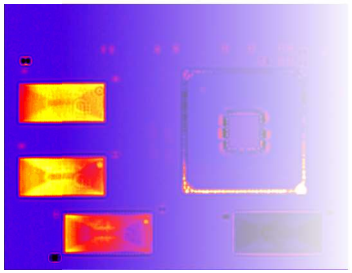

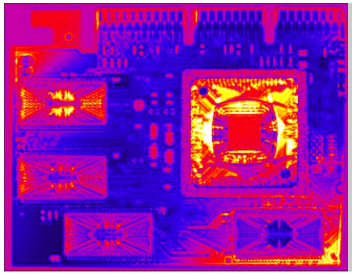

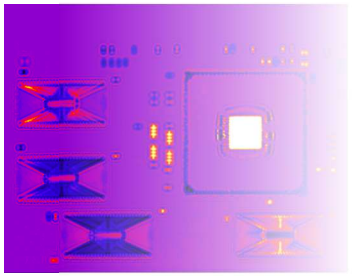

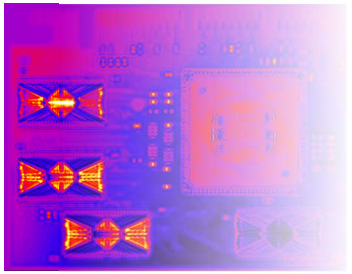

Terahertz Microprobe-enabled Near-Field Imaging for non-destructive testing applications

Protemics GmbH
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D-52074 Aachen
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Outline

- **Introduction**
  - Terahertz near-field microprobe technology
  - Working principle and main applications

- **Application examples**

  <u>R&D:</u>
  - THz source characterization
  - THz Metamaterial characterization

  <u>Non-destructive testing:</u>
  - Thin-film inspection
    - Solar cells, Graphene
  - Laser weld and chip package inspection

Terahertz …
… in numbers

TERAHERTZ

LOW FREQUENCY | MICROWAVES | IR | UV | X-RAY

RADIO WAVES | VISIBLE | GAMMA RAY

THz **frequency** range

0.1 THz **1 THz** **3 THz**

THz oscillation **time** range

10 ps **1 ps** **0.333 ps**

(λ/1000 @ 0.1THz)

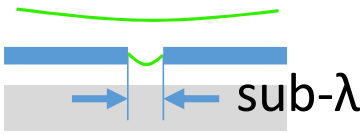
Spatial resolution: THz **wavelength** range protemics **THz Technology**

3 mm **0.3 mm** **0.1 mm** **3 µm**

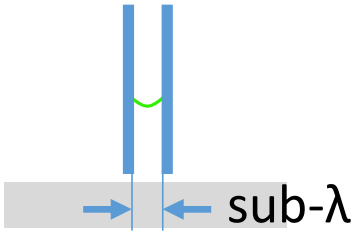
… near-field measurement methods

Passive (metal) structures to isolate/generate the near-field information:

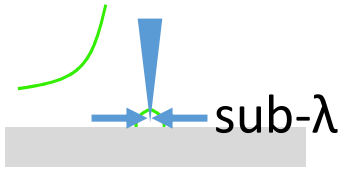
Apertures



Waveguides

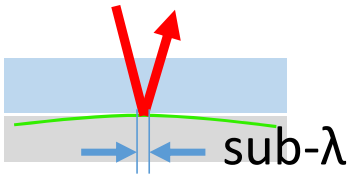


Scattering elements

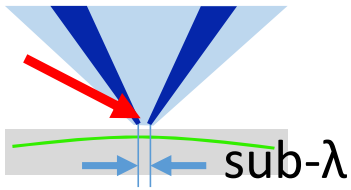


Direct detection in the near-field using active probes:

