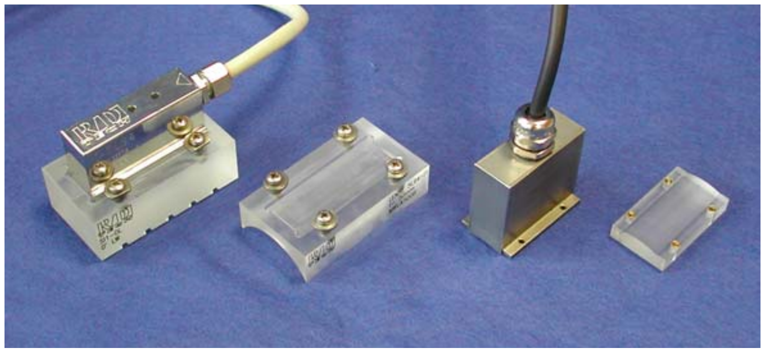


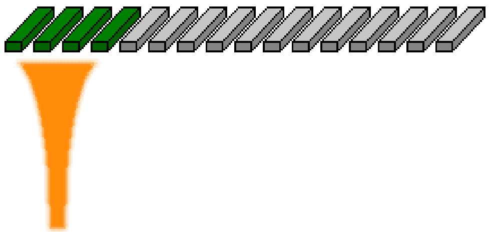
Phased-Array-Technique

- Transducers consist of up to 128 elements
- Phased controlled sender and receiver
- Fast (electronic) linear scanning
- Variable sound field
- Real-Time B- scan

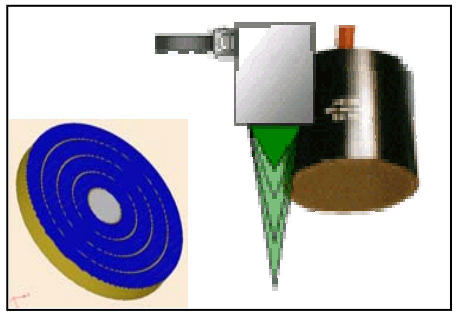
Focussing







Linear scanning



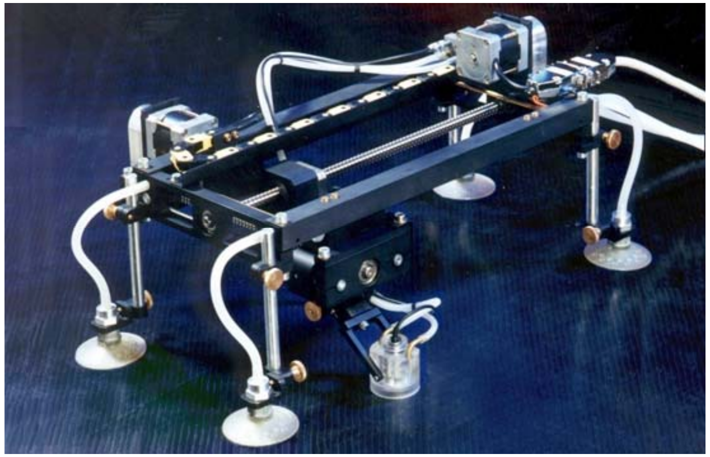
www.imasonic.com

MUSE : Mobile UltraSonic Equipment

- Automatic in-situ inspection providing images
- Closed water circuit for acoustic coupling
- High resolution and high reproducibility

Frequency range:	0.001 to 20 MHz (-3dB)
PRF:	10 kHz
ADC:	14 bit @ 200 MS/s
Imaging:	A-, B-, C- and D-Scans
Dynamic range:	60 dB in a C-Scan
Scanning area:	210 x 170 or 380 x 290 mm^2
Mech. resolution:	20 µm
Scanning speed:	up to 200 mm / s
Coupling:	water split with circulation

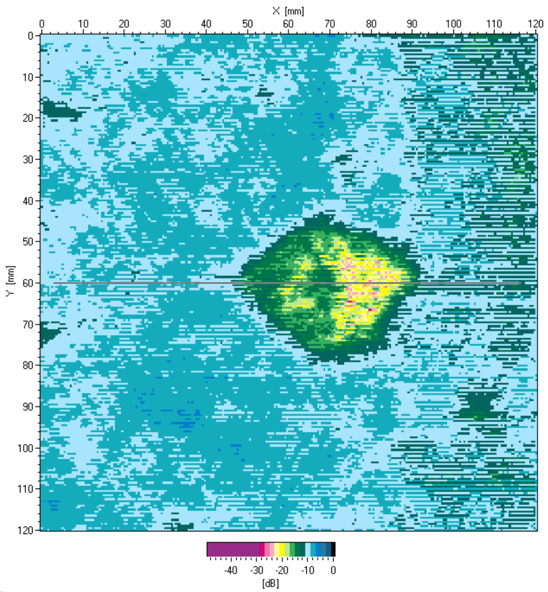
Water circulation system

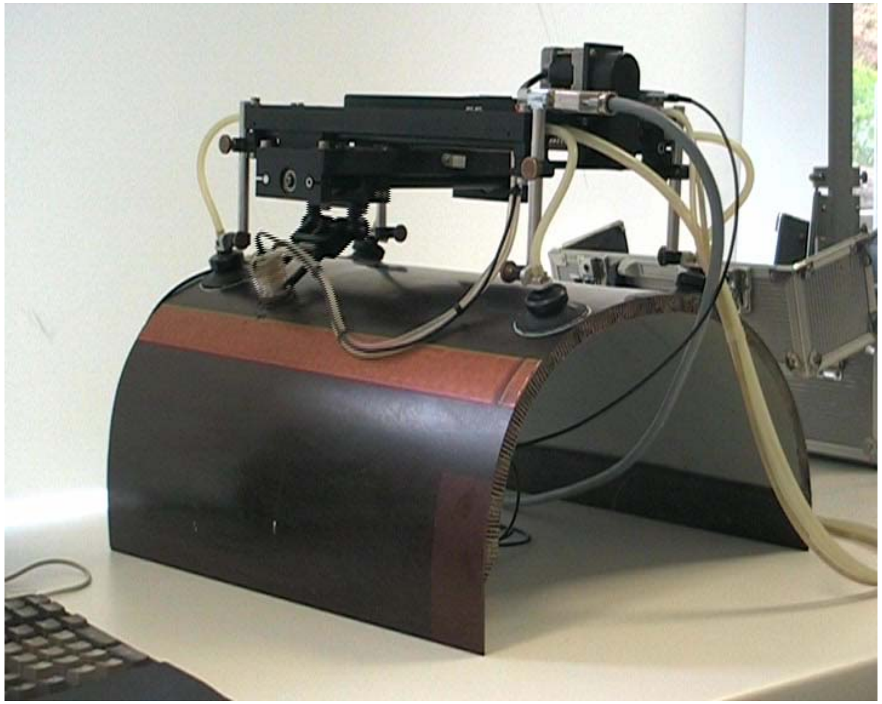


Motor-driven manipulator with suction cups

MUSE : Ultrasonic Imaging for Defects in curved Components

- Elastic (longitudinal) waves provide the detection of defects with high resolution
- C-and D-Imaging show defect sizes and locations





