Potential of TeraHertz Radiation in NDT

18TH WCNDT
DURBAN · SOUTH AFRICA · 2012
World Conference on Non Destructive Testing

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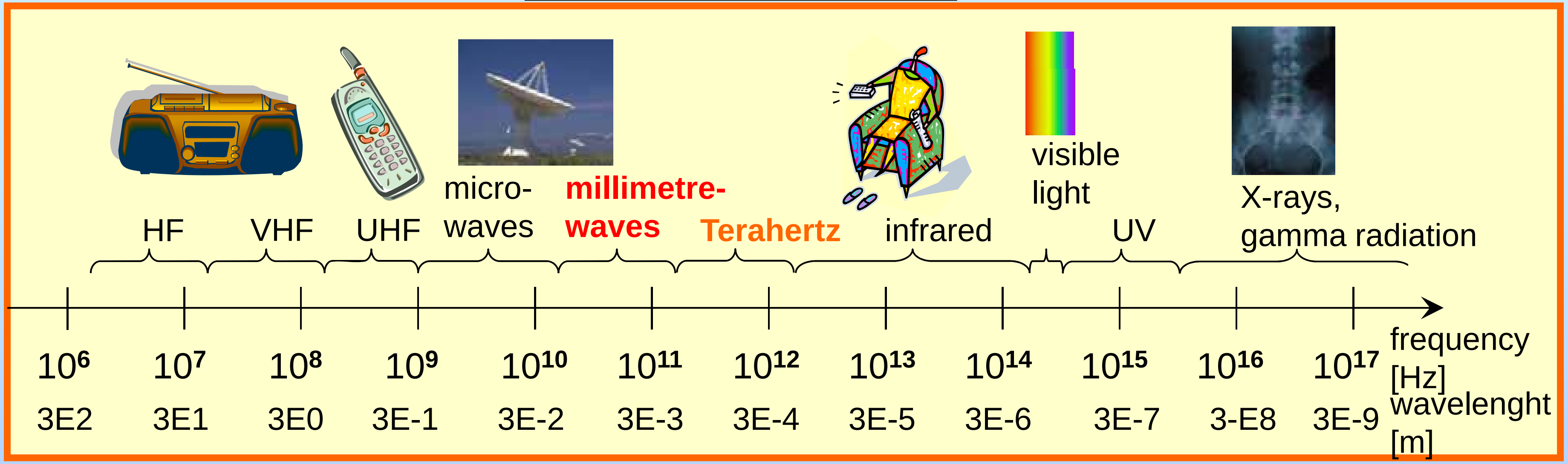
Outline

- **Introduction to THz radiation**
- **Some Security applications**
- **“Pulse Echo” technique– Replacement of UT?**
  - *3D measurement of structures and flaws by time of flight technique*
  - *Applications*
  - *Time of Flight Diffraction (ToFD)*
  - *Comparison to UT - Pulse echo technique*
  - *Synthetic aperture focusing technique (SAFT)*
- **Single beam Computed Tomography - Replacement of RT?**
  - *3D reconstruction of a test phantom*
- **Summary**

THz Technology



Properties of mm-waves und THz-radiation:

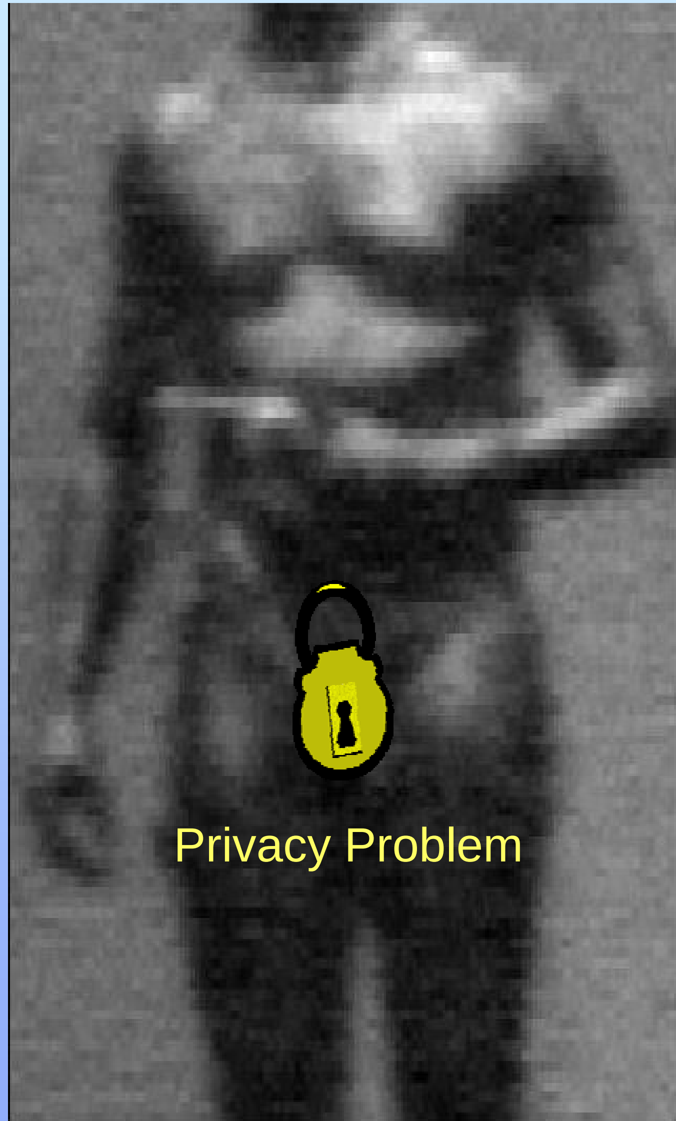
- **frequency range:** *mm-waves*: 30…300 GHz, *THz-waves*: 0.3 …6 (…) THz
- **non-ionising radiation** as compared to X-ray etc.
- **penetrate opaque materials** as clothing, wraps, polymers with minor attenuation.
- **reflected at the skin surface;** potential for body scanner.

Passive THz-Bodyscanner

Detection of body radiation

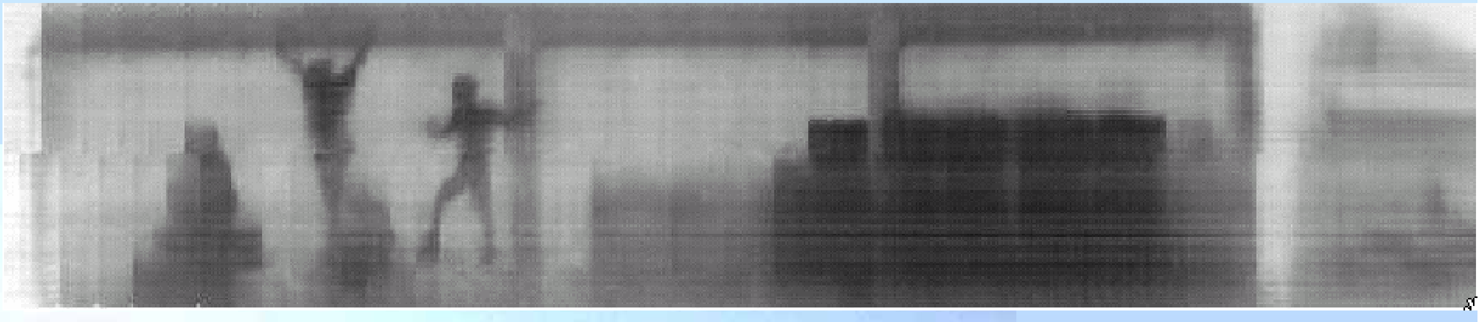
Inspection with mm Waves

Body Scanner



Passive 42 GHz Image of a Truck

Image with Immigrants



THz Inspection of Liquids

Bundesministerium
für Bildung
und Forschung

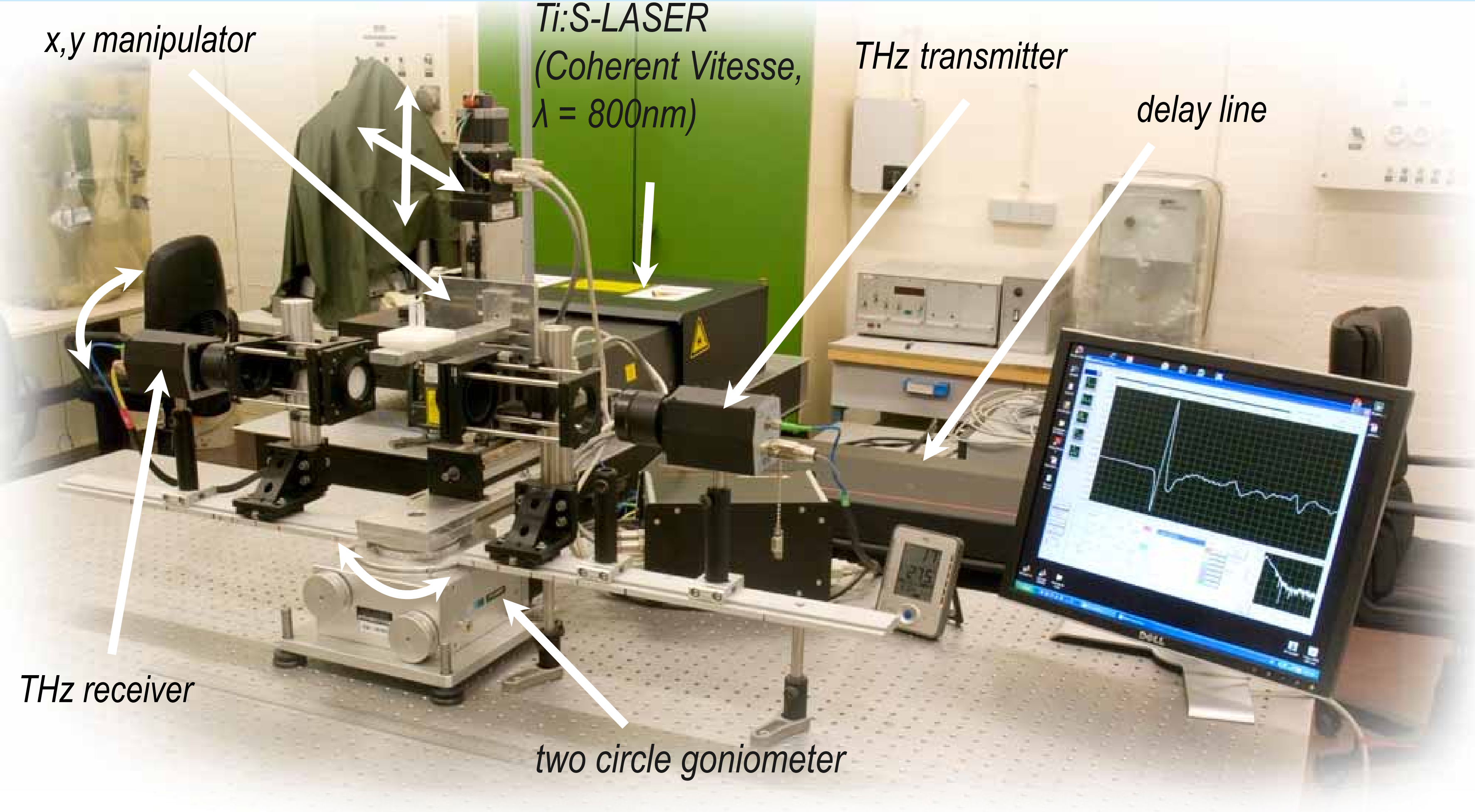
(FKZ 13N9514)

