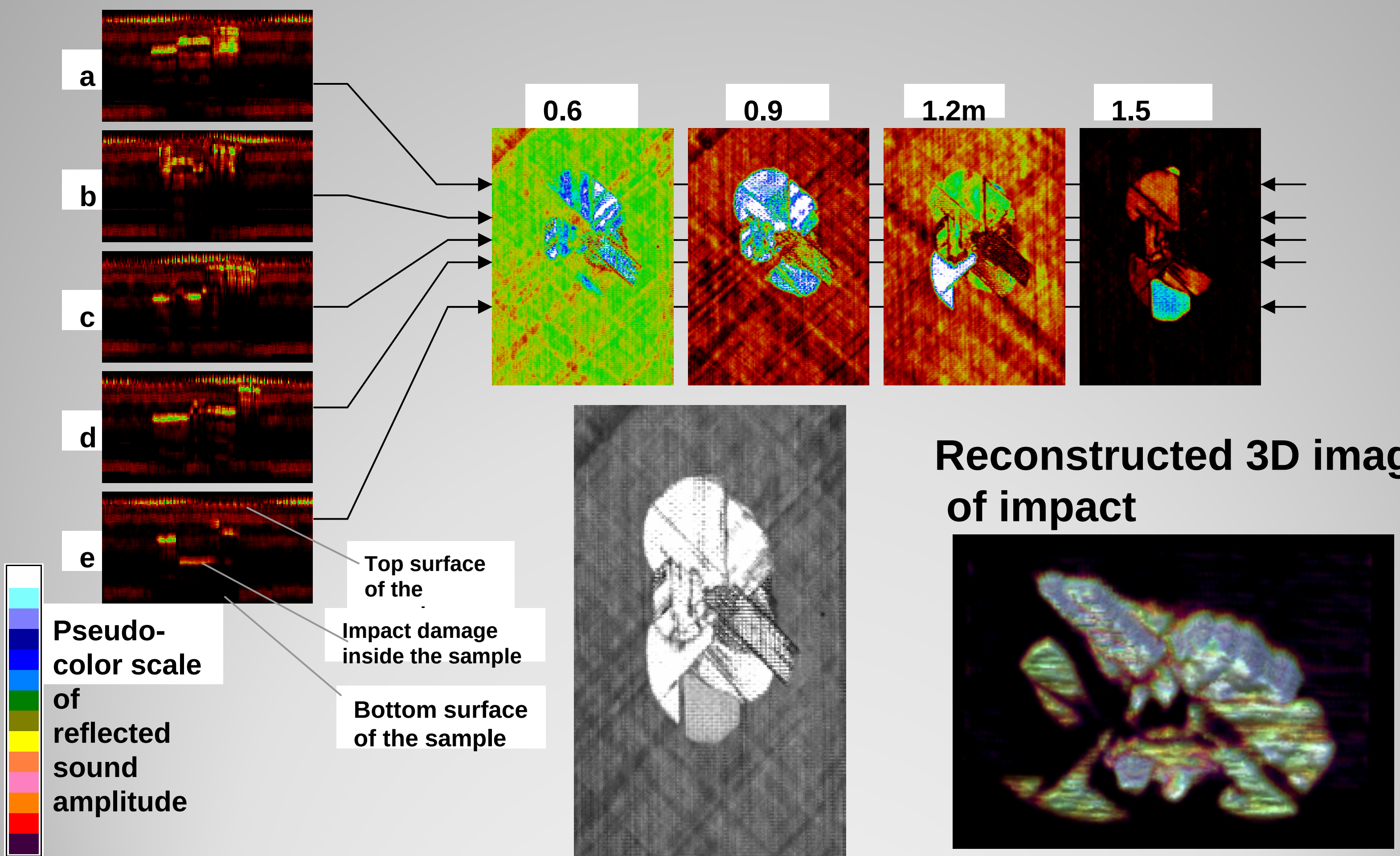
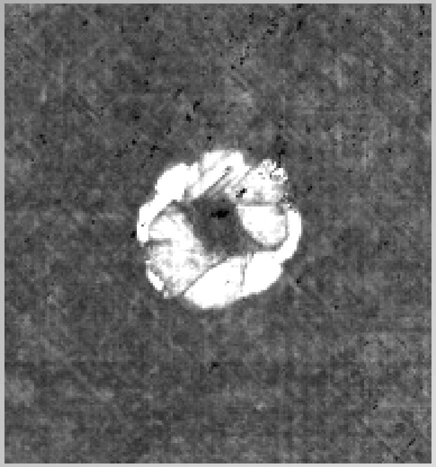
Impact damage in fiber-reinforced composites