Inspection of a tail-unit cut out of a helicopter

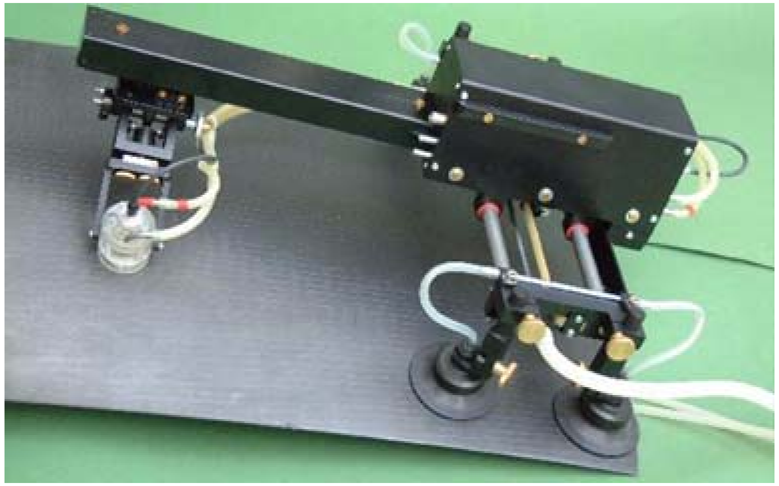
Ultrasonic detection of Porosity

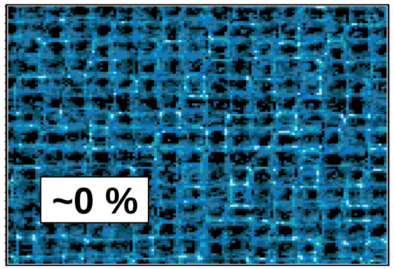
Porosities:

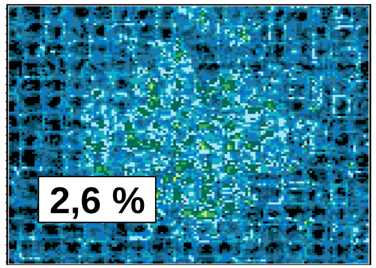
- Statistically distributed discontinuities
- Backscattering instead of reflection
- Conventional method:
  Analysis of backwall-echo

Porosity-Scanner:

- Optimised for high-quality C/D-Scans of backscattered signals
- No use of backwall echo
  (⇒ sandwich skin, sloped backwall)

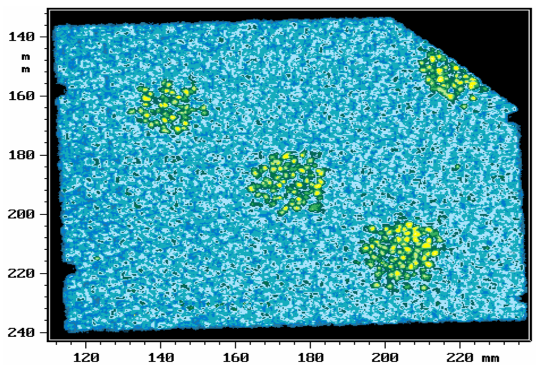




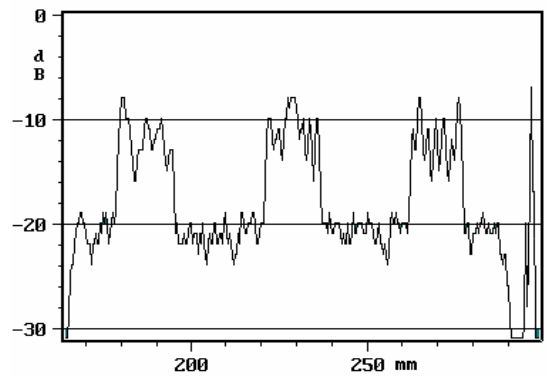


Measurement of the Pore Content

Artificial Pores
(1.2; 1.6 and 2.3 Vol.-%)
in CFRP (4.2 mm)