HANDHELD

Security at airports

THz-System Group;
Prof. Dr. M. Koch, Universität Marburg

BAM THz-TD Spectrometer



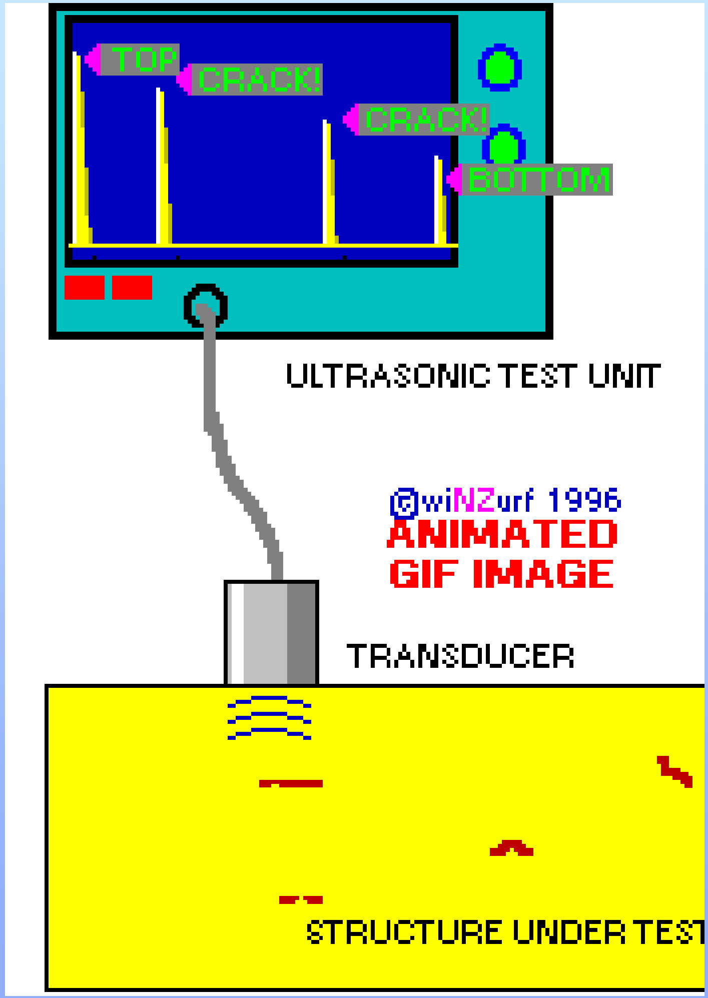
Picometrix T-Ray 2000 fiber coupled THz-TDS System => highly flexible
integrated Huber two circle goniometer => angle dependent measurements

THz-TD Spectroscopy

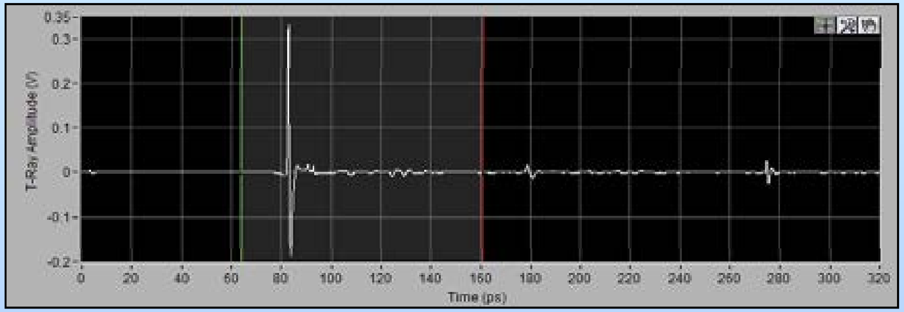
Application areas

	Penetration	Reflection	Volumetric	Surface
Metals	no	interfaces	no	yes
Plastics (low DK)	high	interfaces	yes	yes
Plastics (high DK)	medium	interfaces	limited	yes
Plastic on metals (low DK)	high	interfaces	yes	yes
Glass fiber composites	medium	interfaces	limited	yes
Carbon fiber composites unidirectional	Medium, polarized radiation	interfaces	limited	yes
Carbon fiber composites multidirectional	no	interfaces	no	yes
Human Skin, water	low	interfaces	low	yes

Ultrasonic Pulse Echo Technique



THz pulse and "echos"



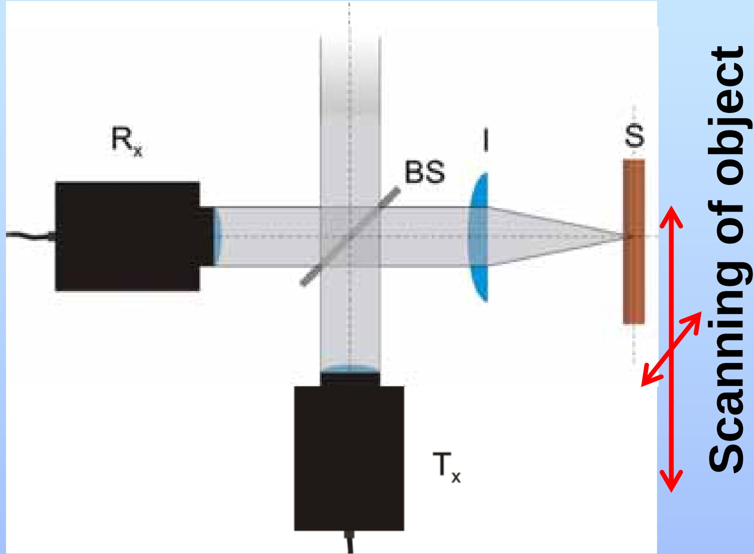
UT Pulse echo device

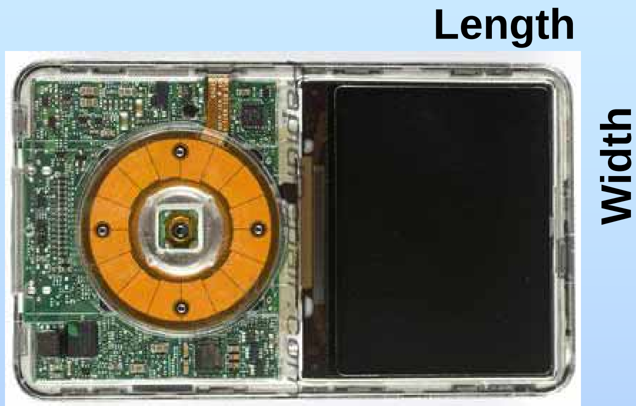
by K. Balasubramaniam, IIT, Chennai

Topographic 3D Imaging of Polymer Structures Above a Metal Plate

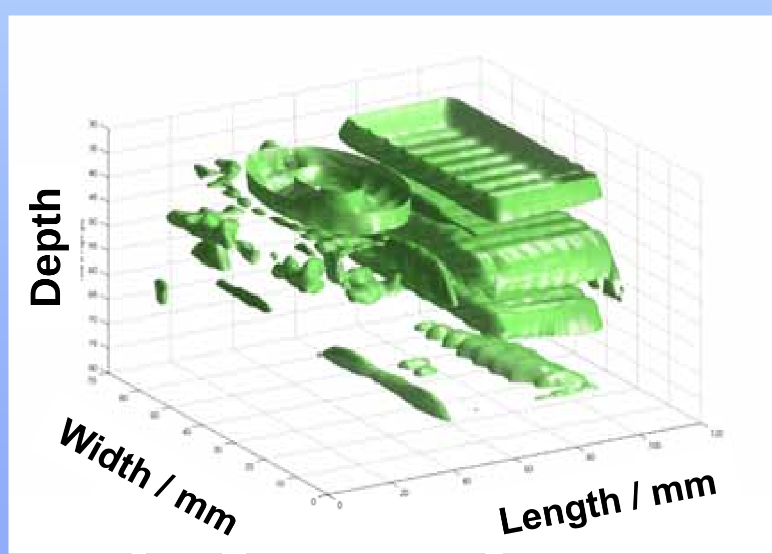
Optically Focused PE Technique

(normal incidence)





THz – 3D Image of i-POD with Plexiglas window

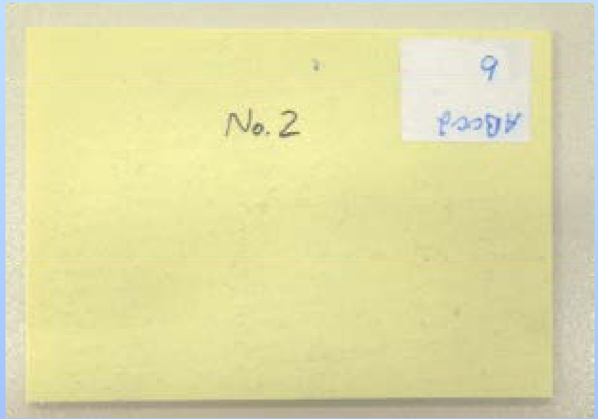


T_x	= transmitter
R_x	= receiver
S	= sample
l	= lens
BS	= beam splitter

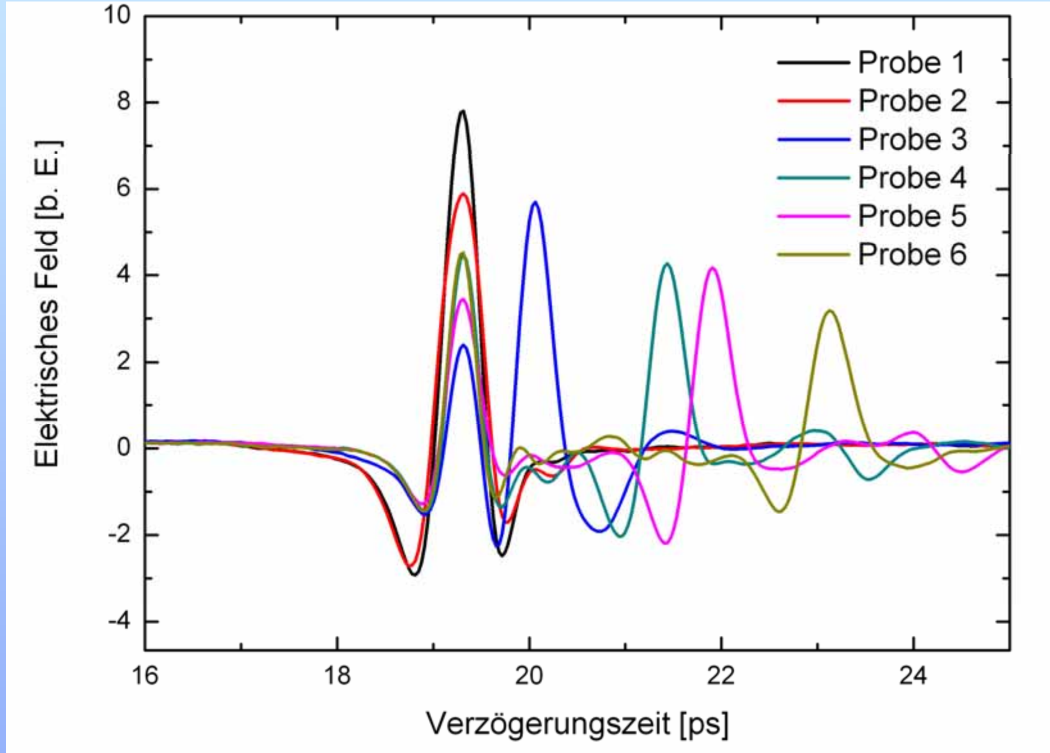
Ewers, Kupsch, Hentschel, Lange, WCNDT 2008

Measurement of Different Surface Coatings

Jonuscheit et al.