SAM imaging of the Impact

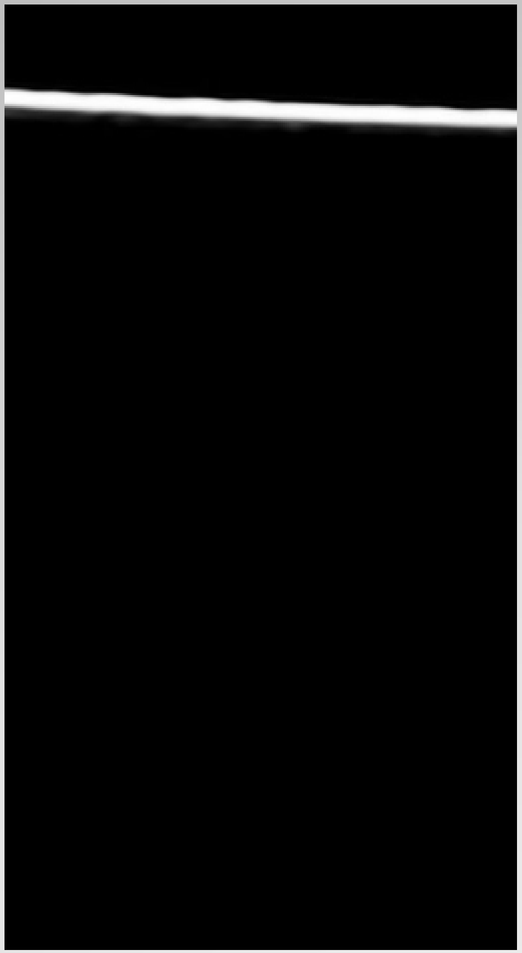


3D Reconstruction



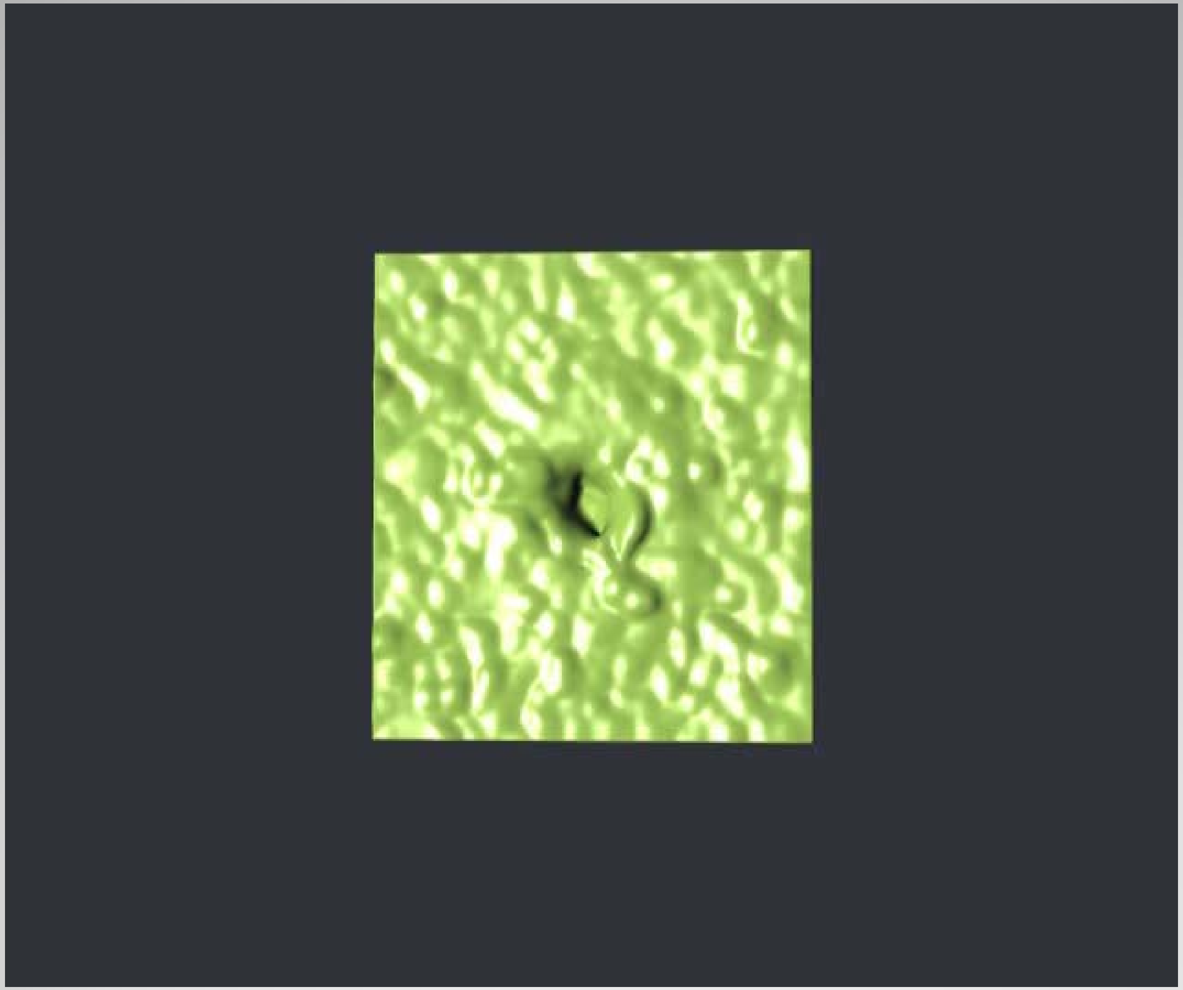
- Original data slices
- 50 MHz
- 40 x 40 mm scan field
- 267 slices
- 267 A-scans in each slice
- 2250 samples per A-scan

3D Reconstruction



- Band pass filtering
- Envelope filter (using Hilbert transform)
- Envelope conditioning (proprietary Tessonics algorithm)

3D Reconstruction



Adhesive bonding of the fiber-reinforced composites

Samples description

Synthetic fibers reinforces plastic (CFRP) composites plates jointed by adhesive strips

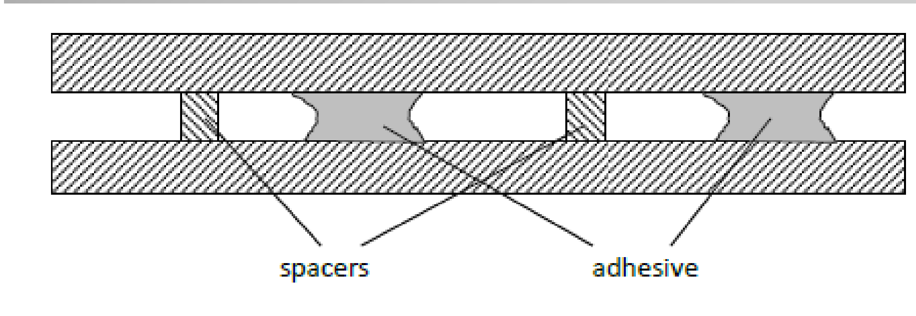
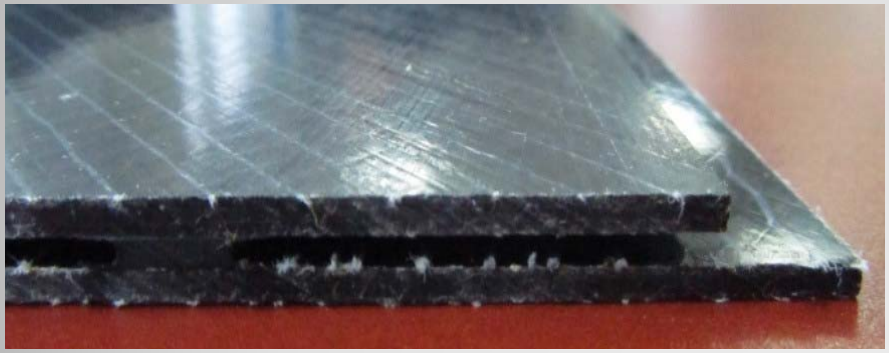
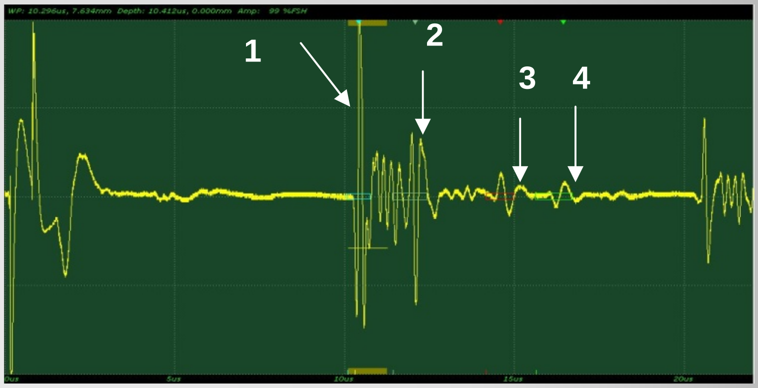


Plate thickness 2.3-2.5 mm

Adhesive thickness 1.8-2.1 mm





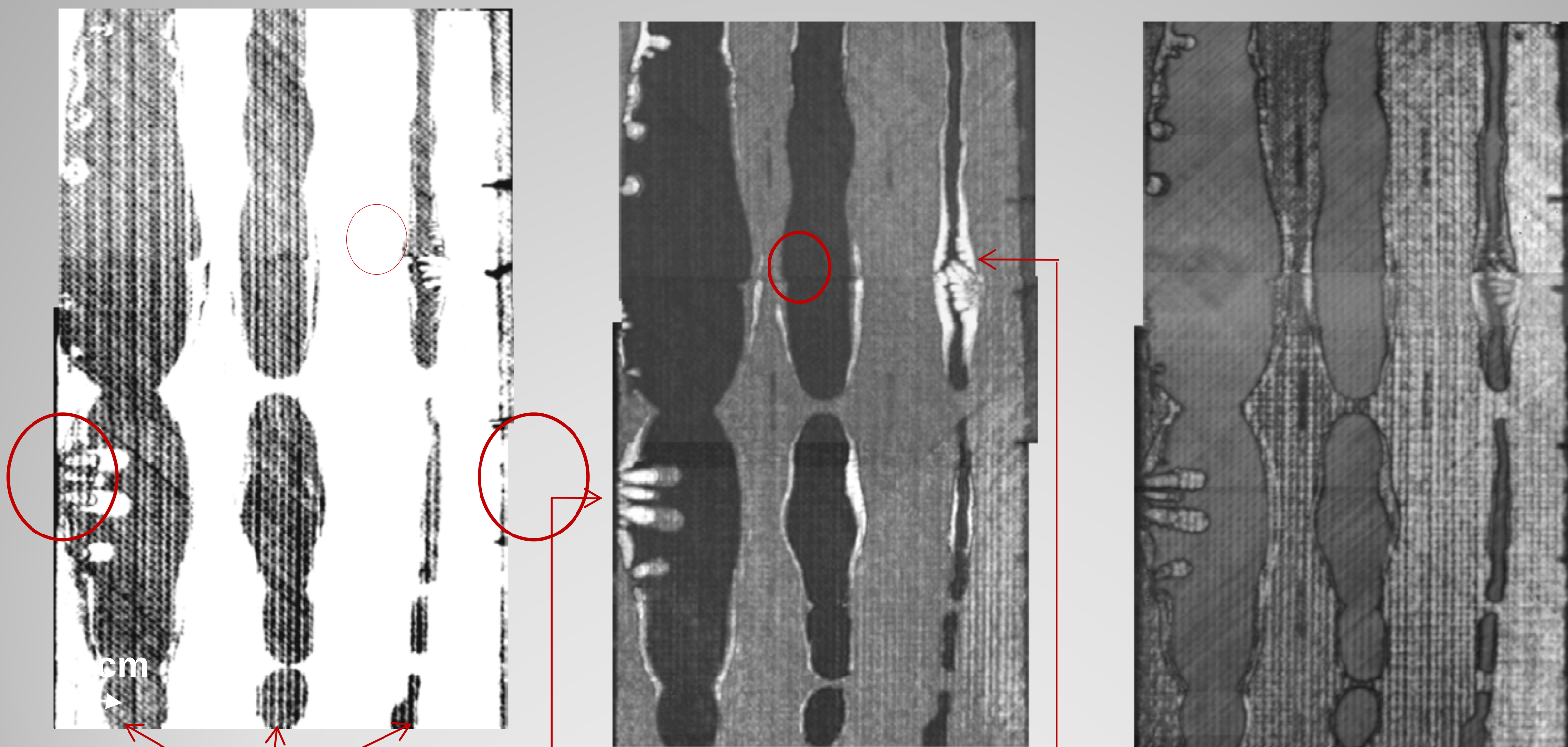
Nominal Adhesive approximate width 10, 35, and 50 mm