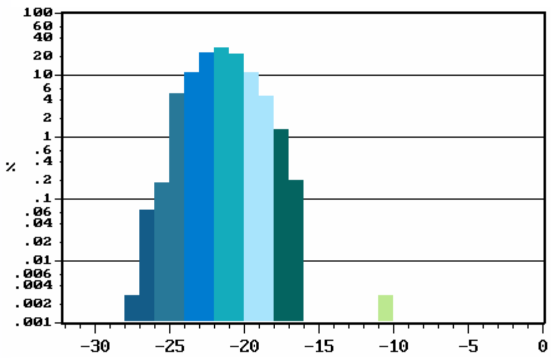


C-scan

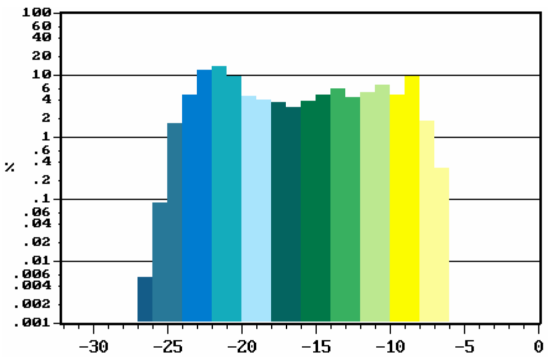


Echo dynamic curve

Histograms



< 0.5 Vol-%



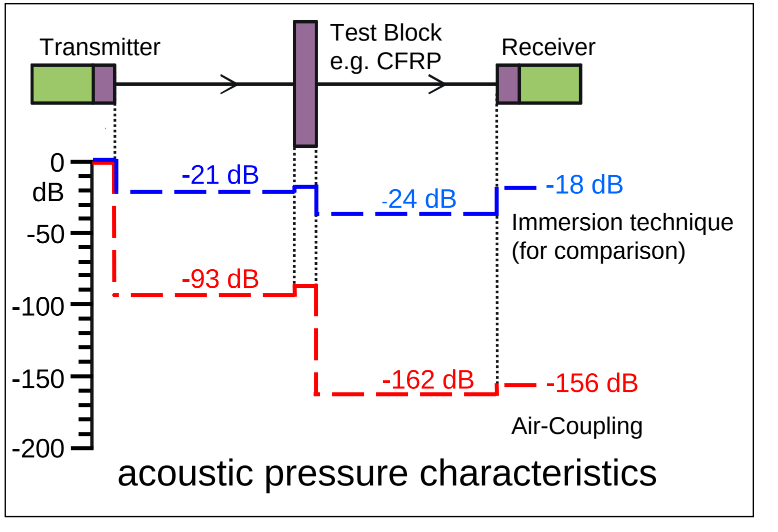
2,3 Vol.-%

Air-coupled Ultrasonic Testing

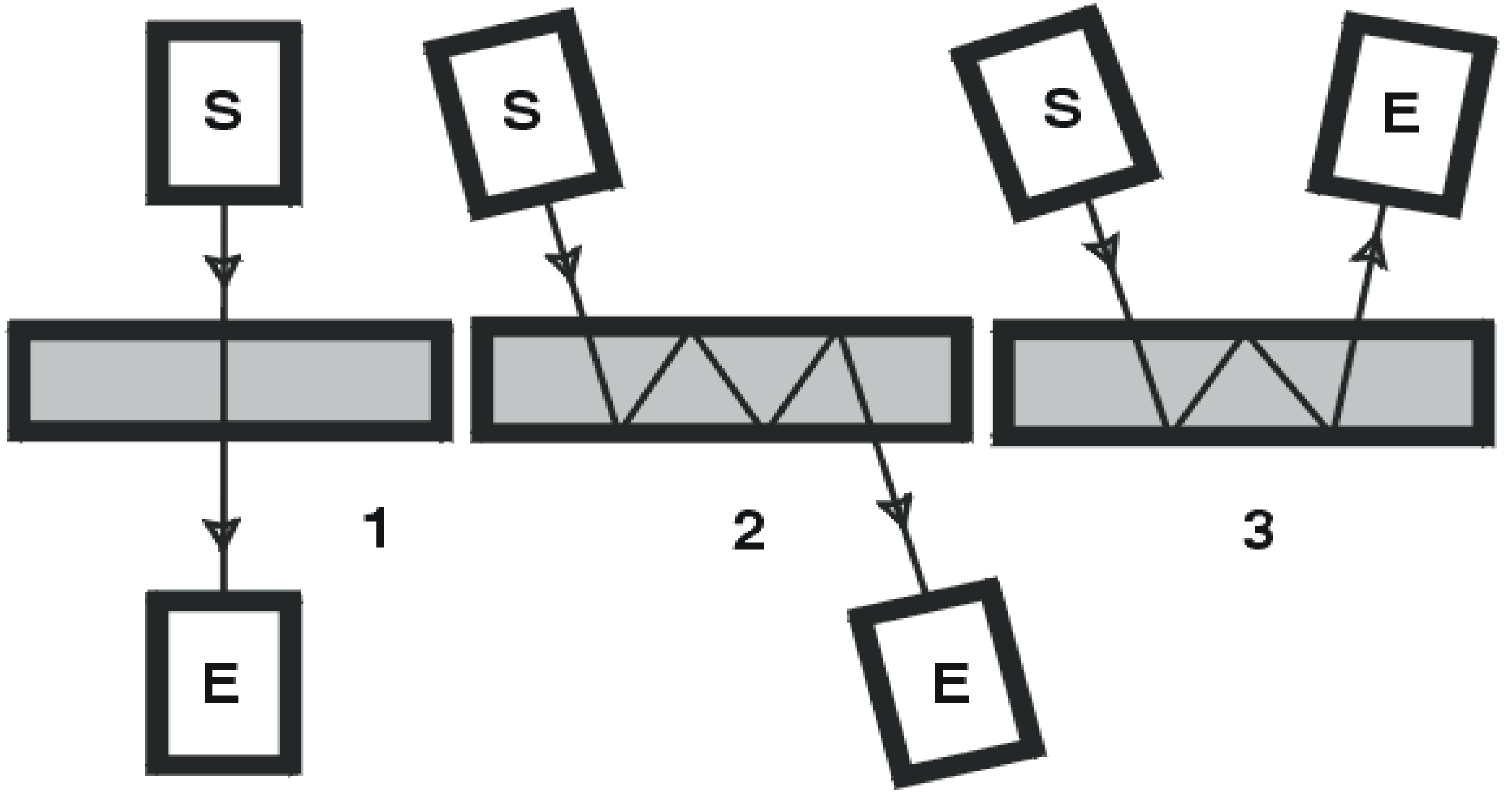
- Non-contact method
- No coupling paste or liquid required
- Constant and reproducible coupling
- No damage caused by incoming water

But:

- Large acoustic mismatch
- More than 160 dB amplitude loss
- Special probes and special US-equipment necessary



Air-coupled Techniques



HFUS 2400 AirTech

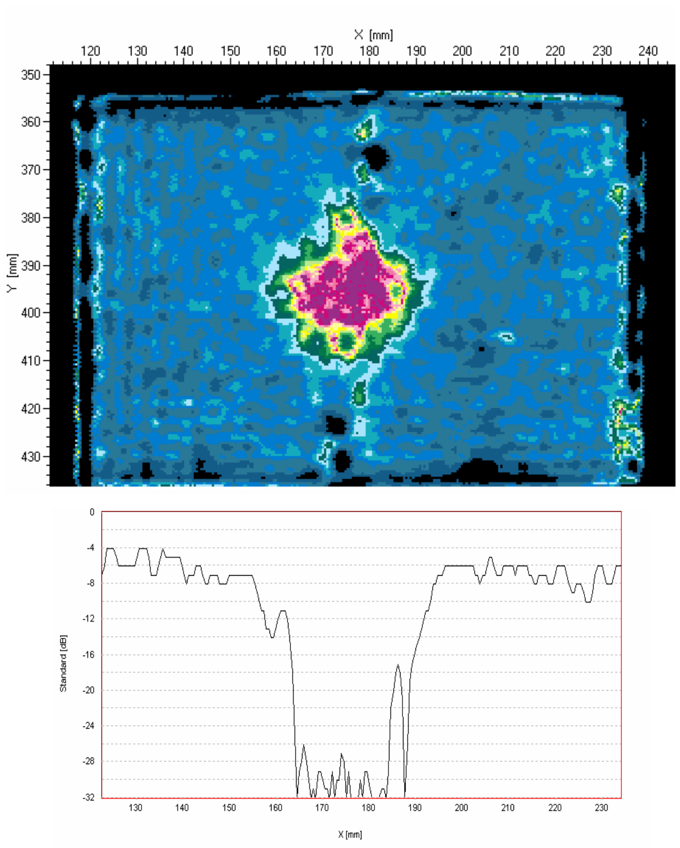
Technical data:

Frequency range:	0.01 to 1.5 MHz (-3dB)
PRF:	up to 1.5 kHz
ADC:	8 bit @ 10 MS/s
Imaging:	A-, C- and D-scans
Dynamic range:	32 dB in a C- scan
Scanning area:	1 m x 1 m
Mech. resolution:	0.125 mm
Scanning speed:	up to 1m/s
Coupling:	Air