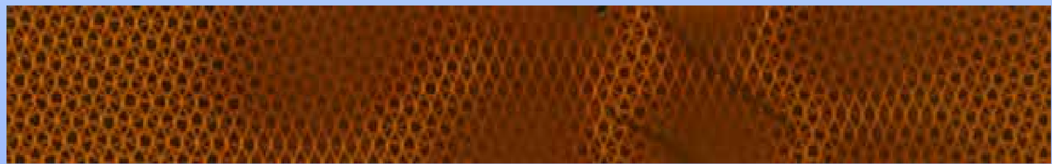
Coating on CFRP



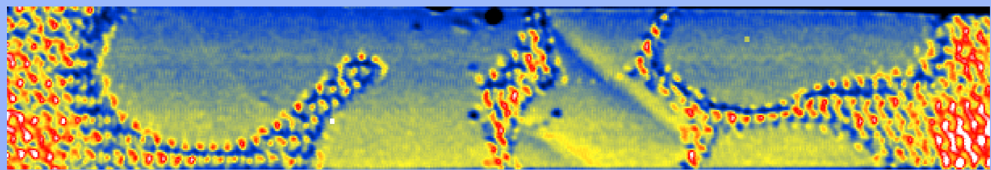
Measurement accuracy about 20 µm.

Measurement of Polymer Thickness above Metal Mesh

Object



Photograph



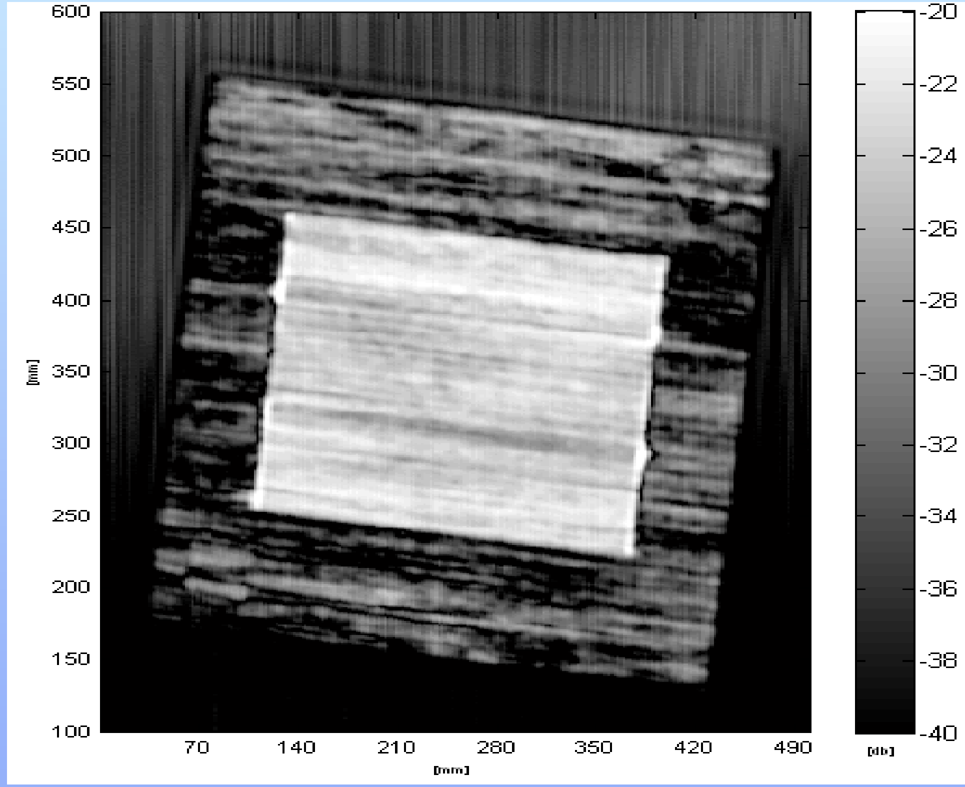
THz image

Jonuscheit et al.

Identification of GFRP Delaminations

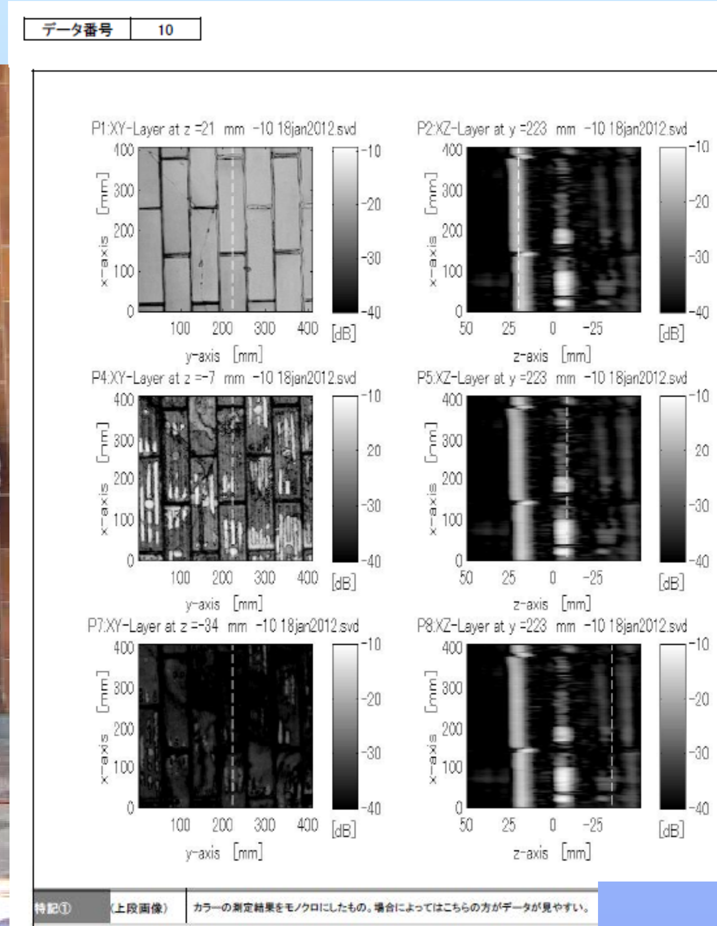
photos of sample:

mm-wave/THz reflectivity at internal layer:



Clear identification of delaminations is possible

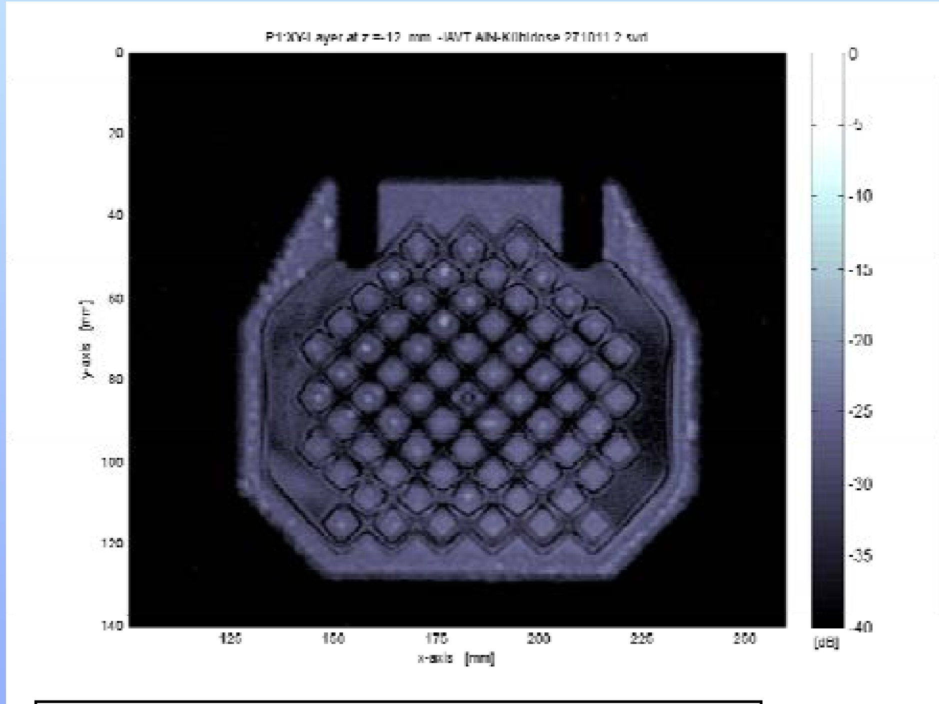
SynViewScan Mobil: Field study in Japan

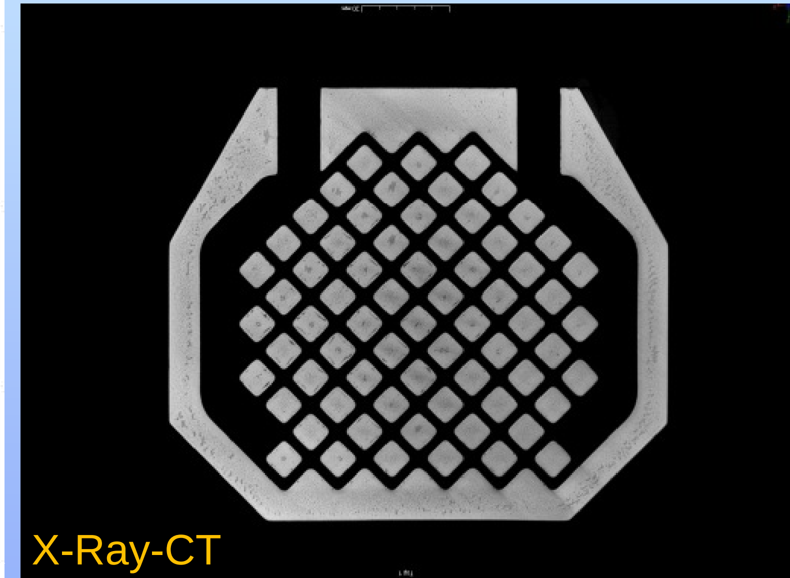


THz inspection of earthquake damages in walls

Investigation of an AlN-Coolingbox
(High Power Electronics)