Composite Adhesive Joint Analysis, Scanning Acoustic Microscopy

Composite/adhesive interface

Below interface

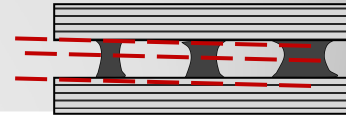
Lower adhesive/composite interface



Adhesive

Voids due to the "springback" effect

Adhesive "shoulders"



Ultrasonic imaging with phased array

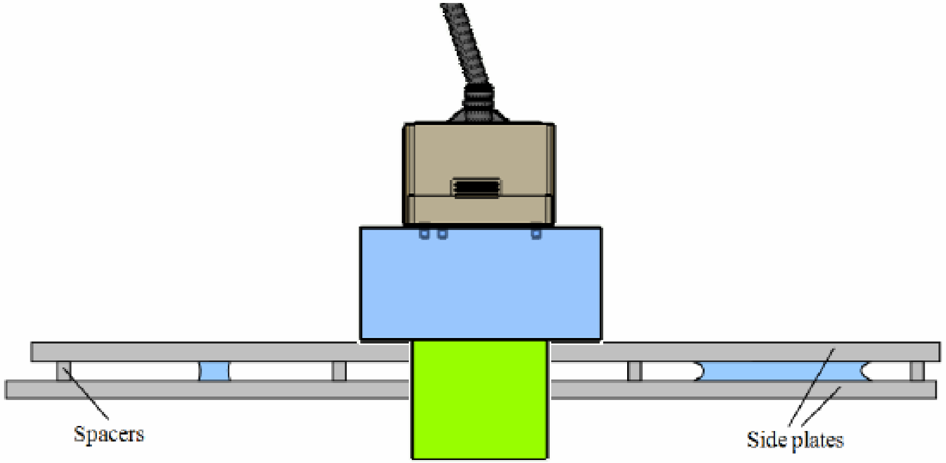
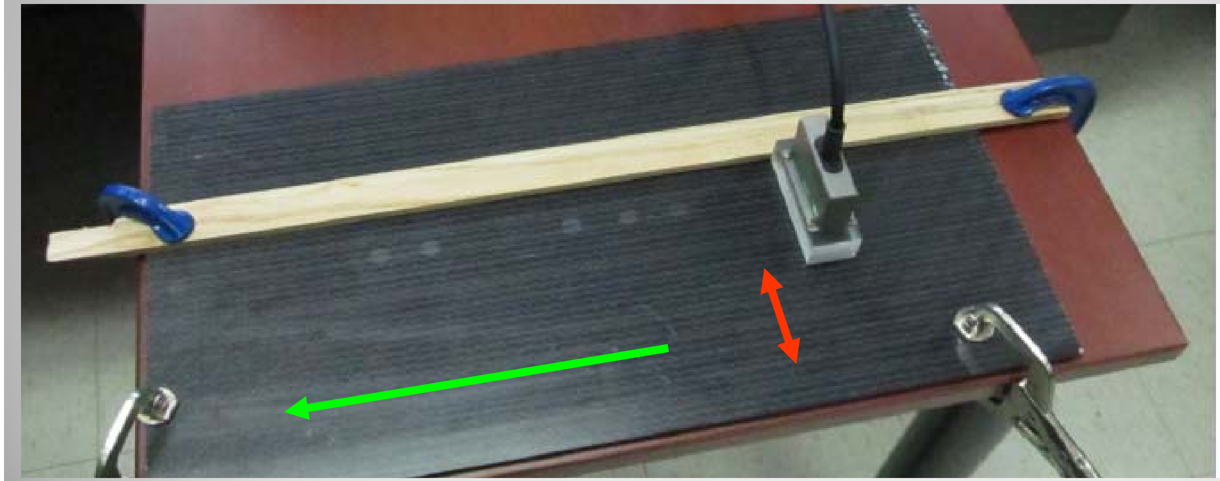


Figure 1: Example of a 0 degree scanning setup using a linear scan.

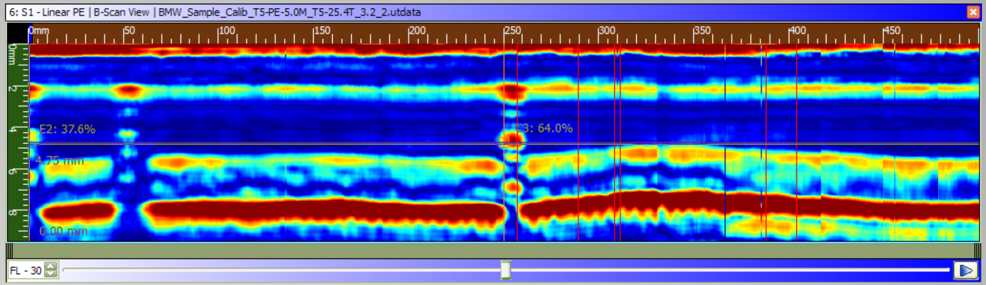
Arrays:
2.25 and 5 MHz
Number of elements 64
Pitch 0.8 mm
Width app. 50 mm