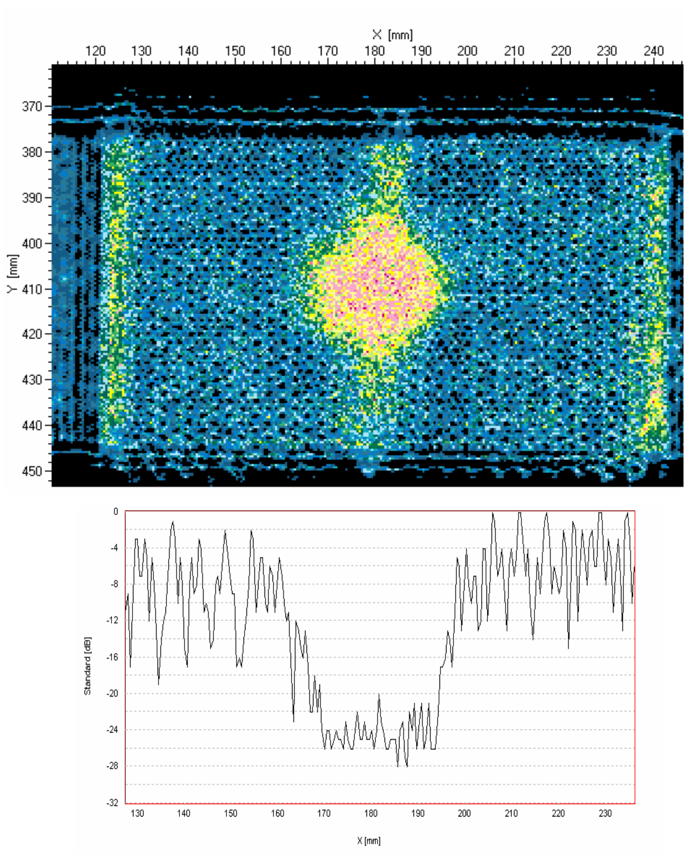
Applications:

- Replacement of Squirter Devices
- Sandwich structures
- Future Airbus Fuselage

C-Sans of Sandwich Components recorded with Air-Coupling

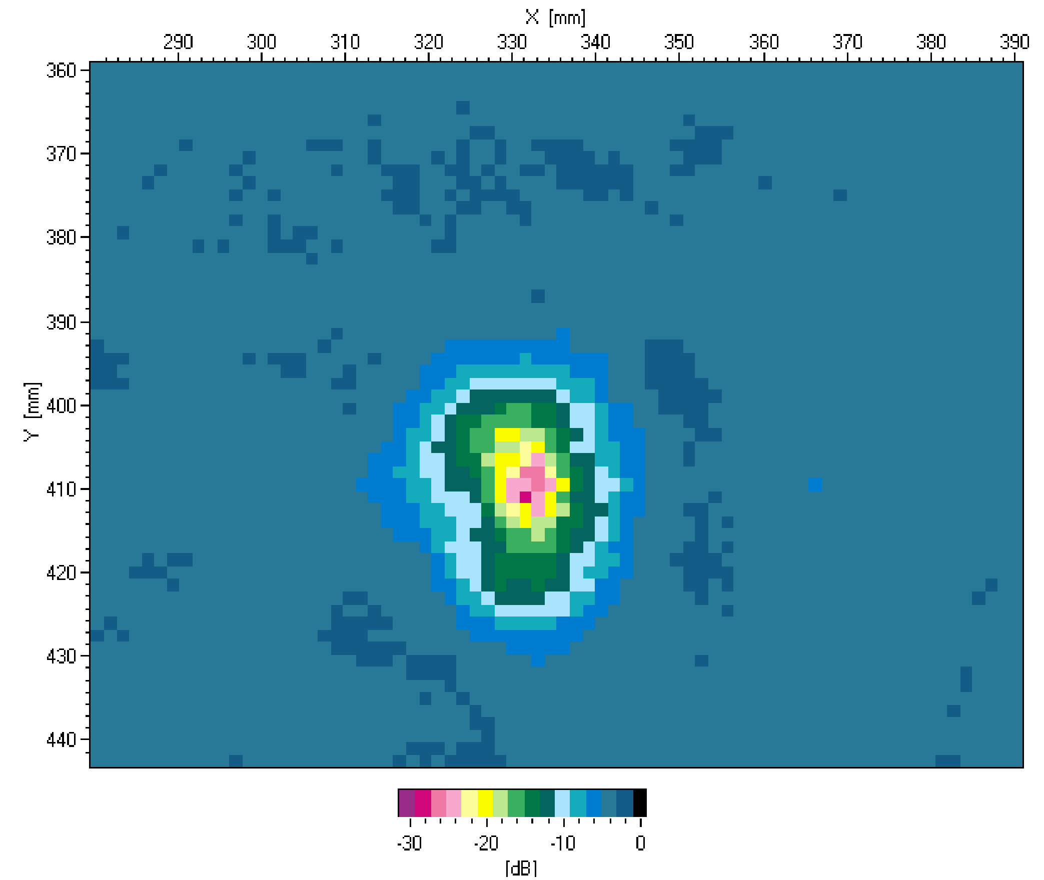


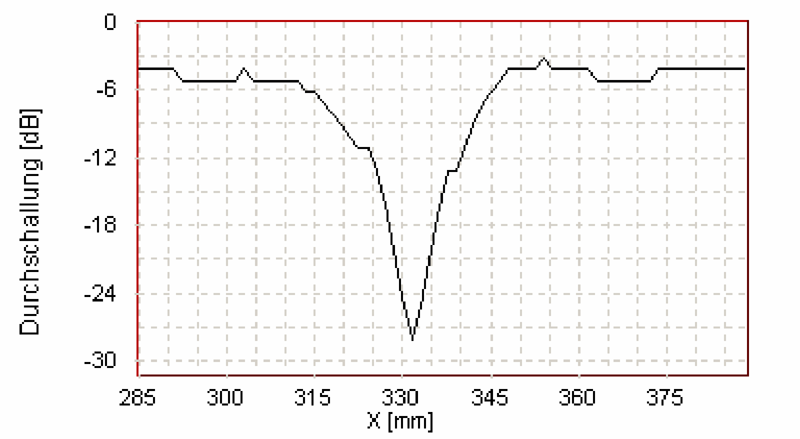
f = 153 kHz



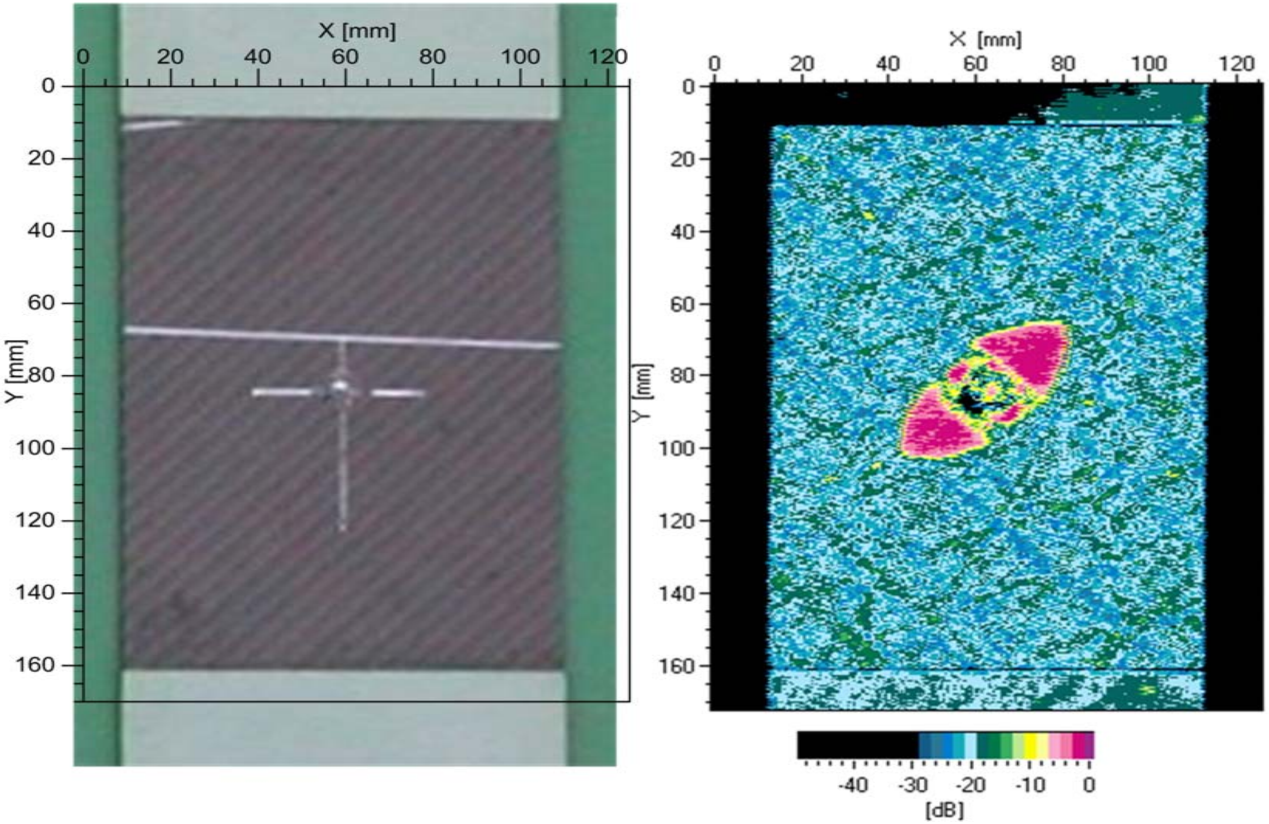
f = 403 kHz

Detection of a 5 Joule Impact





Impacted Sandwich Specimen (20J)



SHM using Lamb Waves

- Lamb waves can penetrate large areas
- No time consuming scanning
- Damages can be monitored in complex structures
- Piezo-patches are often used as transmitters and receivers

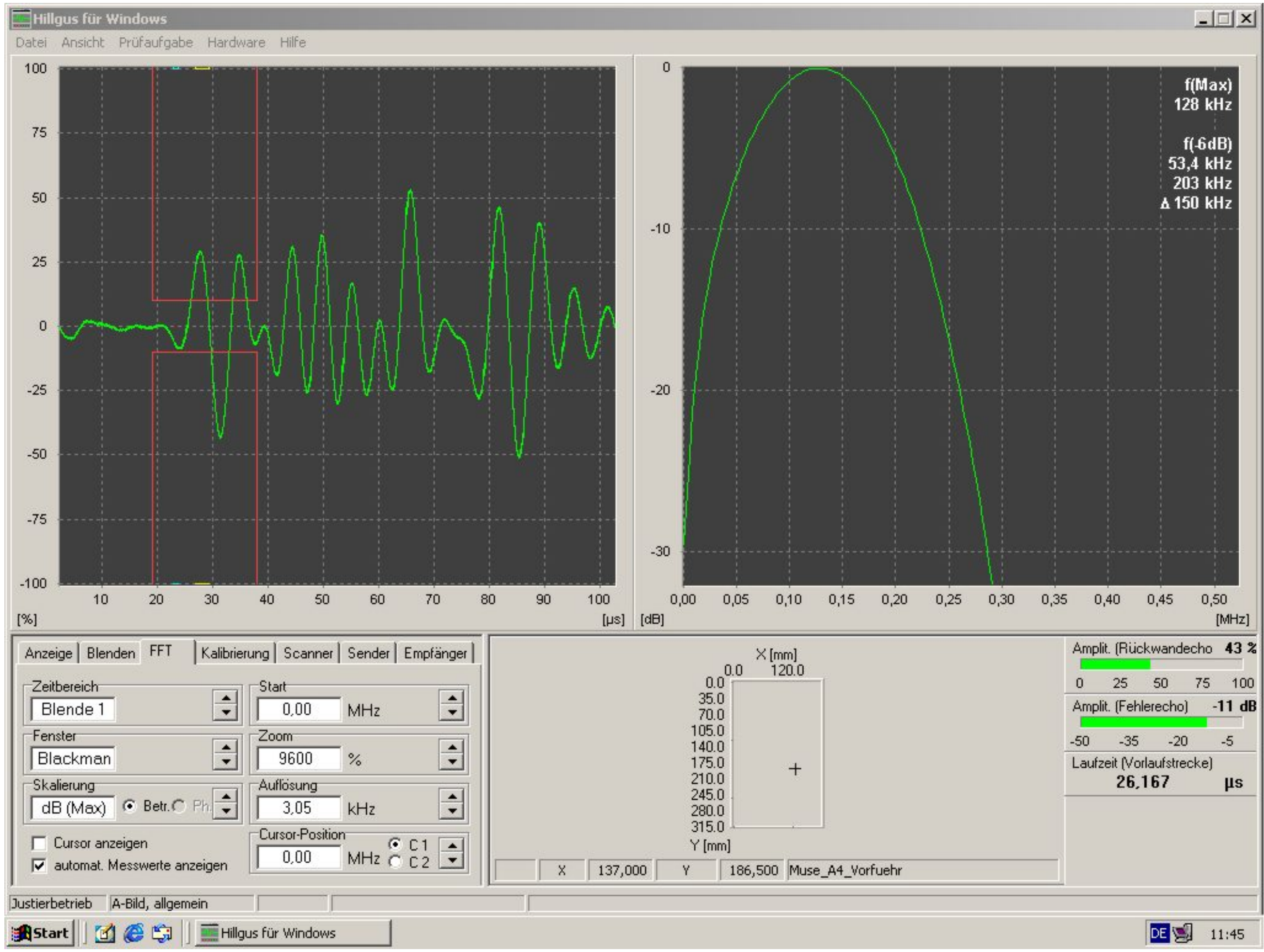
But:

- For each frequency, at least two different wave modes exist
- Each mode is dispersive