C-Scan with Time of Flight of a soldering layer, Comparison to X-Ray-CT





Good Agreement of
THz –Scan and X-Ray CT

beckerphotonik gmbh
messtechnik | dienstleistung | ausbildung

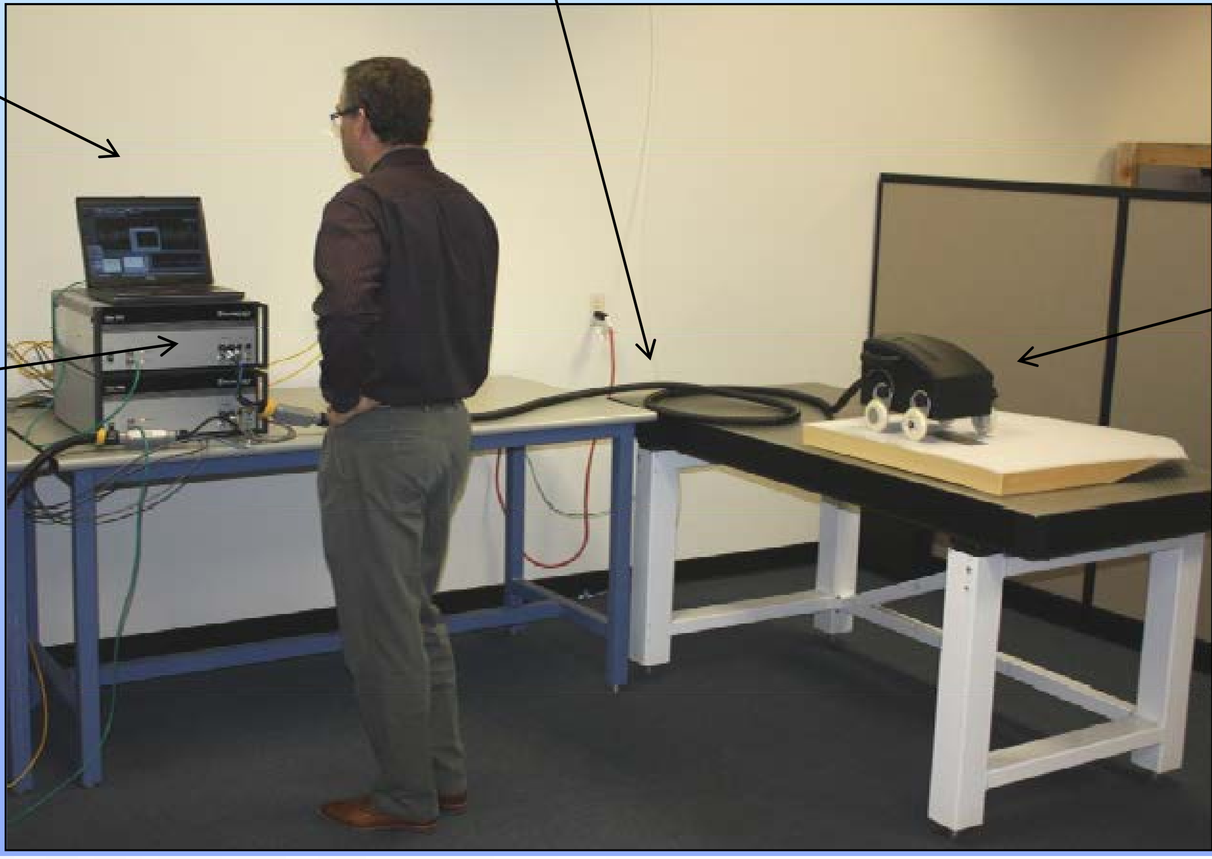
T-Scanner™ Setup

Umbilical

Computer Control / Display

T-Scanner

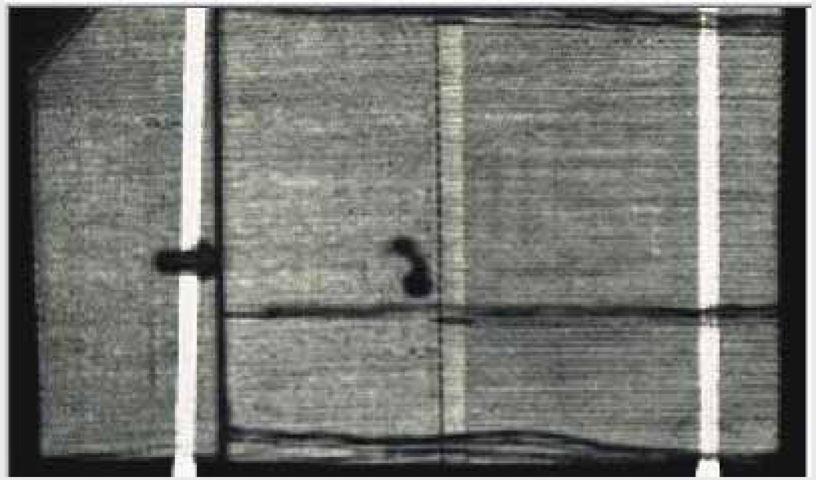
T-Ray 4000 TD-THz Control Unit



Delamination and Water Intrusion

Construction Example

Weather Radome

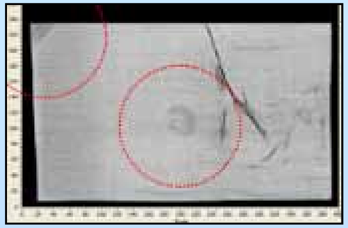


Radome Panel
With Water Intrusion

Water intrusion into composite laminate panel degrades radar performance. Current solution: Tap Testing

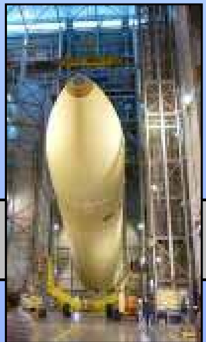
Aerospace applications

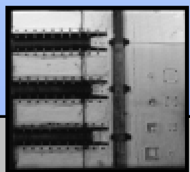
Picometrix T-Ray 4000®



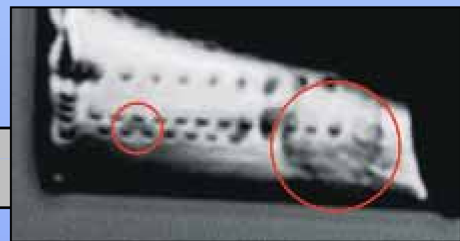
Radar dome delamination and water intrusion;

F35 Intake Specialty Coating thickness measurement



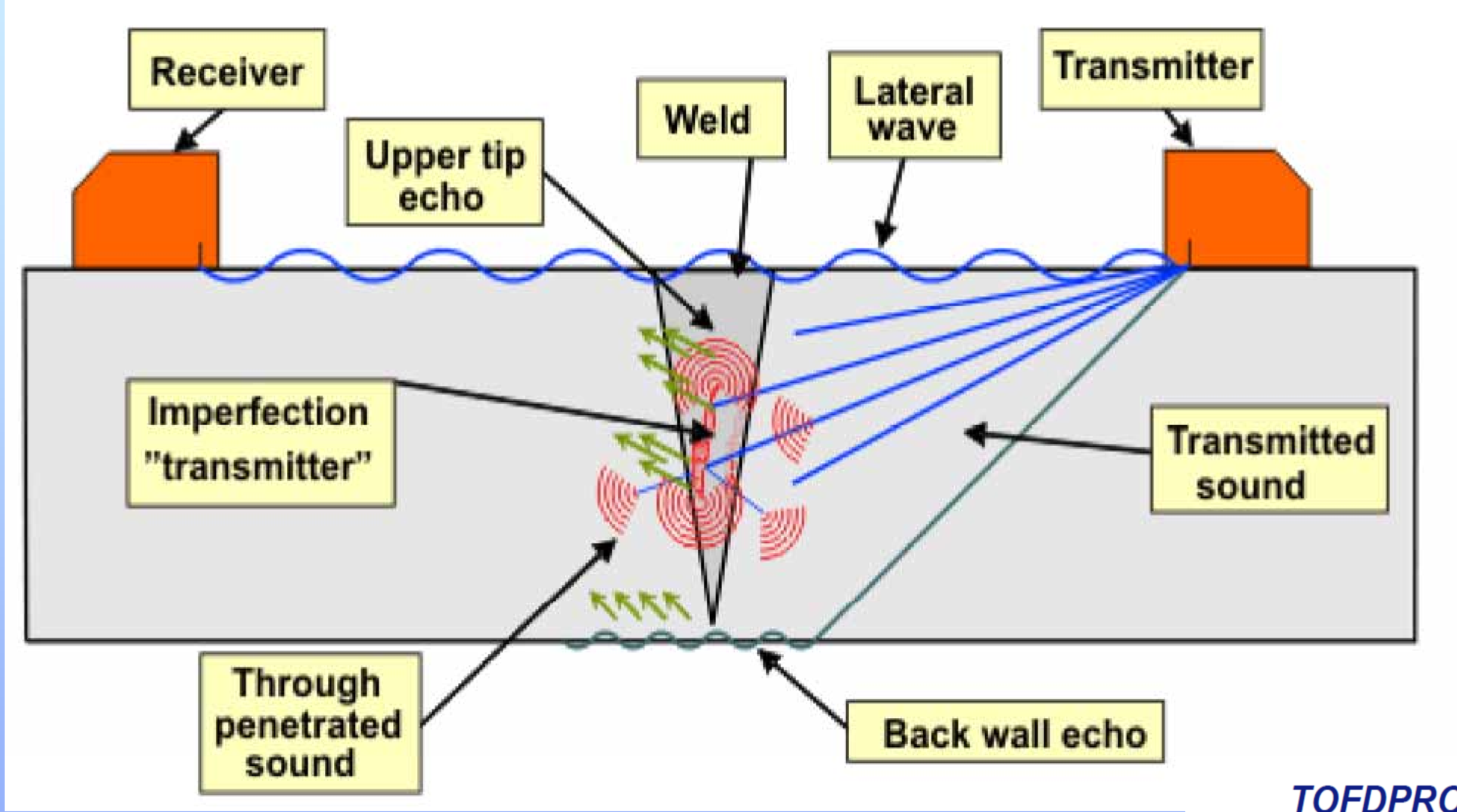


Space Shuttle: ET tank foam NDE;
Orbiter TPS Tiles-hidden corrosion detection;
Next Gen Orion and Ares Applications: NASA