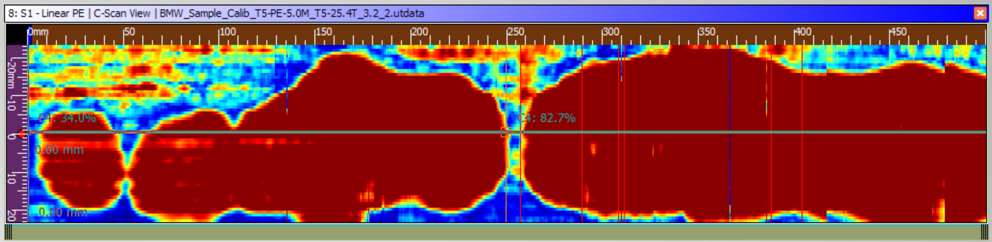


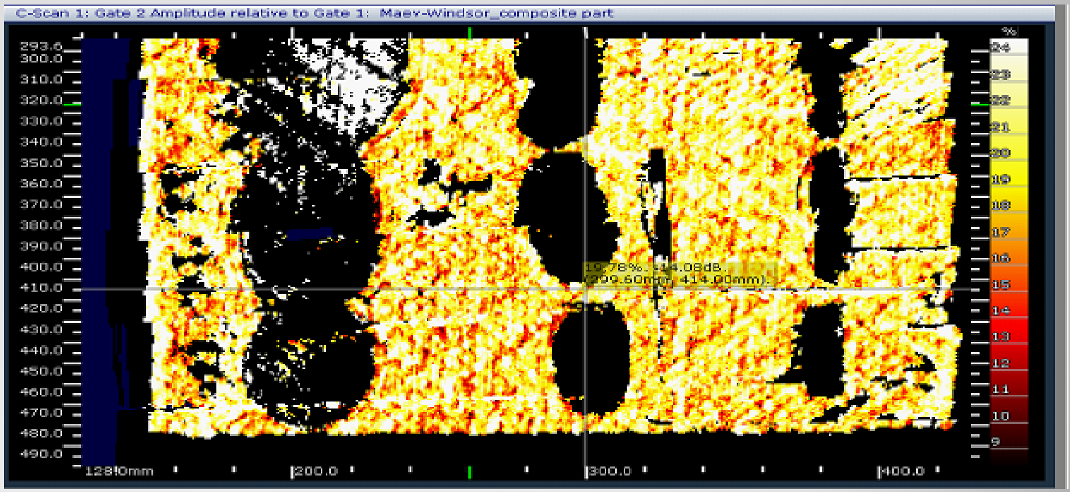
Manual translation

Electronic scanning

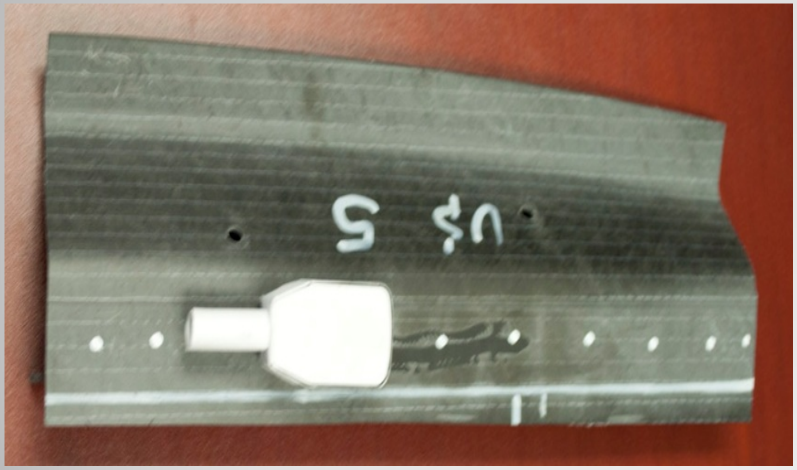
Composite Adhesive Joint Analysis, Phased array



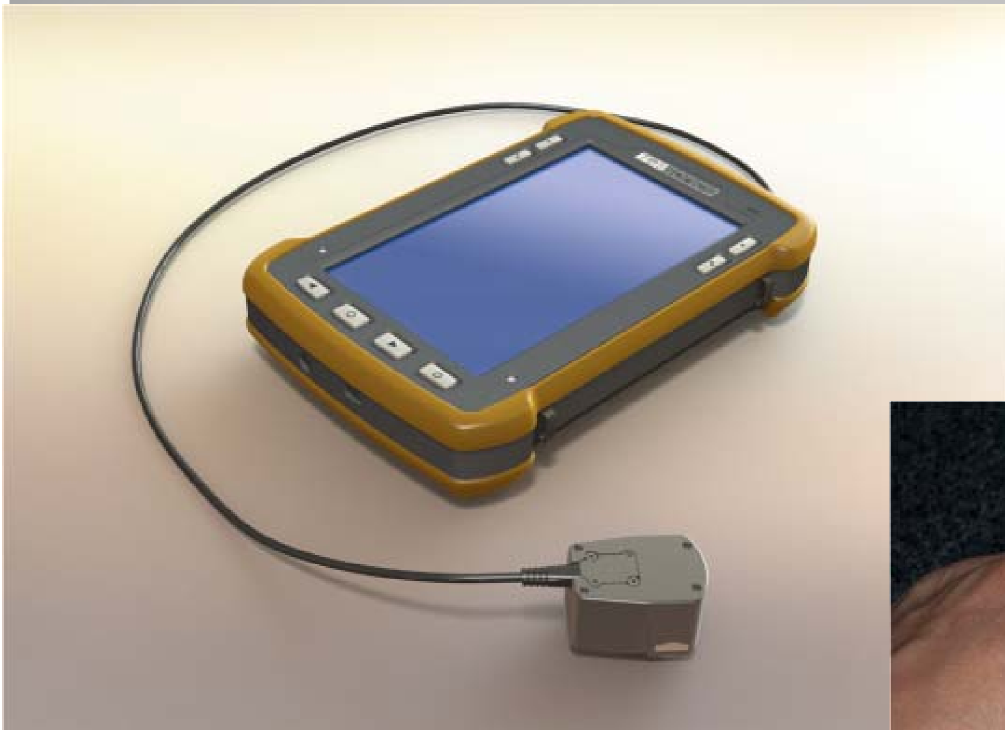




Complex shape of the samples



Hew generation of adhesive testers



- Phased array 64 elements
- Frequency 5 MHz
- MEMS and optical positioning

The Air-Coupled Acoustic Imaging Technique

The air-coupled imaging technique

Pros and cons

- High acoustical mismatch
- High attenuation of ultrasound in air
- Absence of contaminations and damages
- Fast scan of the object

Technology employed

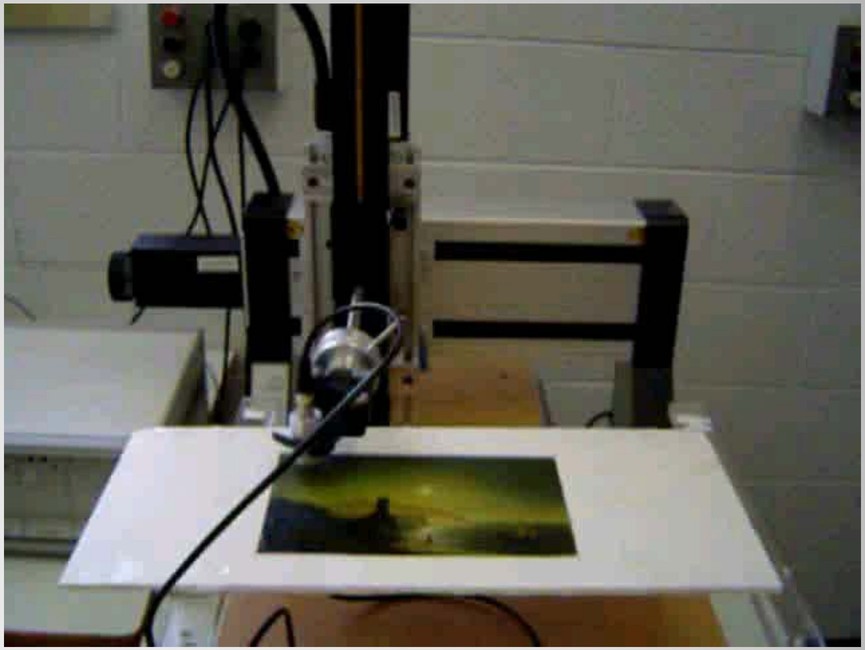
- NCA1000-2E
- Techno Stepper DaVinci
- Three pairs of Ultran transducers

f = 221 kHz	f = 485 kHz	f = 910 kHz
Bandwidth = 80 kHz	Bandwidth = 148 kHz	Bandwidth = 290 kHz
Active Diameter = 25 mm	Active Diameter = 12.5 mm	Active Diameter = 12.5 mm