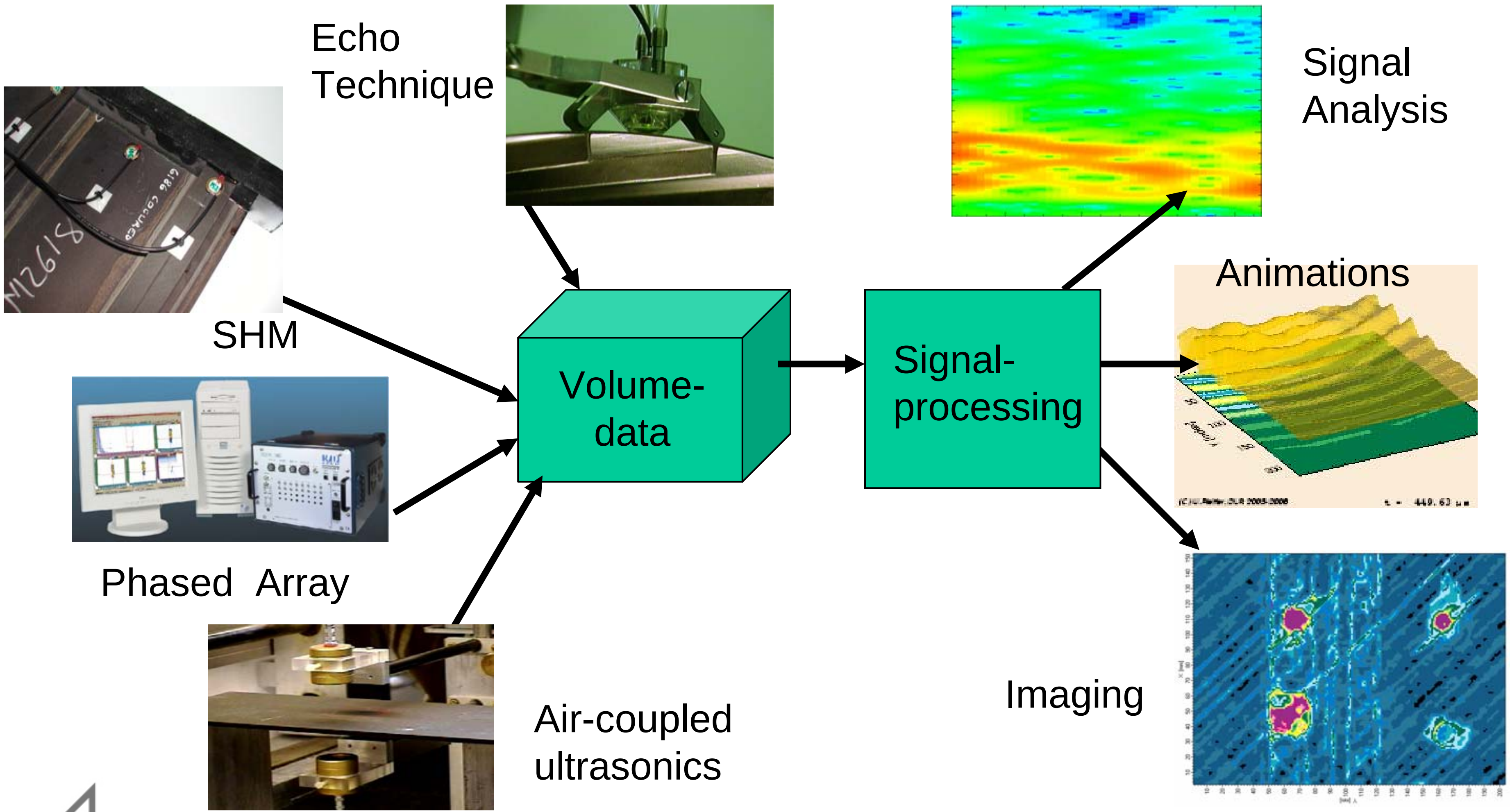
Therefore:

- The modes have to be carefully optimised for different types of damage and for the material of the component