Aeroturbine Thermal Barrier Coating measurement

Comparison to UT - ToFD

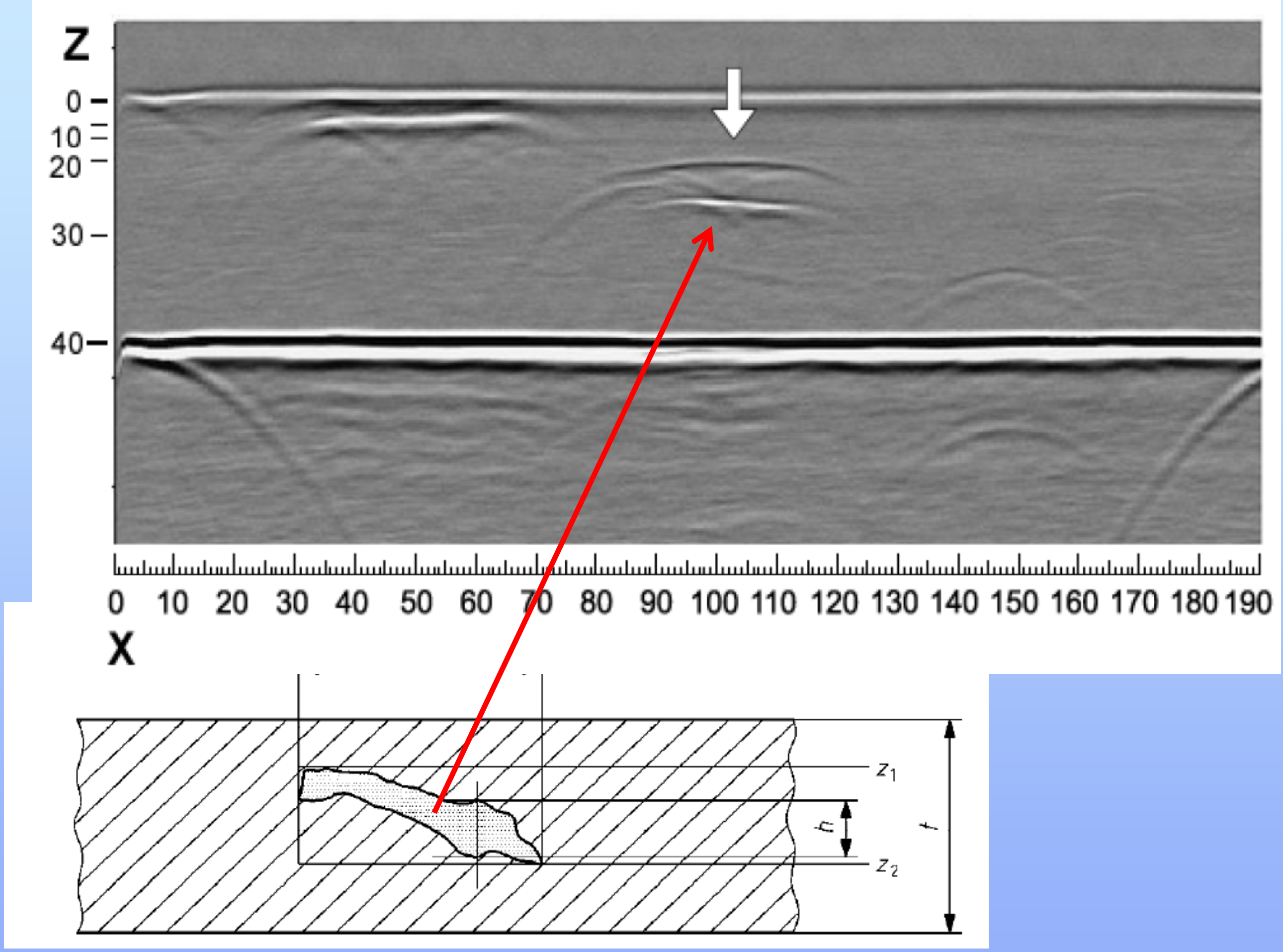


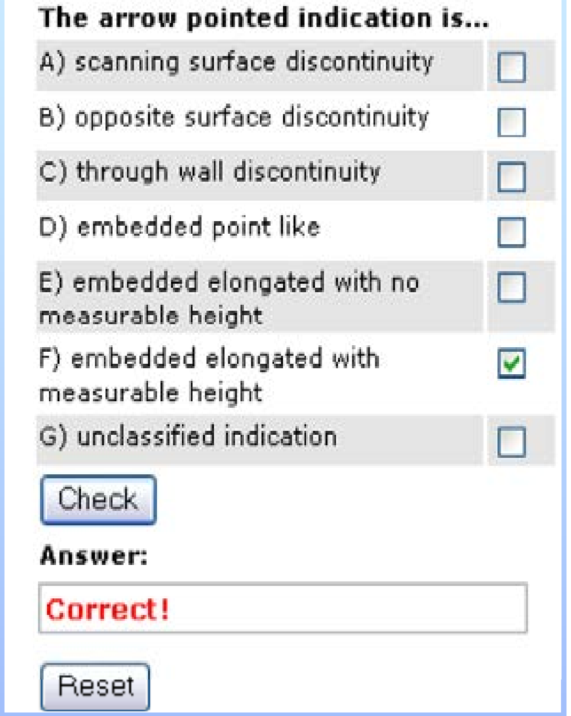
TOFDPROOF

Toni Hakkarainen, TOFDPROOF Meeting, Paris 2005

Internal Defect for UT - ToFD Measurement

TOFD B-Scan

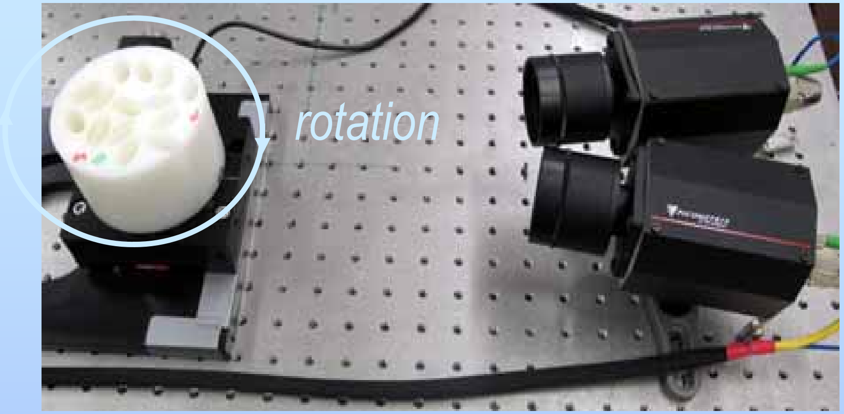




Toni Hakkarainen, Paris 2005

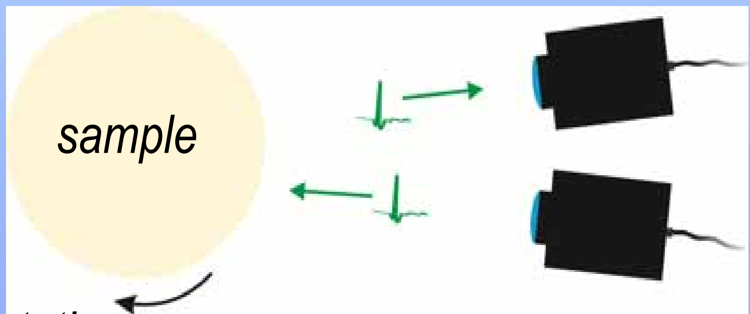
Measurement of Phase Contrast by THz-SAFT