Electrooptic crystals



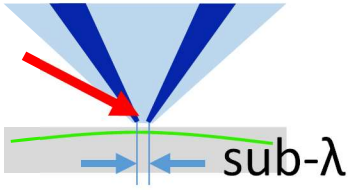
Photoconductive microprobes

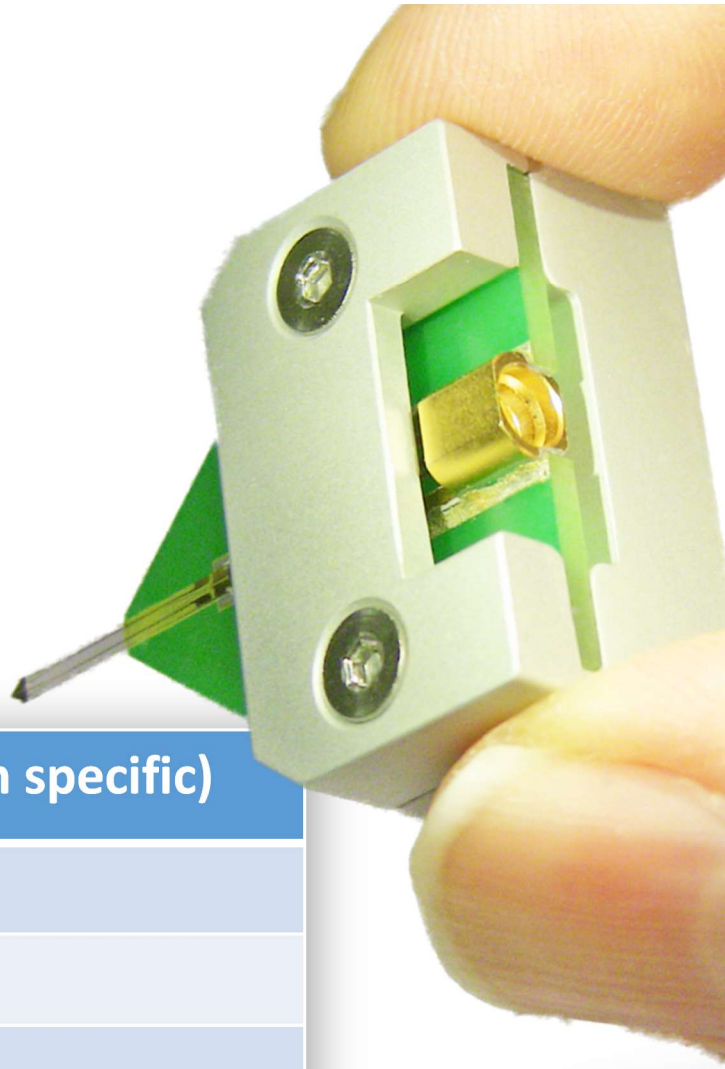


Terahertz …

… near-field microprobe

Photoconductive microprobes

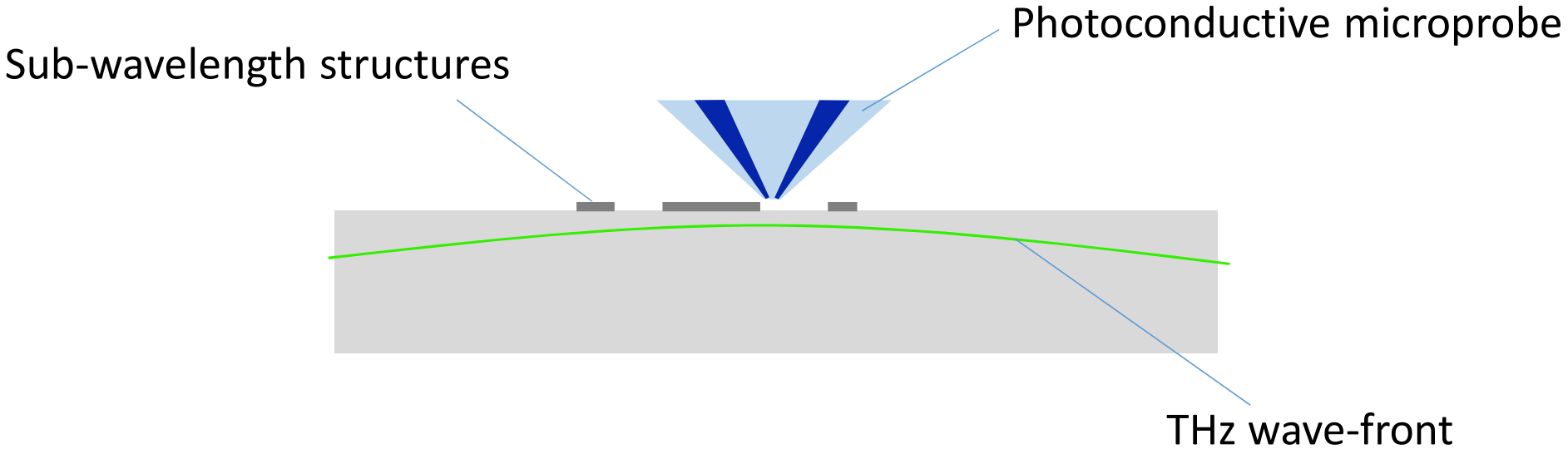




Main benefits	Up to … (system specific)
High speed	1 ms/point
High bandwidth	0.05 .. 4 THz
High spatial resolution	3 µm
Contact less/Low invasive	1 .. 1000 µm (Typ. Distance)
Large scanning area access	Quasi „unlimited“ (typ. wafer scale)