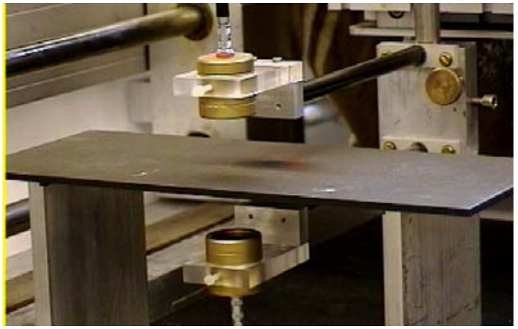
Ultrasonic System for Lamb Wave Testing

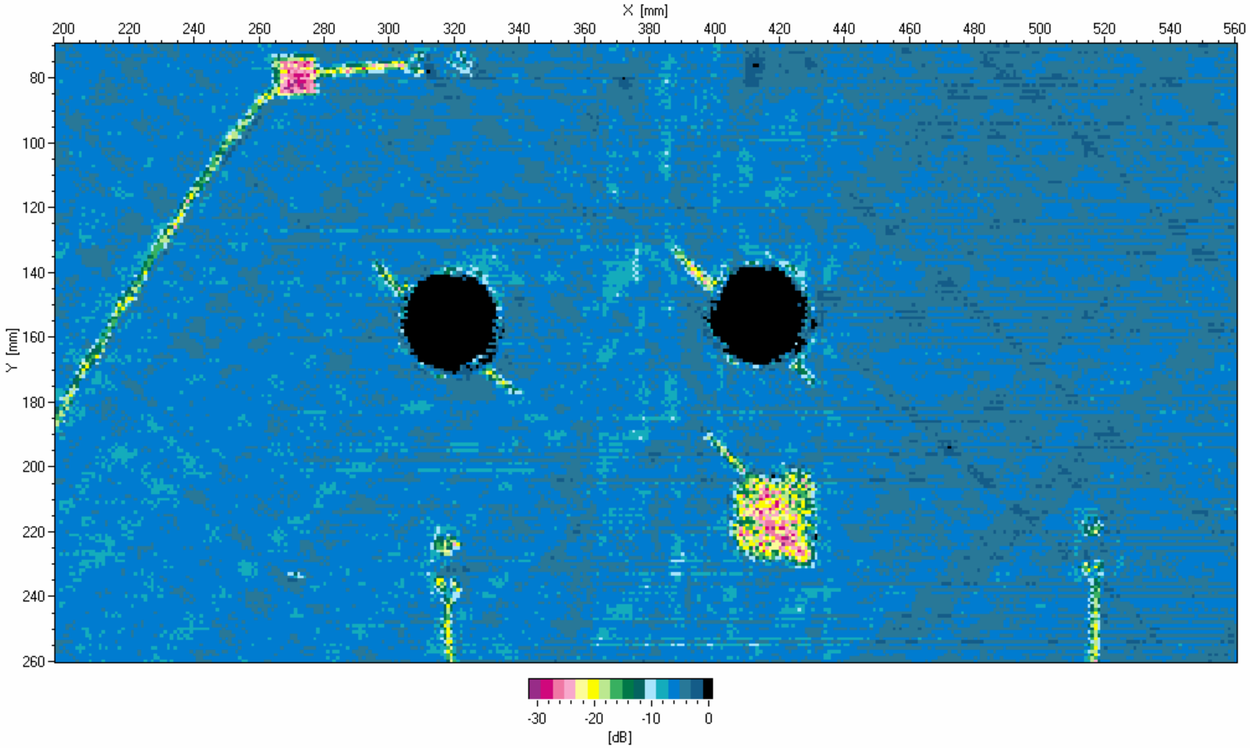


Combination of NDT and SHM

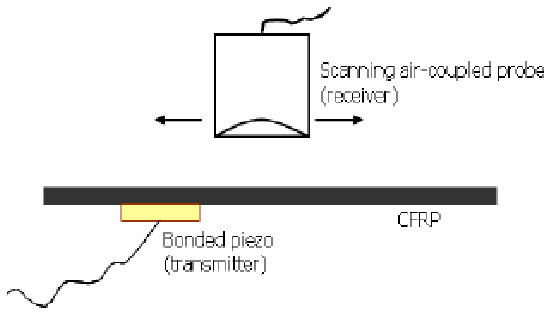


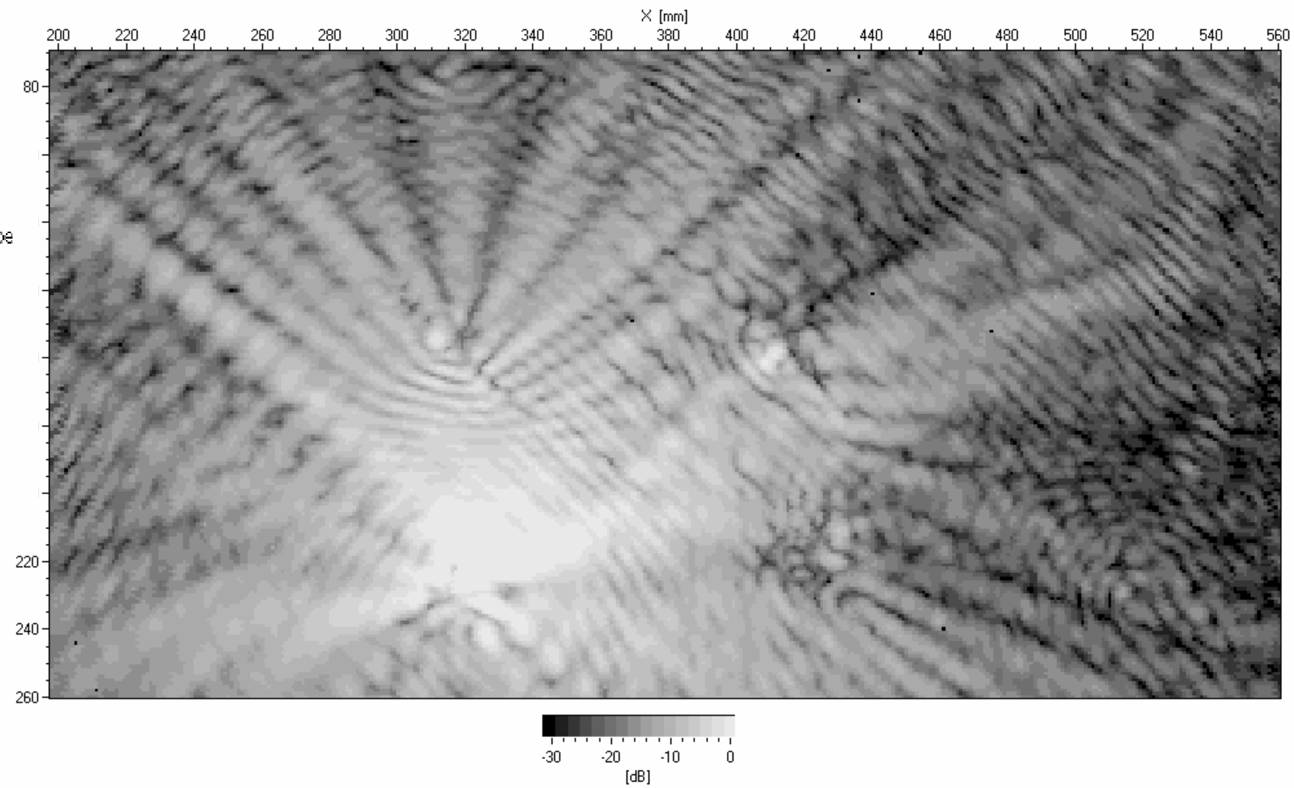
Air-coupled Ultrasonic Imaging



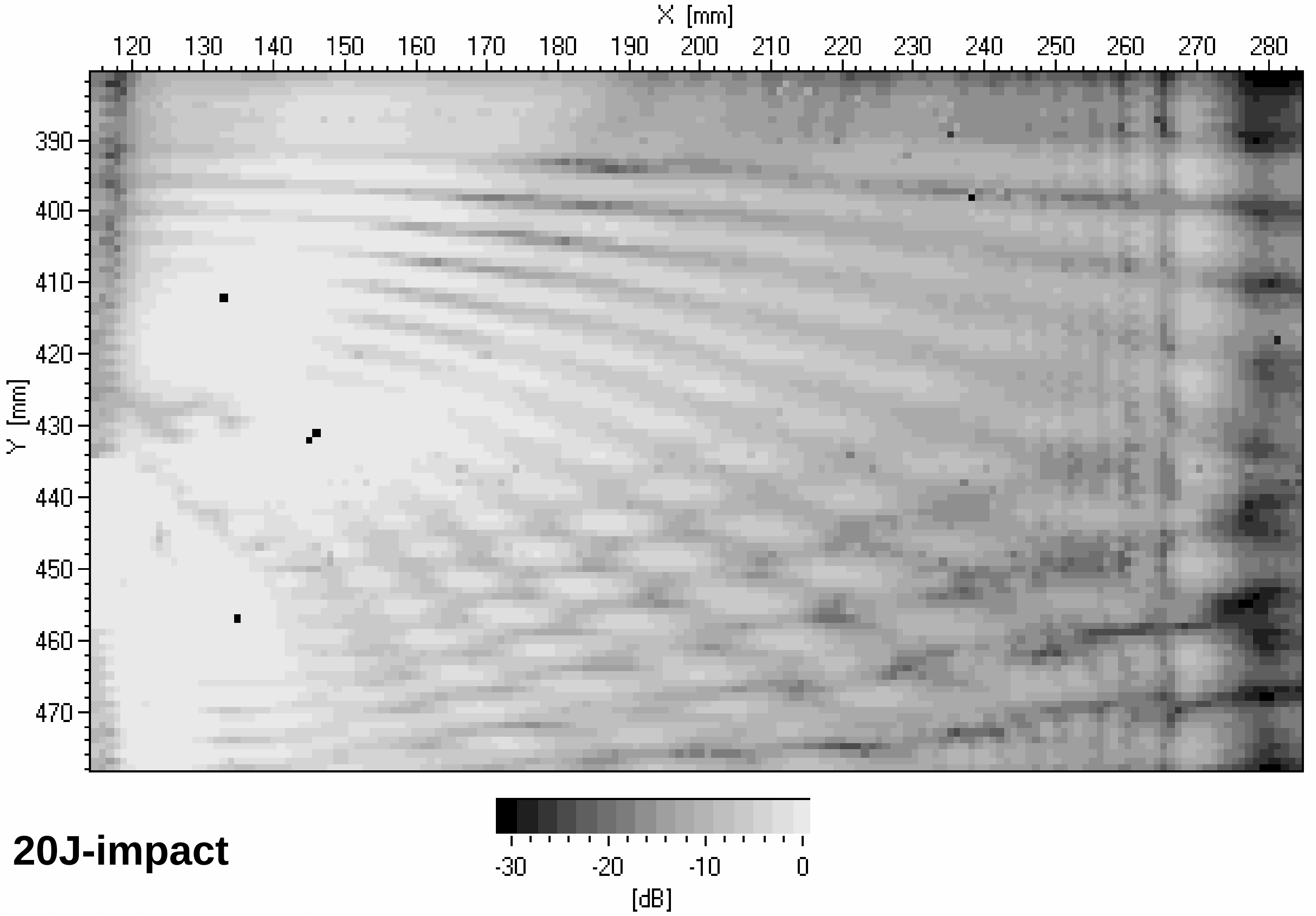


Lamb-Wave C-Scan





Air-coupled Lamb-wave C-scan of monolithic Specimen 3.6.4



20J-impact

Summary

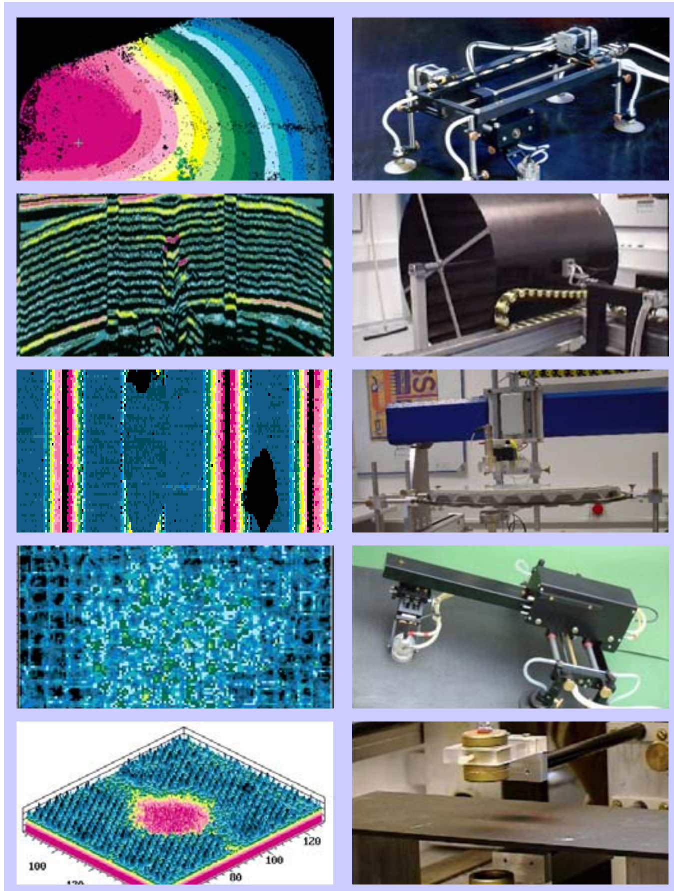
Our NDT Group provides:

- Routine Testing of “New Materials”