15° geometry



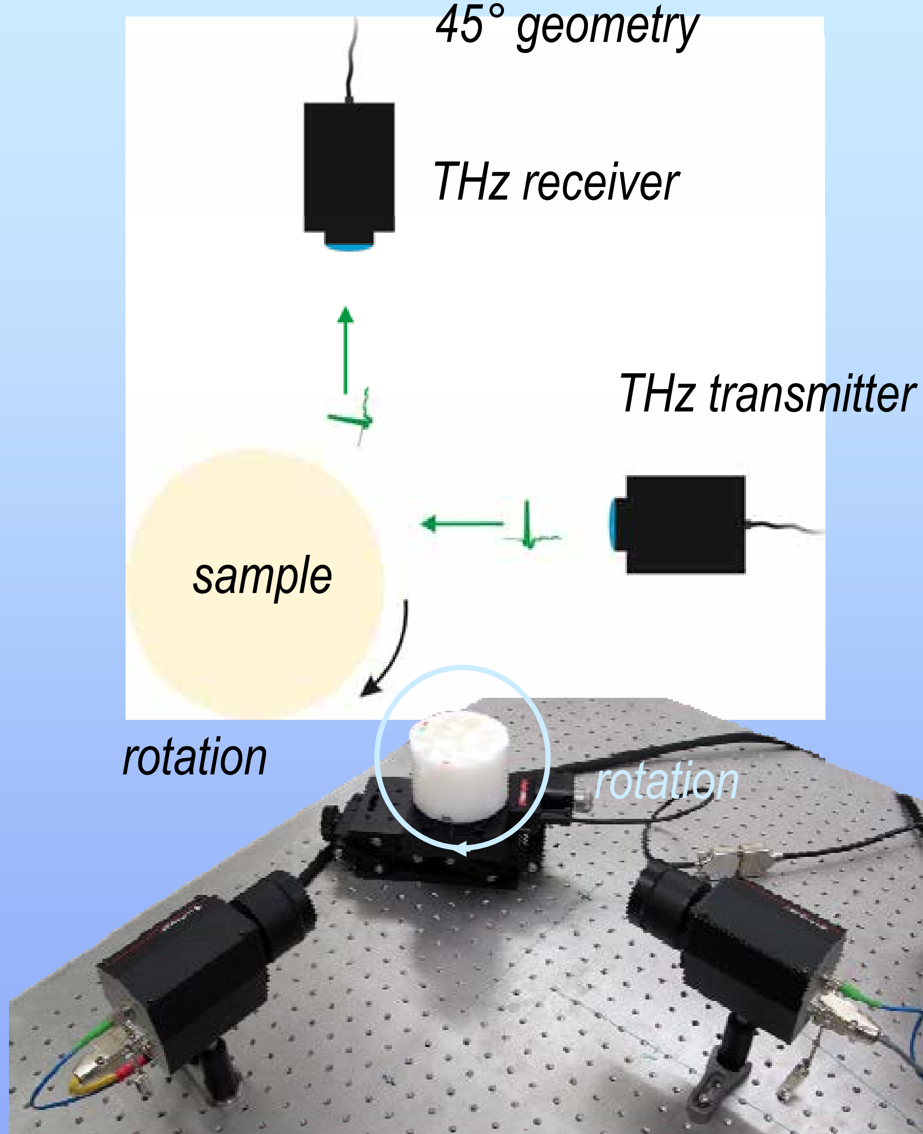
Experimental Setup - THz

THz receiver

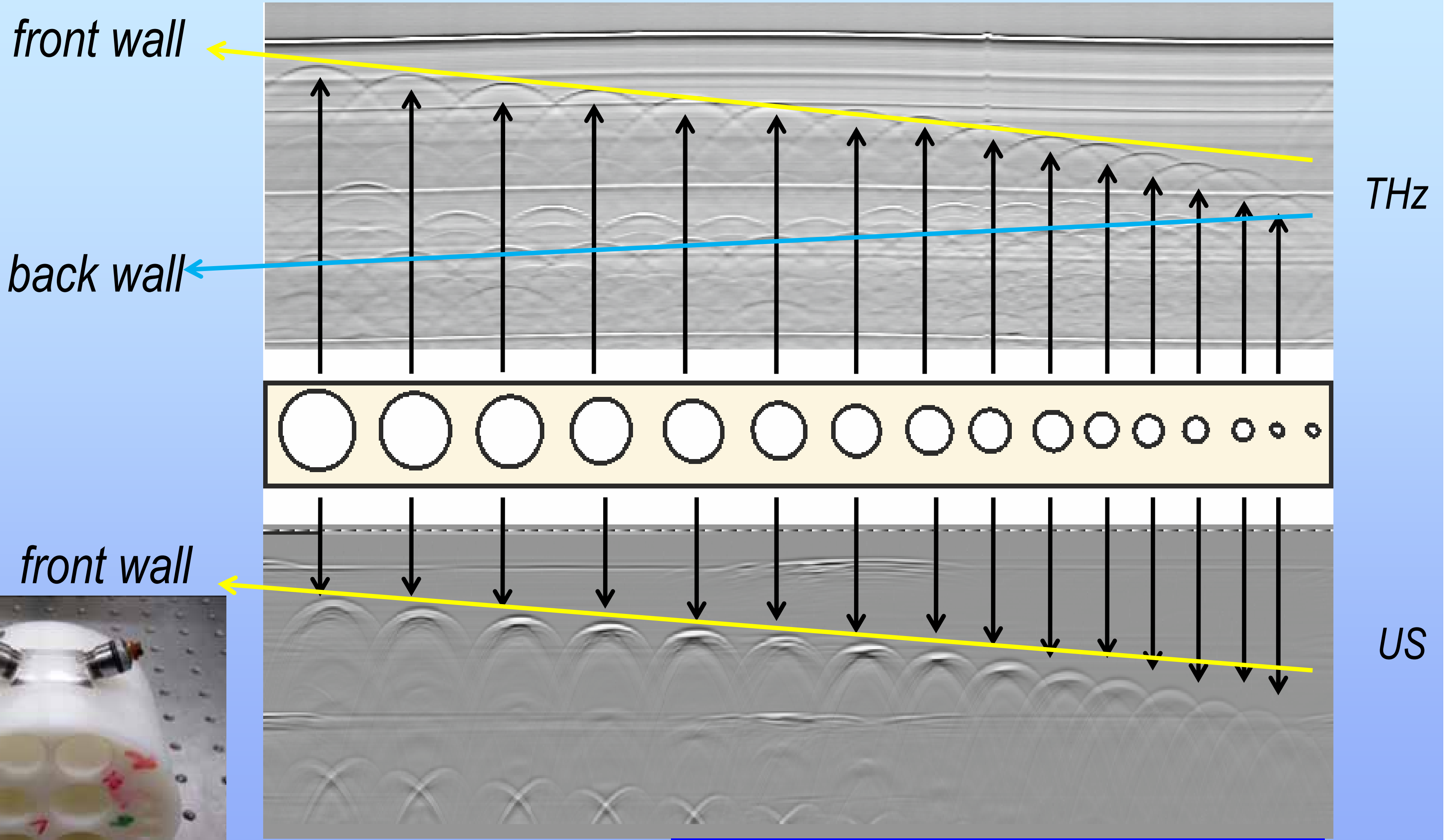


rotation

THz transmitter

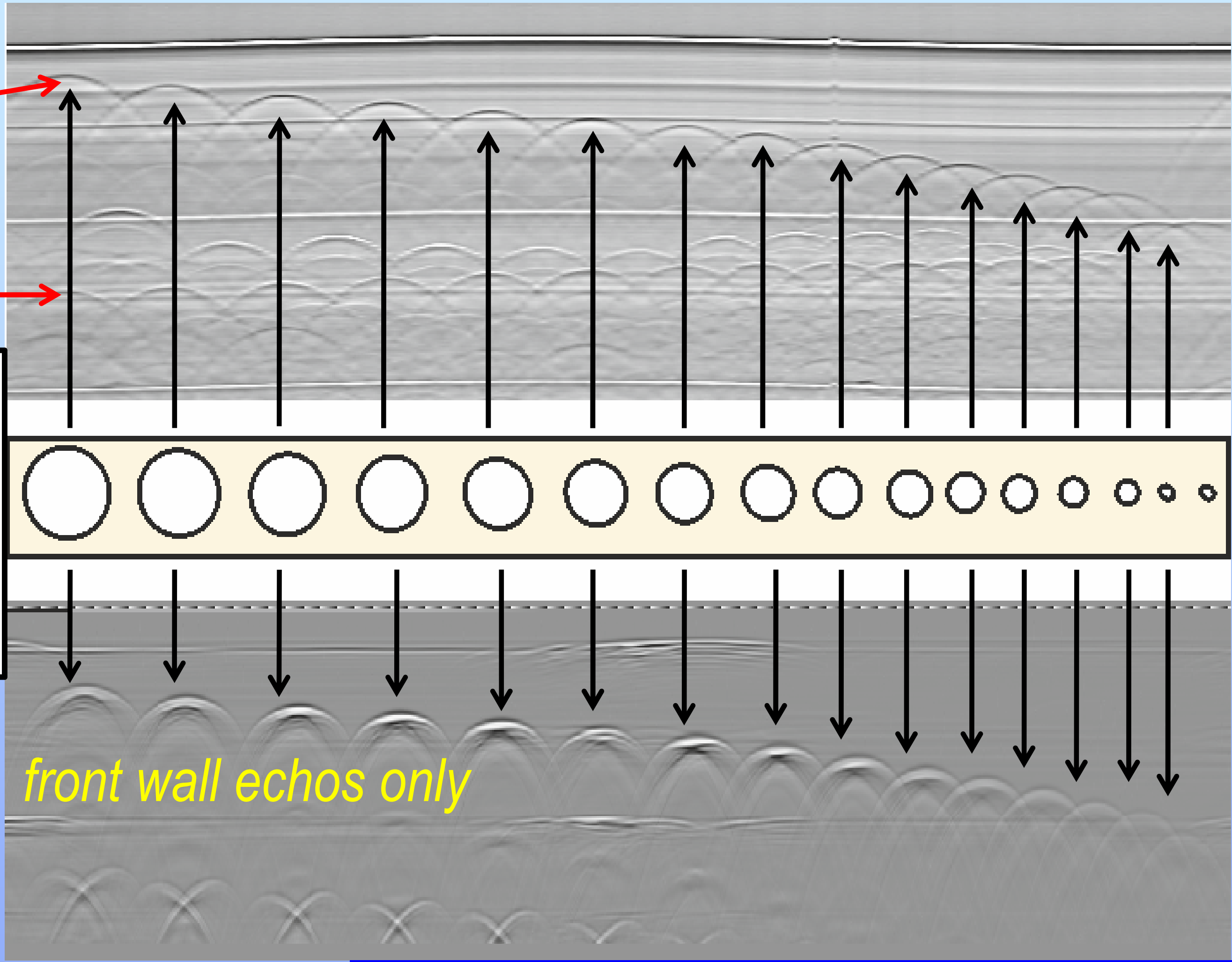


THz vs. UT PE - Sample #2

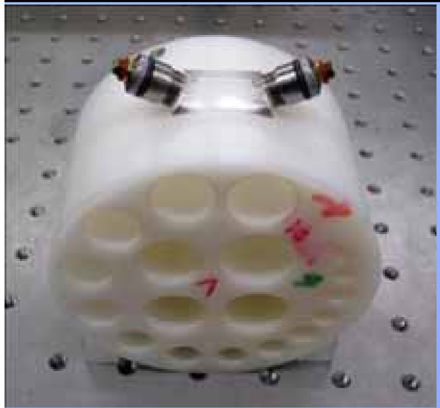


No back wall echo by US

Pulse Echo Techniques: THz vs. UT



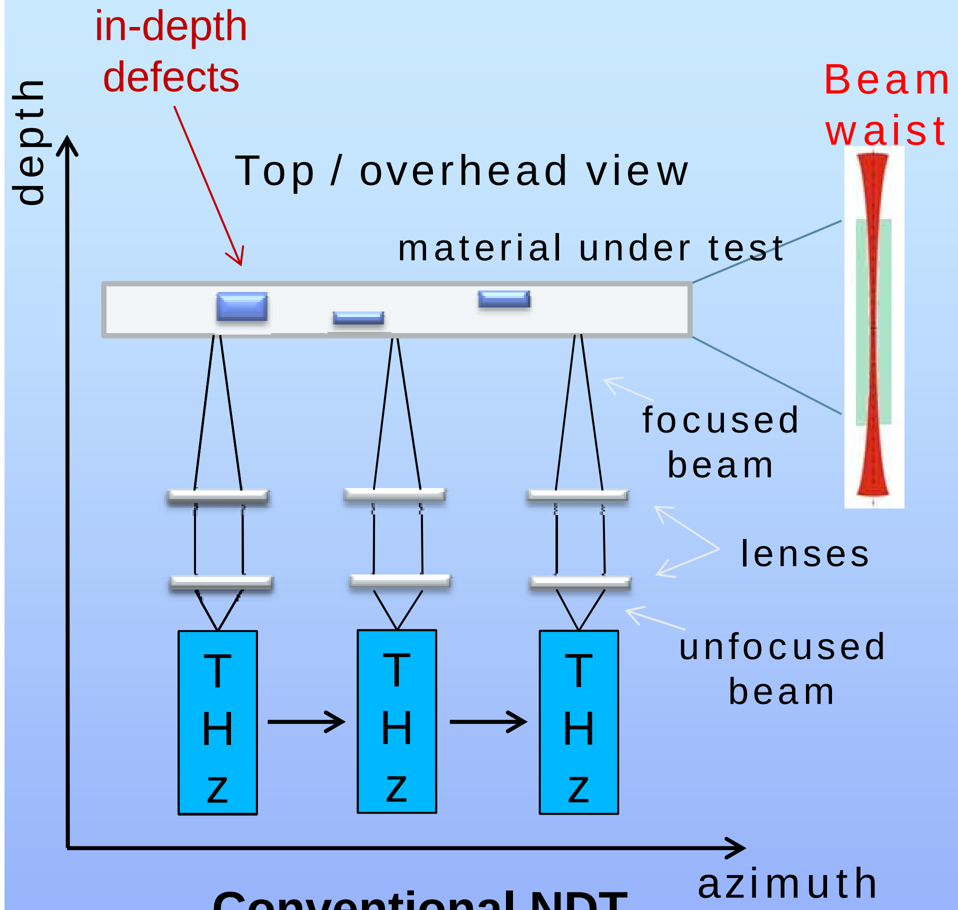
Comparison of THz and ultra sound pulse echo technique of a polyetylene cylinder with drilled side holes.