Air-coupled Ultrasound

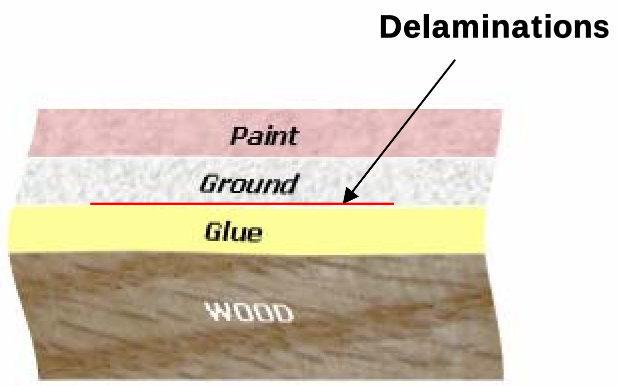
- At the UoW, researches have been carried out on wooden panel paintings
- The lateral resolution of the used planar transducers goes from 15 mm up to 3.5 mm
- By using focused transducers, we can achieve a lateral resolution of few tenths of mm

Air-coupled system in through-transmission configuration



Wooden Paintings

Structure of a typical panel painting

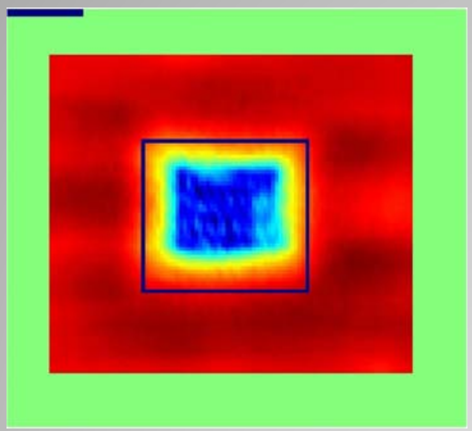


The layered structure is formed by:

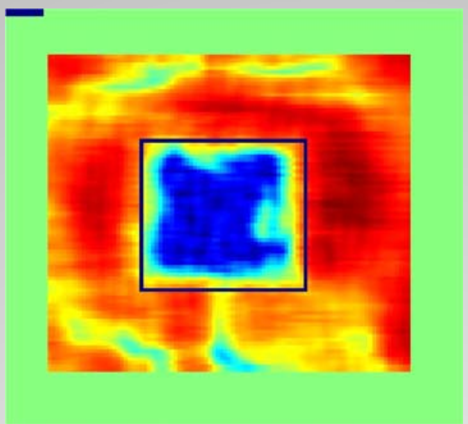
- **Wood support**
- **Animal Glue**
- **Ground (gesso + animal glue)**
- **Design layers: underdrawing, imprimatur, underpaintings, paint, glazing, varnish, retouchings**

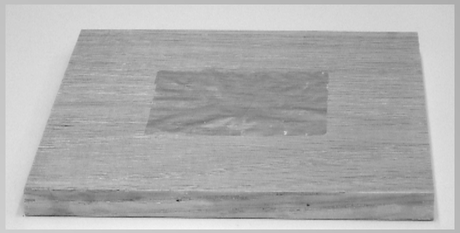
Non-Contact Ultrasound

Through Transmission configuration
f = 200 kHz

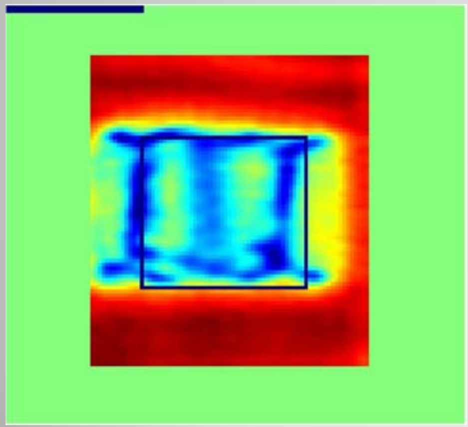


Through Transmission configuration
f = 1000 kHz

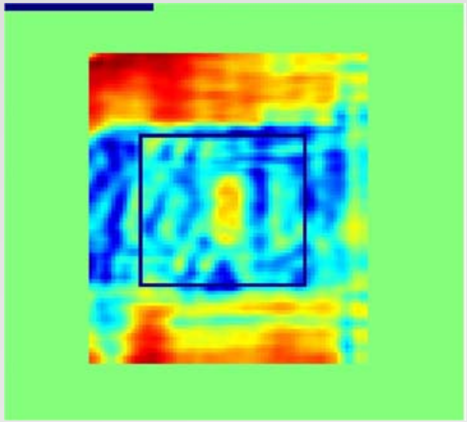




Single Sided configuration
f = 200 kHz



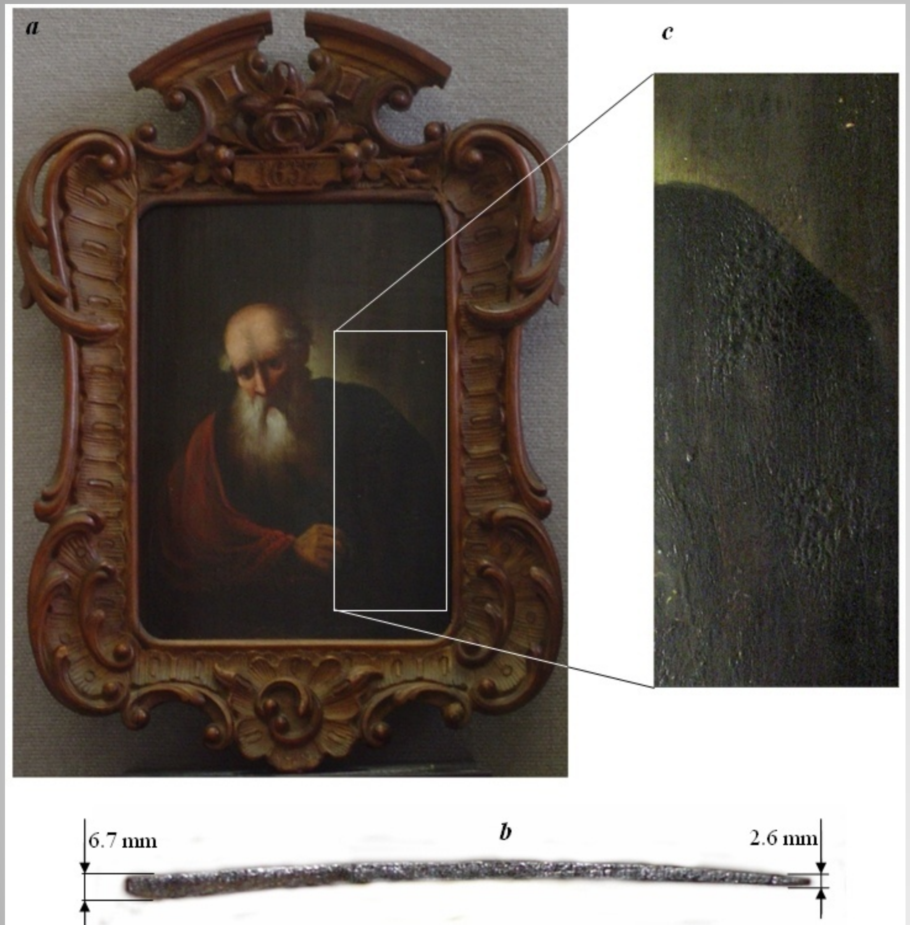
Single Sided configuration
f = 500 kHz



Studying simulated rectangular delamination between the wood support and the ground:

C-scans in various non contact ultrasonic layouts (*through-transmission* and *single-sided configurations*)