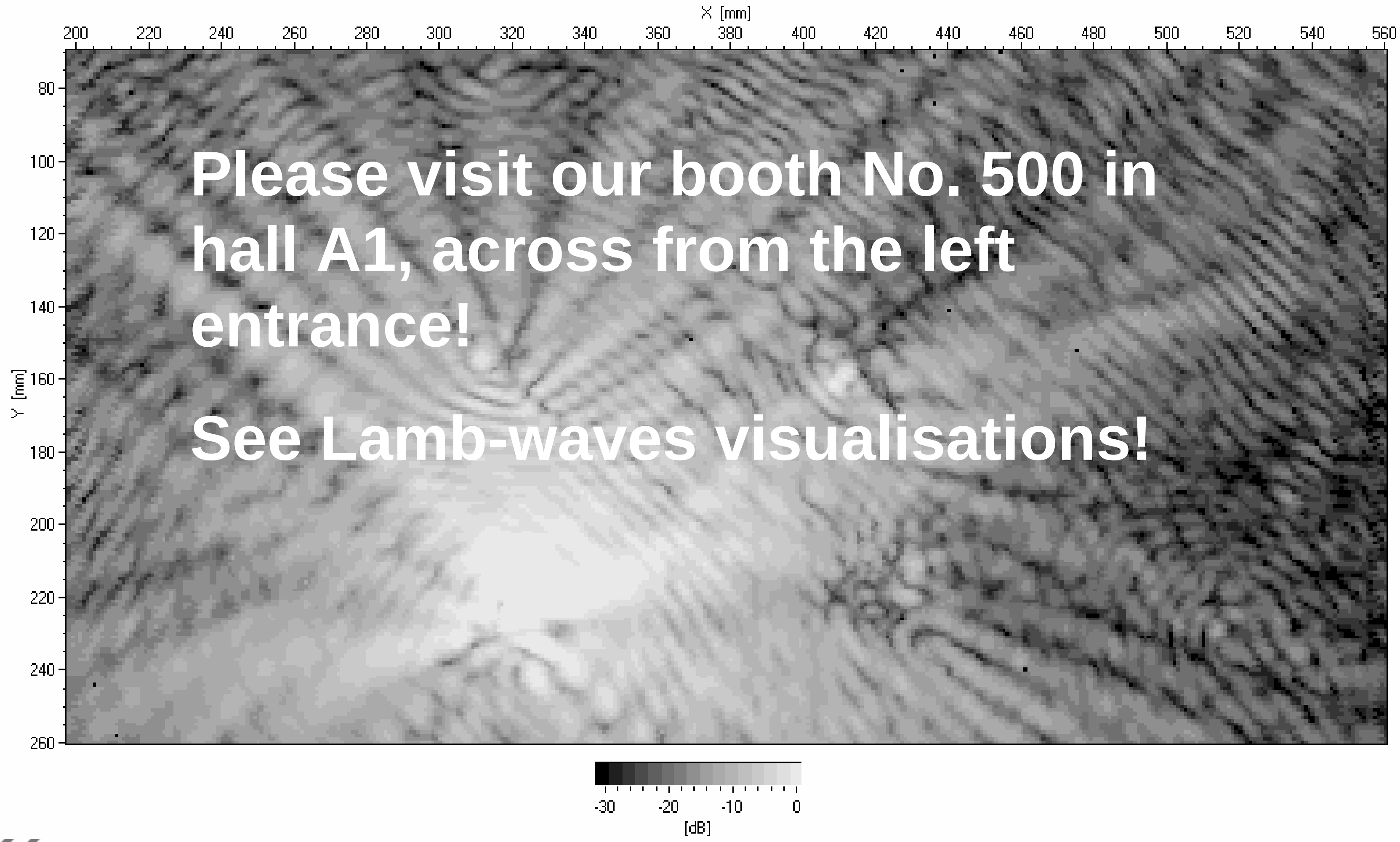
  Frequency range f = 10 kHz to 120 MHz

→ CFRP, Sandwich, FSW

- User-specific developments
- Basic research
  - → e.g. MaTech:
    Air coupling, porosity-detection with echo technique
  - → e.g. AISHA (Aircraft Integrated Structural Health Assessment):
    Lamb Waves visualisation
- **Your project: Please contact us!**



Thank you for your attention!



Please visit our booth No. 500 in hall A1, across from the left entrance!

See Lamb-waves visualisations!