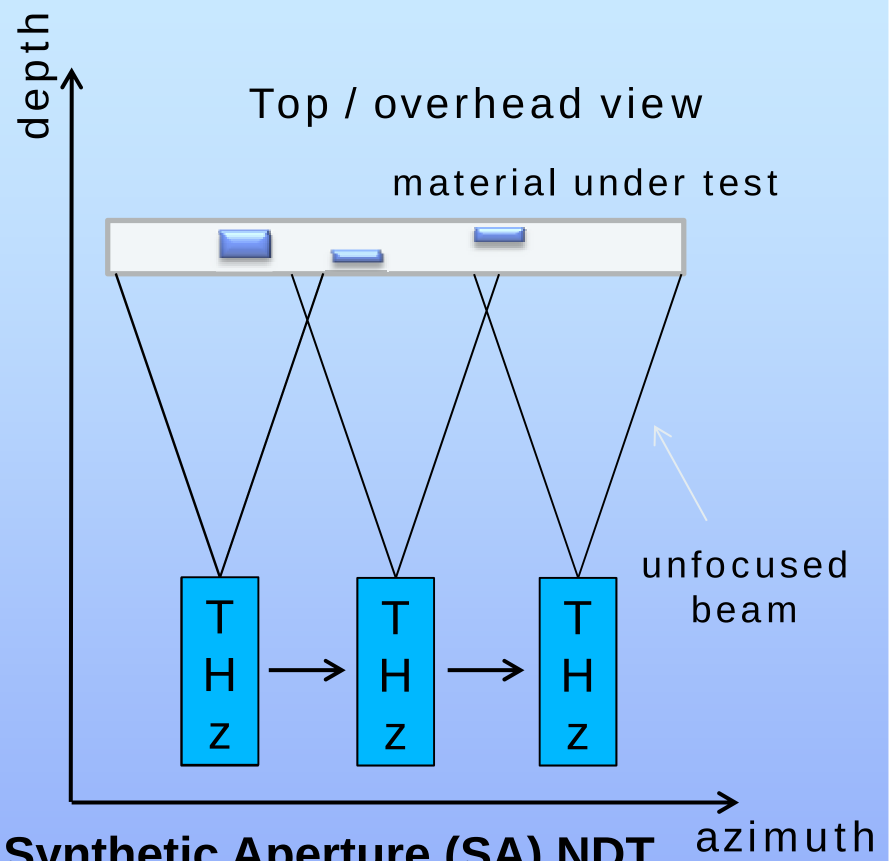
No back wall echo by Ultra Sound

Edison Cristofani, Marijke Vandewal

SA NDT System



Conventional NDT



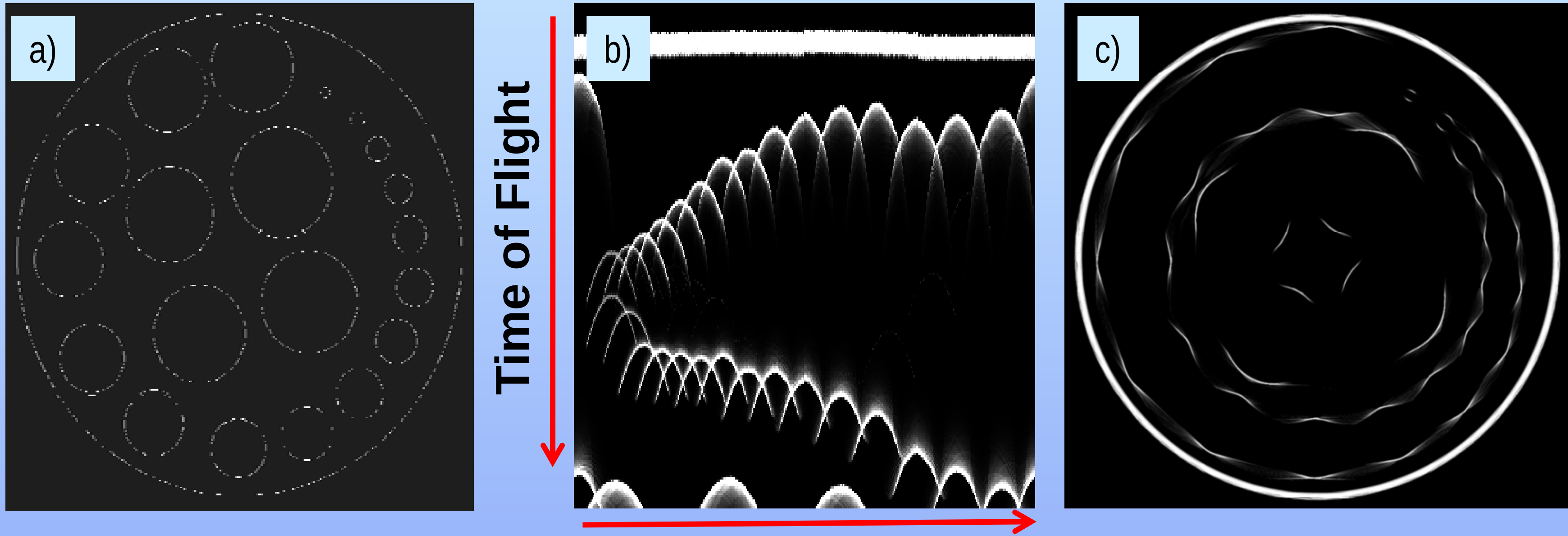
Synthetic Aperture (SA) NDT

- Small focused beam
- Diffraction-limited
- Beam waist deforms image
- Data already focused

- No lenses needed
- Wide unfocused beam (16º)
- Data is focused in software
- Lateral resolution is constant in range

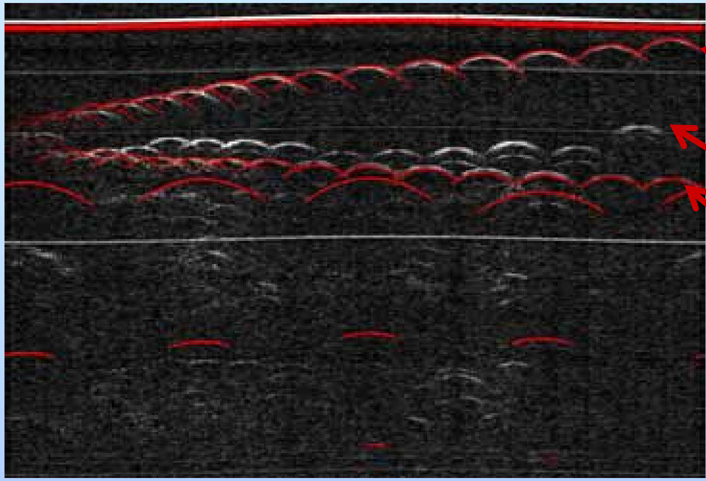
THz Simulation of Hole Phantom # 2

hole phantom **THz B-scan** **SAFT reconstruction**



Rotation angle
(0° - 360°)