Non-Contact Ultrasound



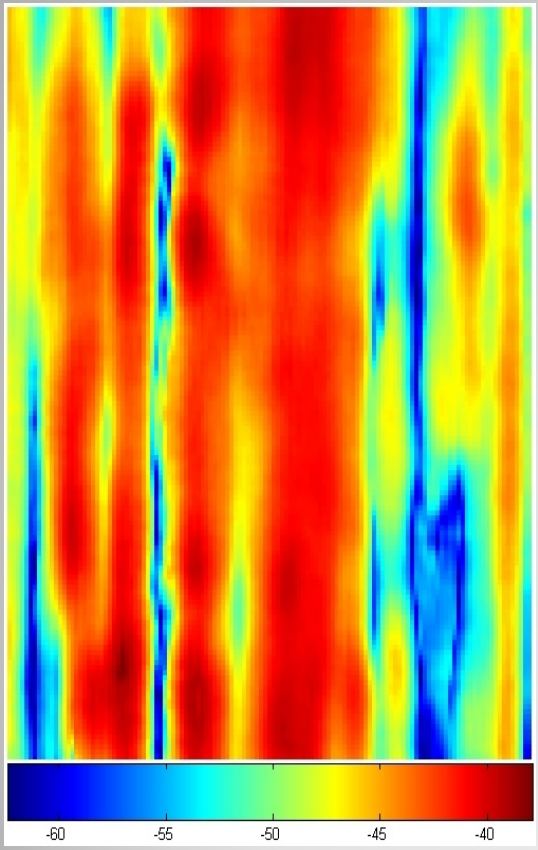
a) Wooden panel painting; b) Variable thickness; c) Inset of the damaged area

Four hundred years old painting (Private collection)

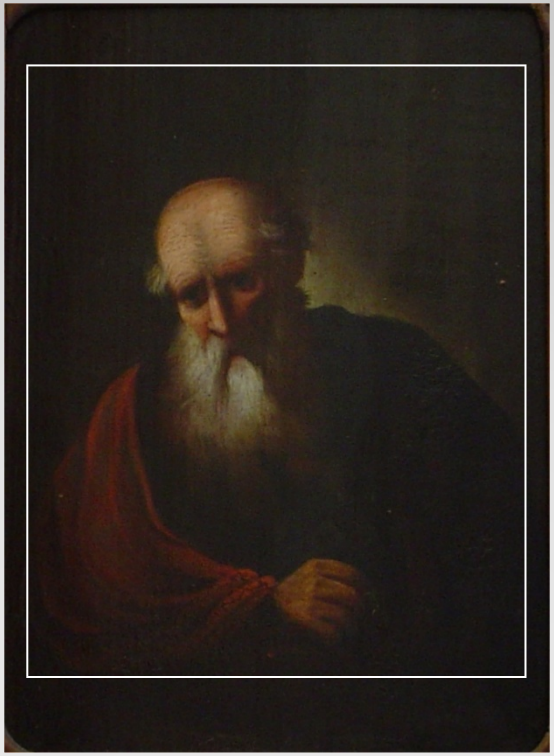
***Characteristics*:**
- Mahogany support;
- Dimensions: 187 x 263 mm^2
- Really variable thickness (*Fig.b*) from 2.6 mm (right) up to 6.7 mm (left)
- Suspect damaged area in the lower right region (*Fig.c*)
- Recently restored region around the forehead of the subject

Non-Contact Ultrasound

Single-sided scan using the 200 kHz transducers



Optical image with checked region highlighted

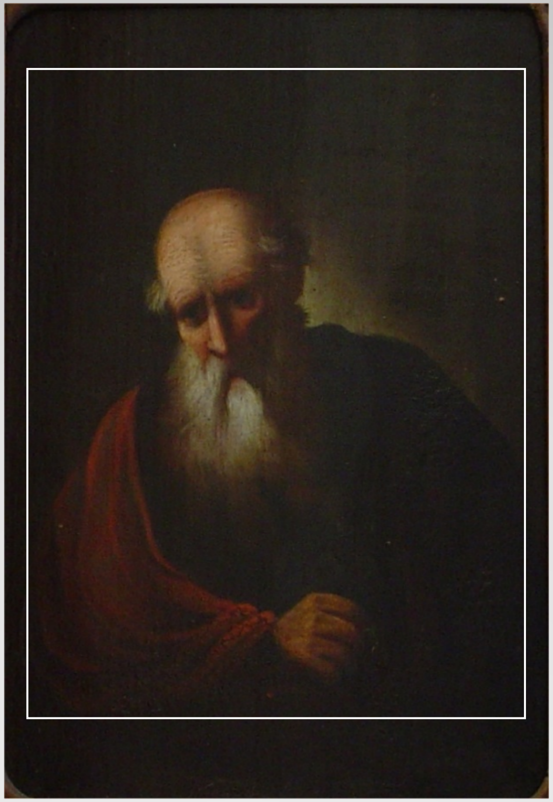


Scan in single-sided configuration. Confirmed the results obtained in through-transmission configuration. The visible damaged area is effectively a defective region, but the real extension of the detachment is wider than what was visible to naked eyes

Non-Contact Ultrasound

Binary image

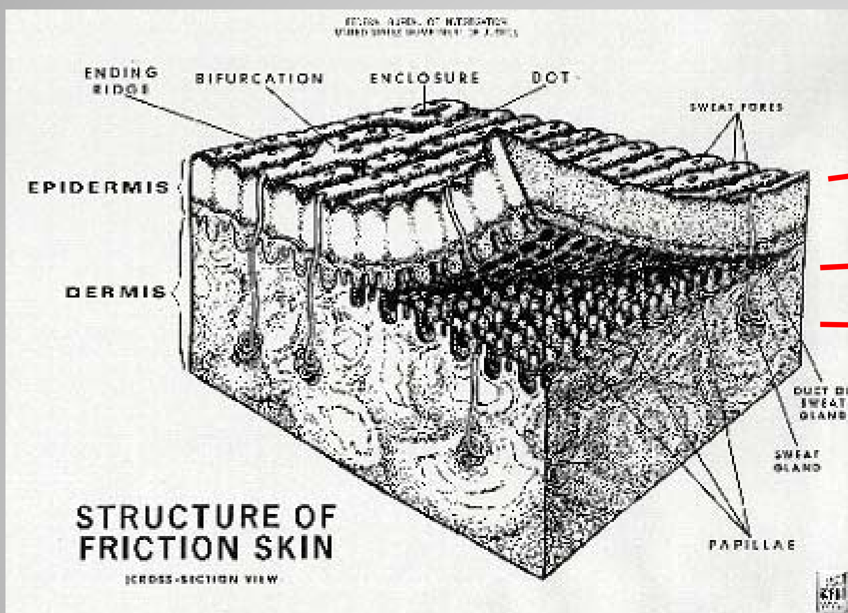
Optical image with checked region highlighted

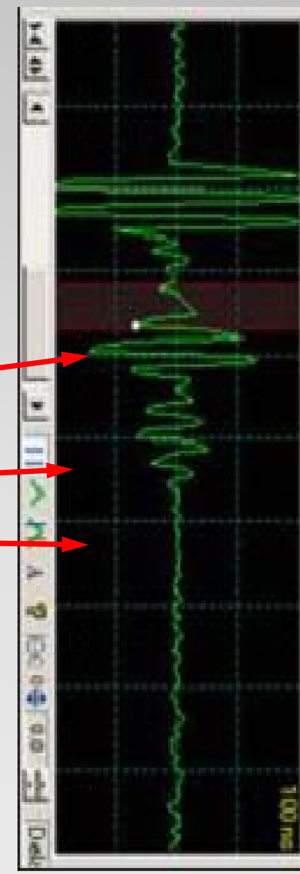


Scan in single-sided configuration.
Binary images with highlighted the delaminated regions (White -> sound zones; black -> detached zones)
The scanned region is that one inside the rectangle