Measurements vs. Simulation

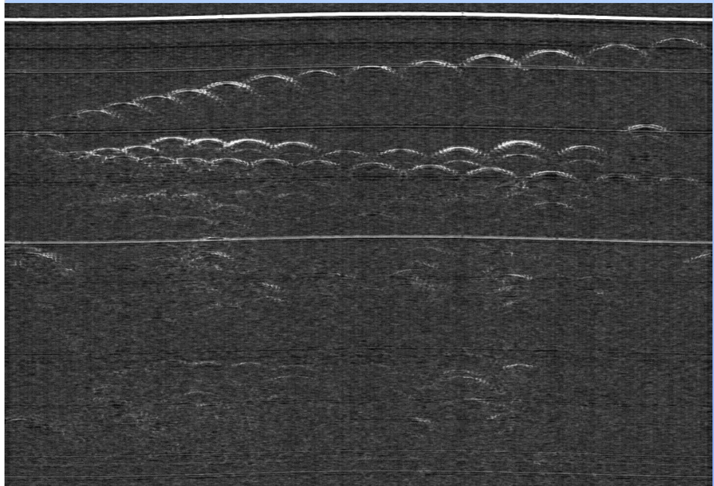


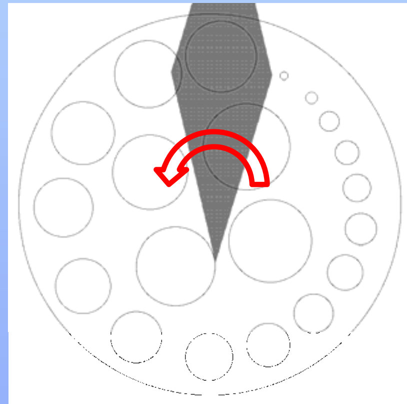
Front wall echo of holes

Artifacts

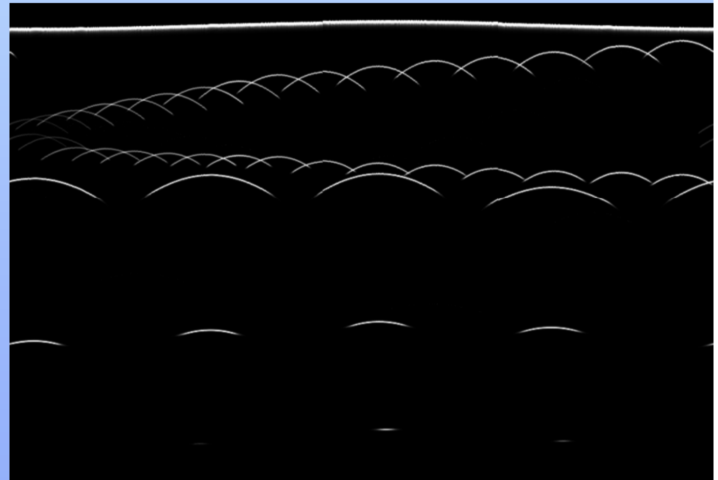
Back wall echo of holes

Measured data



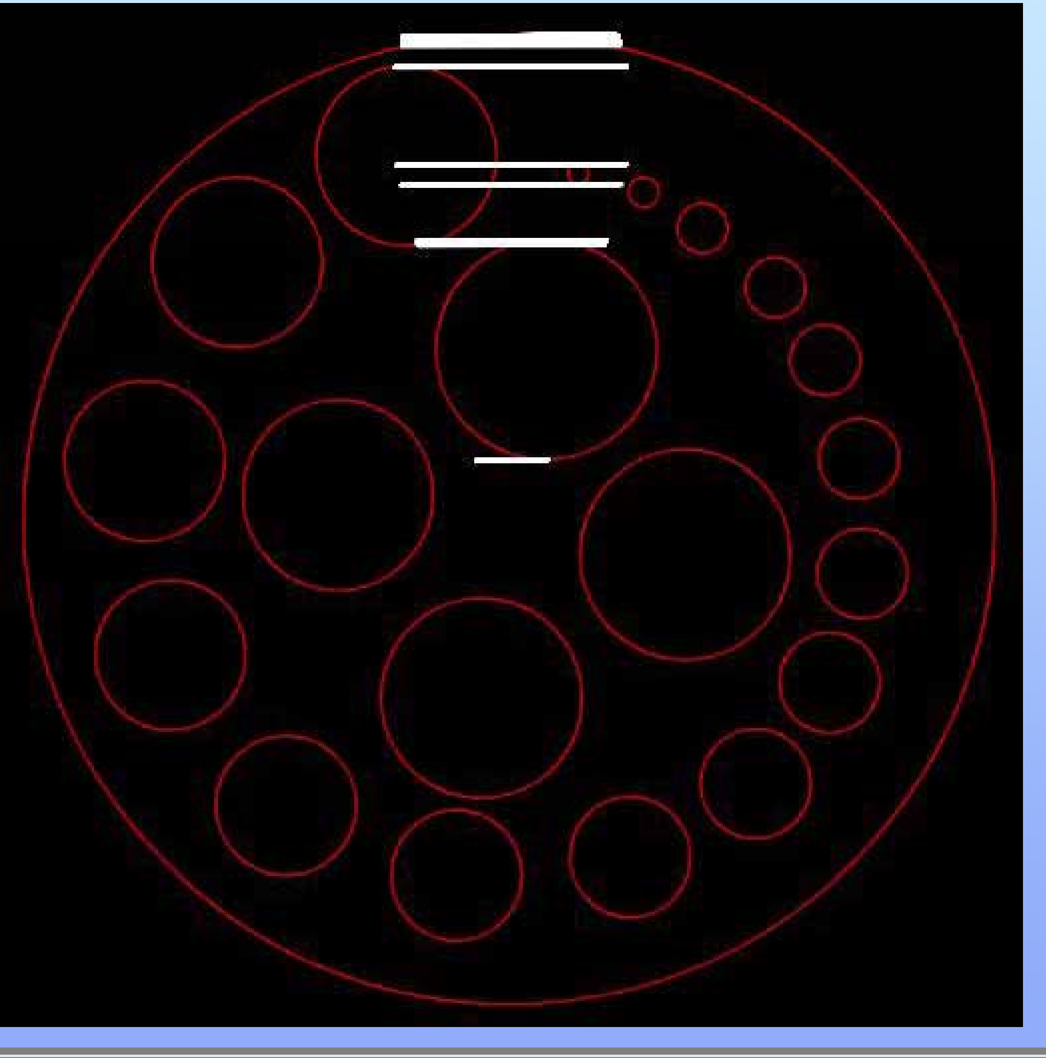


Simulated data

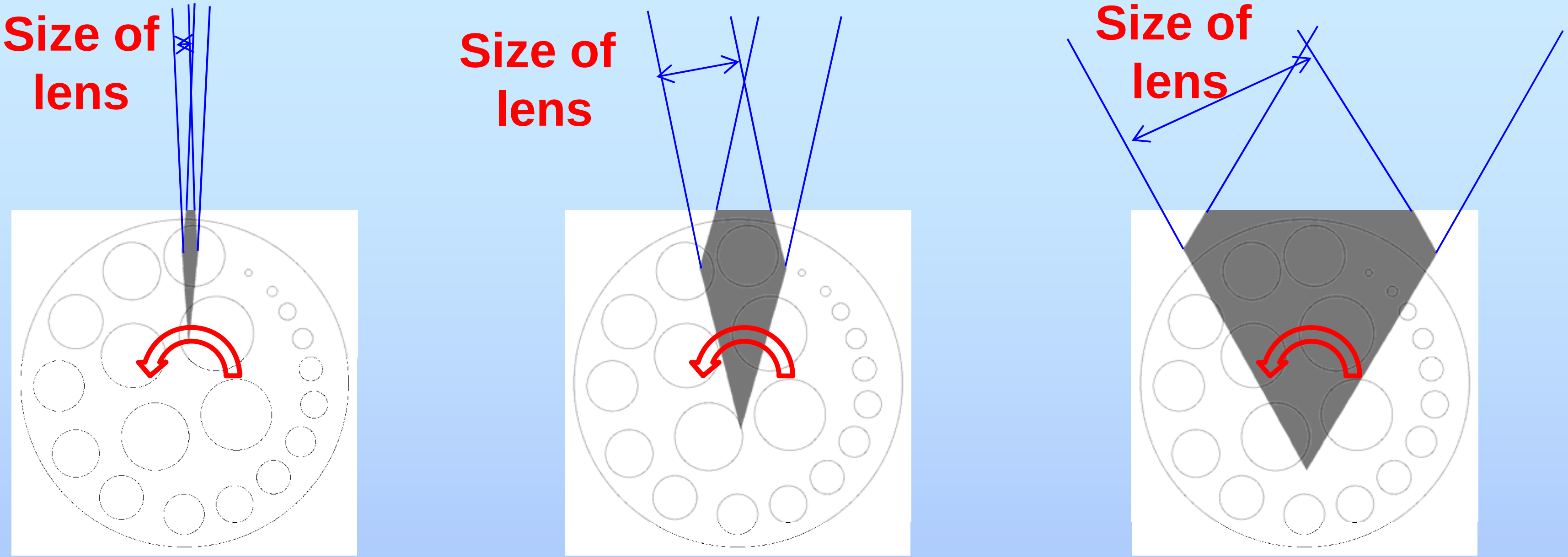


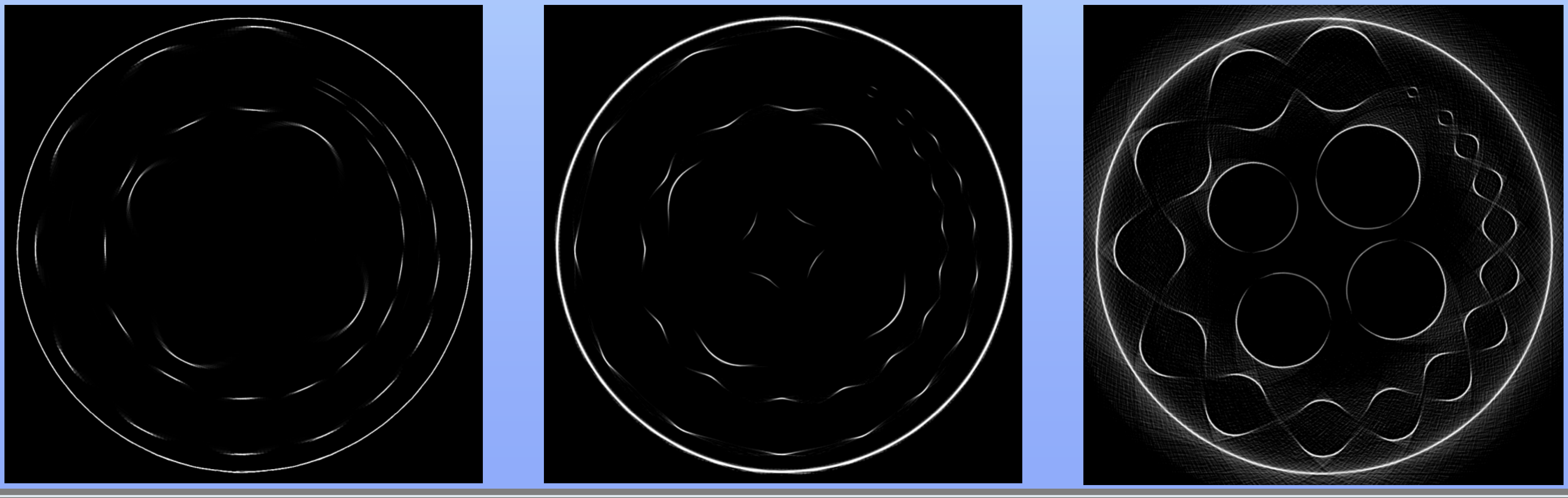
- Matching of simulated and measured data at given lens size .
- Additional echoes need further investigation.

Reconstruction of Hole Phantom # 2 by Synthetic Aperture Focusing Technique



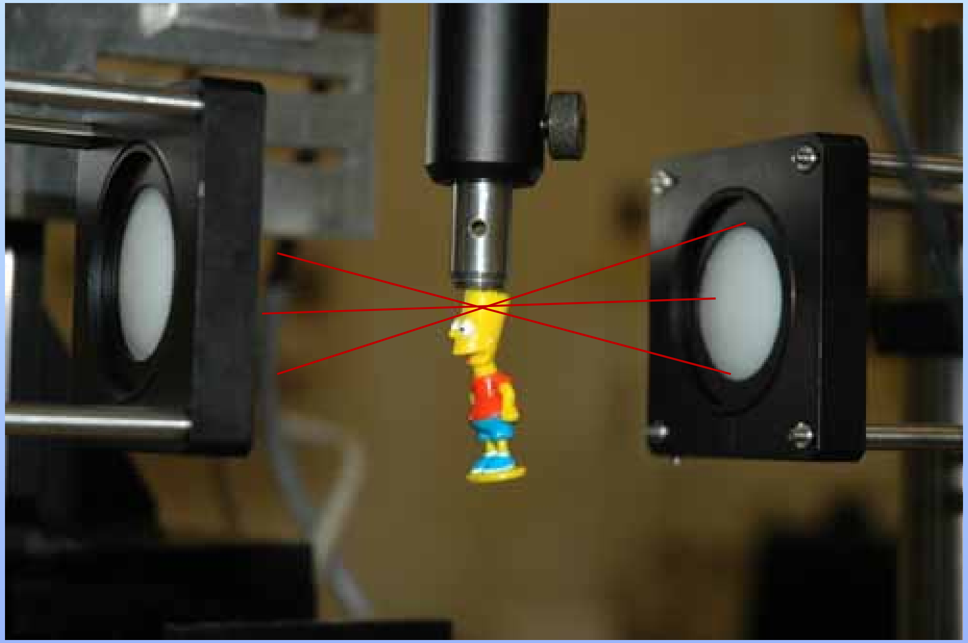
Influence of Lens Sizes





T-ray CT: Experimental Set-Up

Our sample



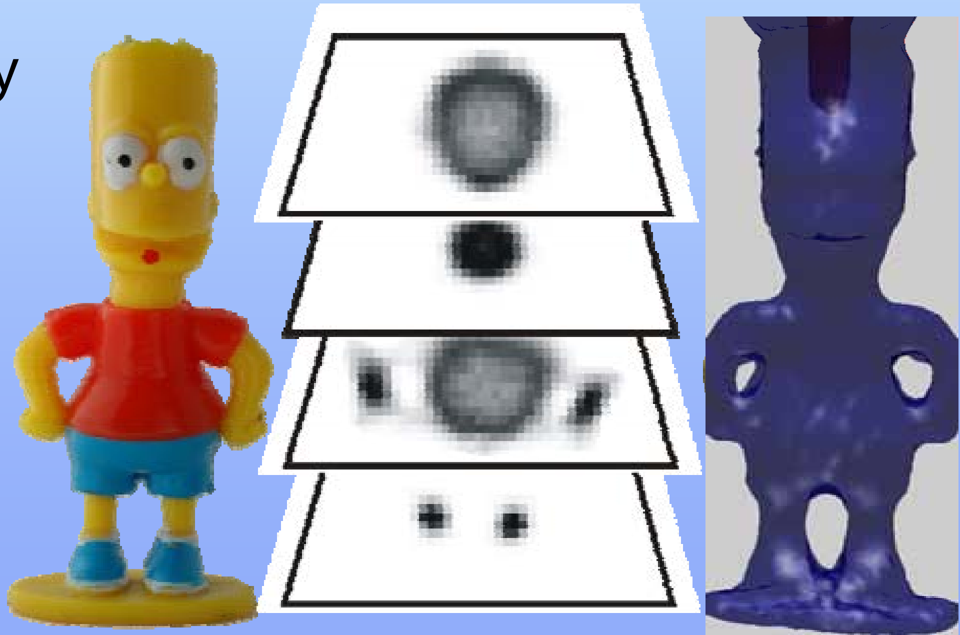
…in the focus

Focussed beam Technique

Ewers, Kupsch, Hentschel, Lange, WCNDT 2008

T-ray CT: Experimental Results

- reconstruction by standard algorithm (filtered backprojection)
- assumption: ideal parallel beam
- neglecting non-linear effects
- *y* slices reconstruced separately
- isosurface algorithm for 3D imaging



Ewers, Kupsch, Hentschel, Lange, WCNDT 2008

Conclusion

- **THz radiation** is explored **as replacement for RT and UT** volumetric inspection of non-metallic materials.
- **THz measurements are contactless** and **do not need any coupling medium in contrast to UT** and **do not require radiation protection in contrast to RT.**
- **THz CT was performed in radiographic penetration mode**
  - The classic CT set up with a single beam and rotation translation technique was successfully tested for volumetric 3D inspection.
- **THz CT in UT pulse echo mode**
  - The Time of Flight technique (ToF) was used in analogy to UT inspection.
  - A topographic 2D scan was combined with time of flight measurements for reconstruction of a 3D surface image (phase contrast) in front of a metal plate.
  - Time domain THz measurements can be performed similar to the UT - Pulse echo technique and be interpreted correspondingly.
  - Several applications were shown.
  - THz pulse echo measurements with SAFT provide phase contrast in analogy to UT SAFT, but THz visualizes also multi phase geometries.

Acknowledgement

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