High-resolution 3D ultrasonic fingerprint imaging

Acoustic image of skin structure



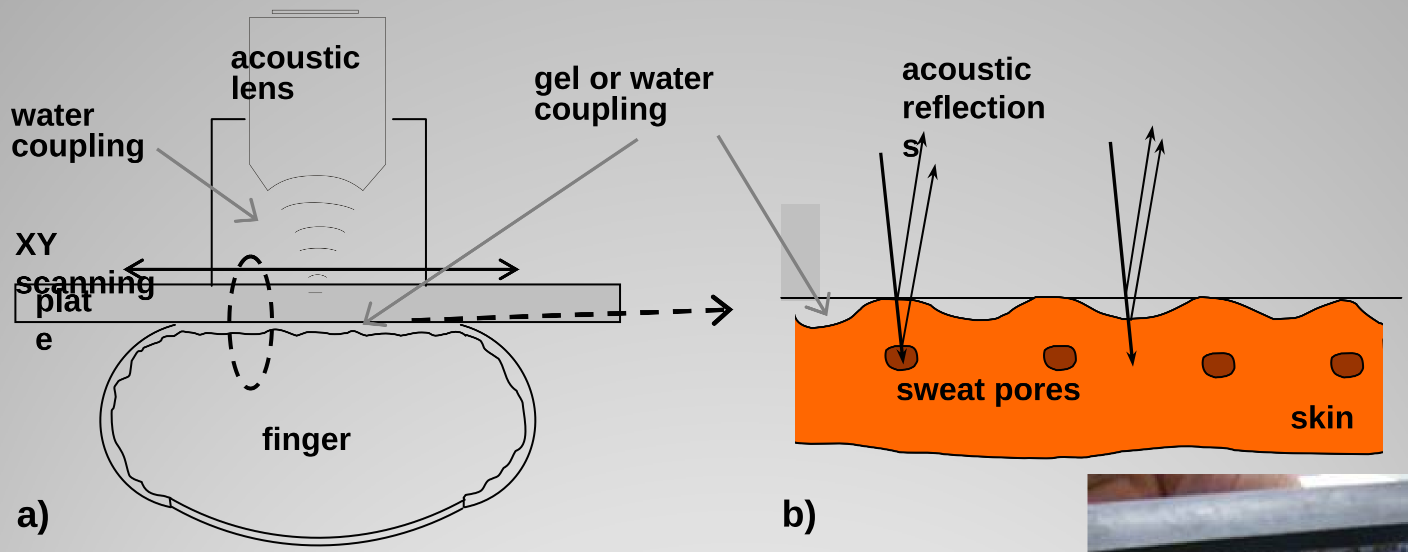


Reflection from skin surface

Reflection from dermis

Reflection from skin / subskin tissue interface

Imaging with acoustic microscope



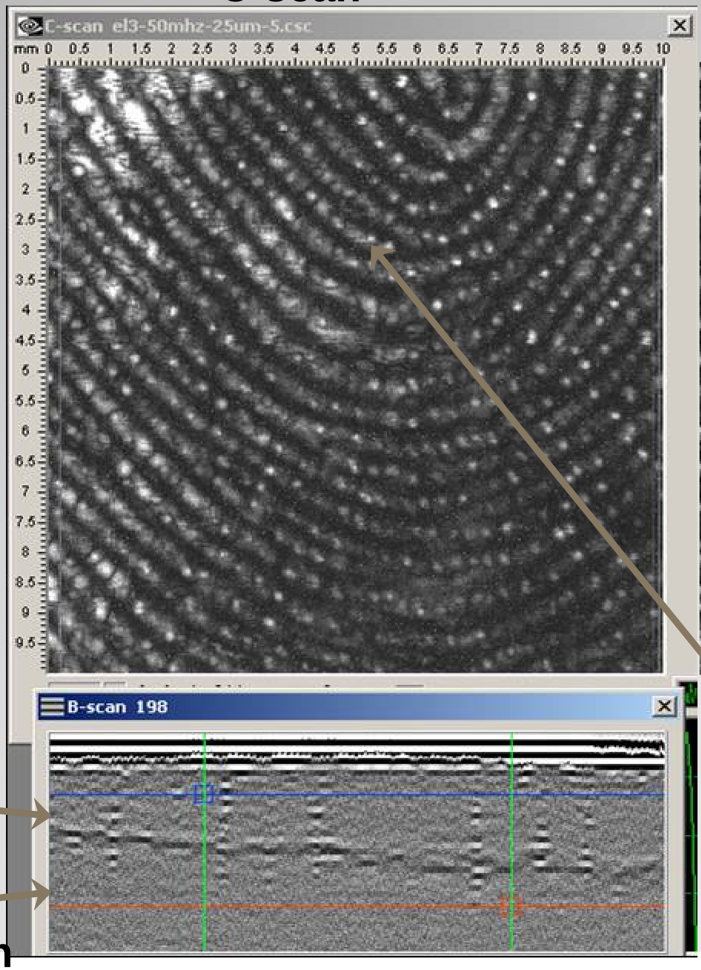
Hardware:

- Scanning acoustic microscope "Tessonics AM-1103" (Tessonics Corp., Canada),
- Short-pulse reflection mode,
- Narrow-aperture focused ultrasonic transducer with a frequency of 50 MHz (Panametrix), spatial resolution of about 50 μm (when focused under the plate).

Experimental results

Acoustical and optical images of the same fingerprint area

C-scan



Paper ink-print

Wide C-scan gate

bottom of the plate

bottom of skin

grooves are seen as light regions in C-scan and as dark regions in paper print

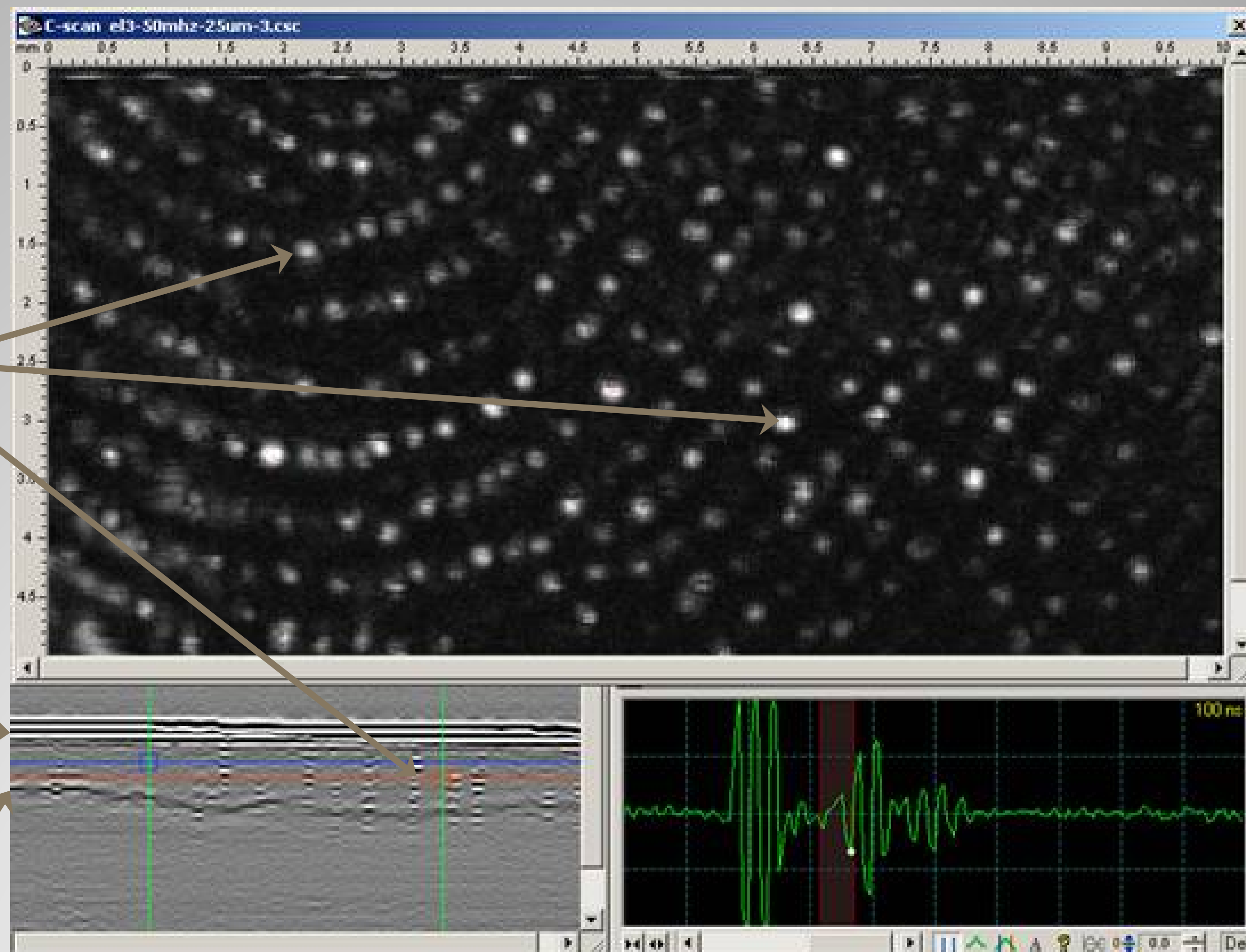
Experimental results

C-scan (zoomed)

sweat pores

bottom of the plate

bottom of skin

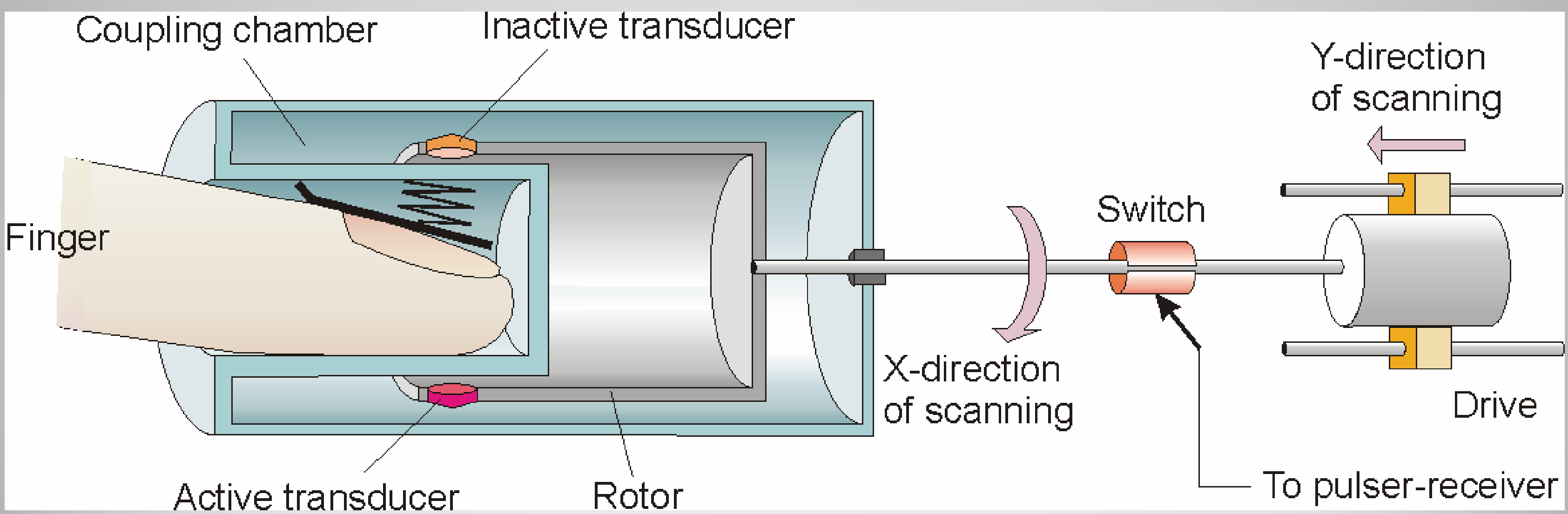


B-scan

A-scan

Fast multi-lens cylindrical scanner

Prototype design of a fast-scanning miulti-lens fingerprint imaging system:
A finger is inserted into a hollow cylinder of the scanner and pressed onto the concave surface of the cylinder, and a system of rotating focused ultrasonic transducers scans over the cylinder

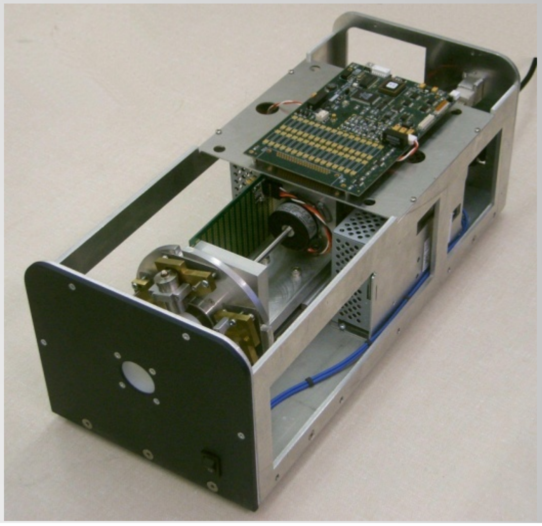


The first prototype (2011)

was presented at the Biometrics Conference in Washington DC, in January 2011

Our first prototype:
It was developed procedures and algorithms

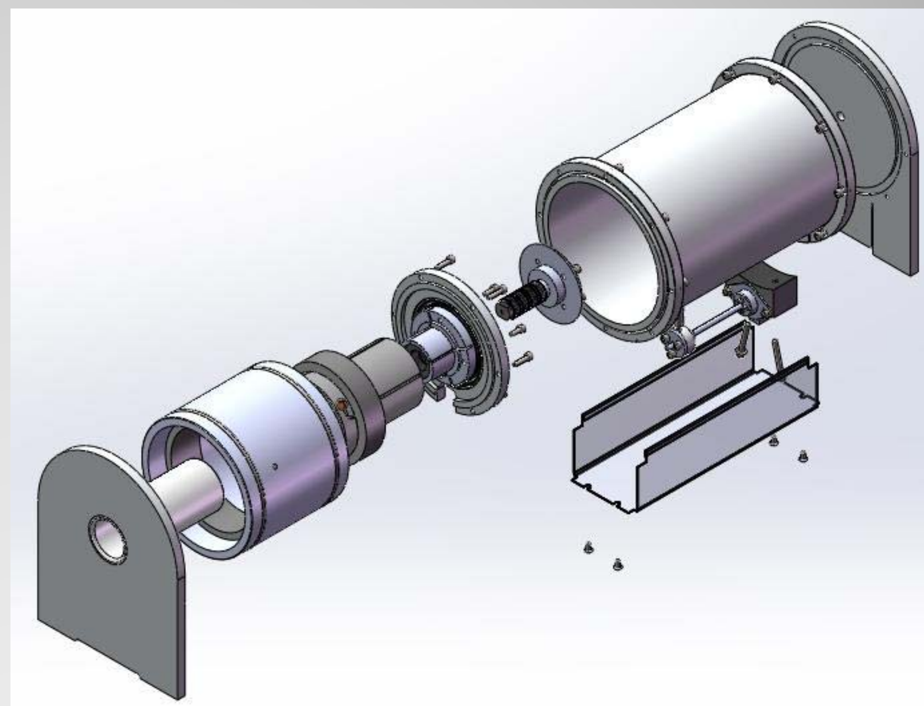
- Simplified mechanical design
- Assembled from market-available parts



Newest design

- Compact and robust
- Direct rotor drive

- Higher accuracy



- Commercial production
- Affordable price

Thank you for your attention