Terahertz …

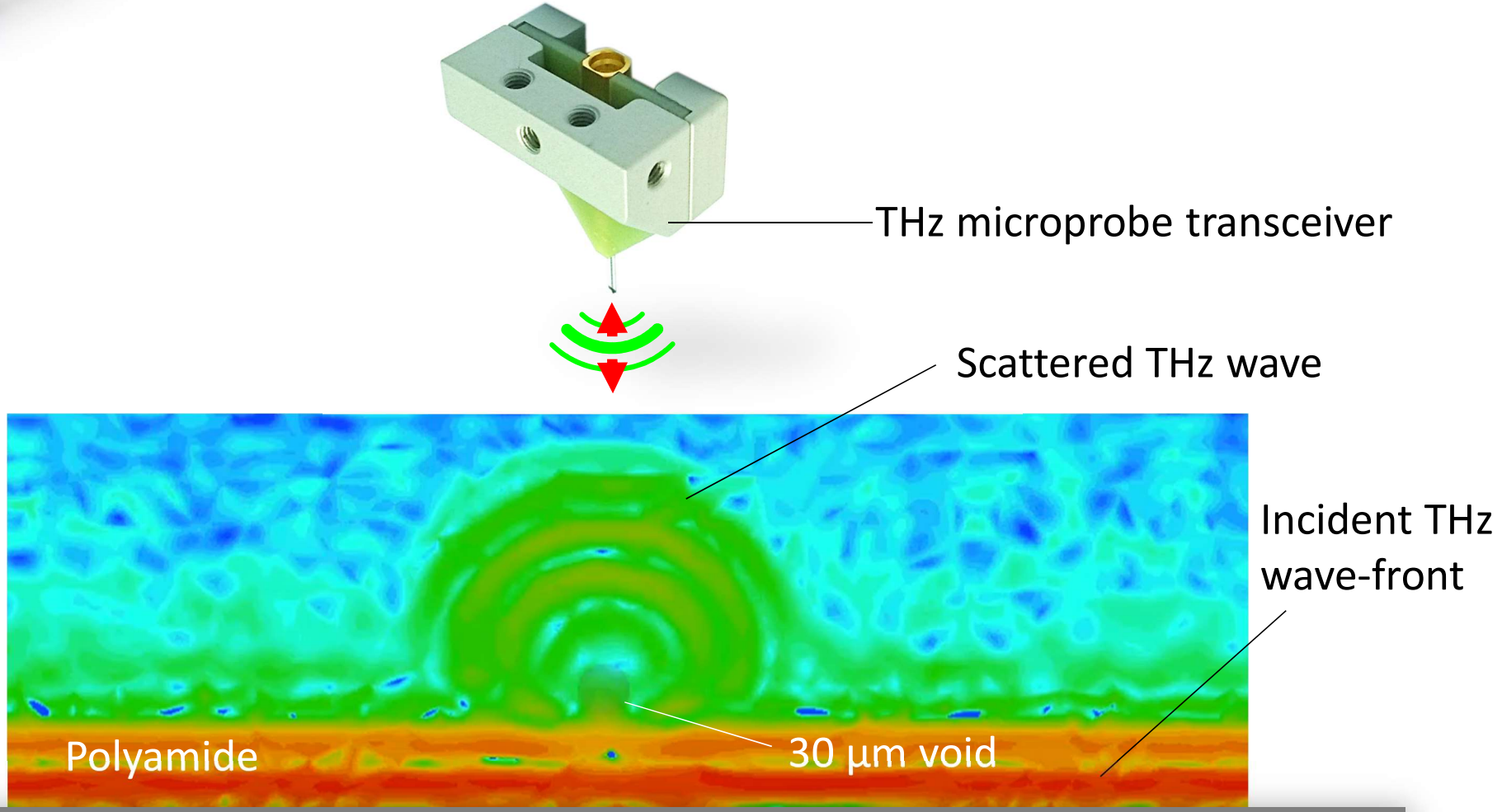
… near-field transmission imaging



Small structures can be resolved because of increased field sensitivity near the probe tip.

Terahertz …

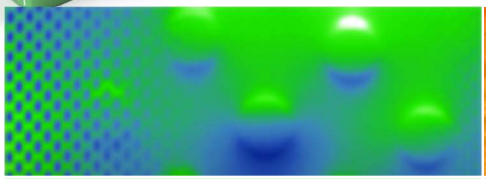
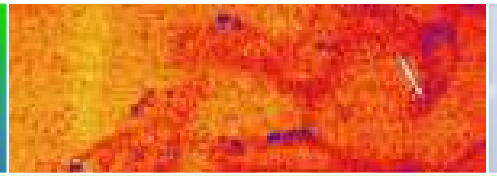
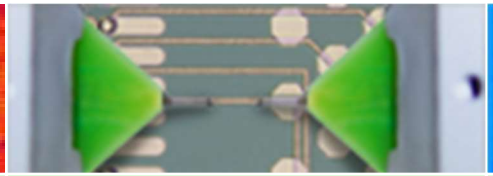
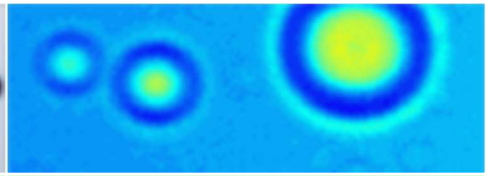
… near-field reflection imaging



Small (buried) structures can be **recognized** by the scattering signal they generate. Measuring in close distance to the scatterer helps to detect these weak signals

Terahertz microprobing applications:

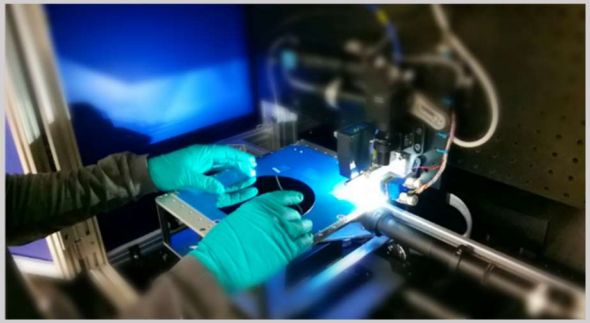
Taking advantage of Terahertz benefits without being compromised by wavelength-based resolution limitations.

Terahertz Research	Wafer Inspection	Chip-Testing	Volume Screening
Application areas: • Metamaterials • Plasmonics • Devices • Waveguides • Sensor surfaces • Graphene	**Application areas:** • Solar cells • Displays • Flexible electronics • Doping layers • Graphene • Transparent conductors	**Application areas:** • Time-domain reflectometry • Fault isolation • Packaging level inspection • 3D integration • Through silicon via (TSV)	**Application areas:** • Plastic weld inspection • Fiber inforced polymers • Chip underfill inspection • Organic layer screening
Benefits: • Near-field access • High-sensitivity • Low-invasiveness • Polarisation sensitive • Broadband	**Benefits:** • Sheet resistance imaging • Contactless • Micron-scale resolution • Large-area scanning • High-speed scanning	**Benefits:** • Market leading TDR resolution • Contactless • Non-destructive • Cost advantage	**Benefits:** • Non-destructive • Fast inspection • Screening of opaque plastics • Detection of microdefects

Full system solution

TeraCube Scientific



- **Table-top THz time-domain near-field imaging system**
- **Transmission- or reflection-mode**
- **XYZ-T-scanning system**
- **Up to 310 mm x 310 mm scanning area**

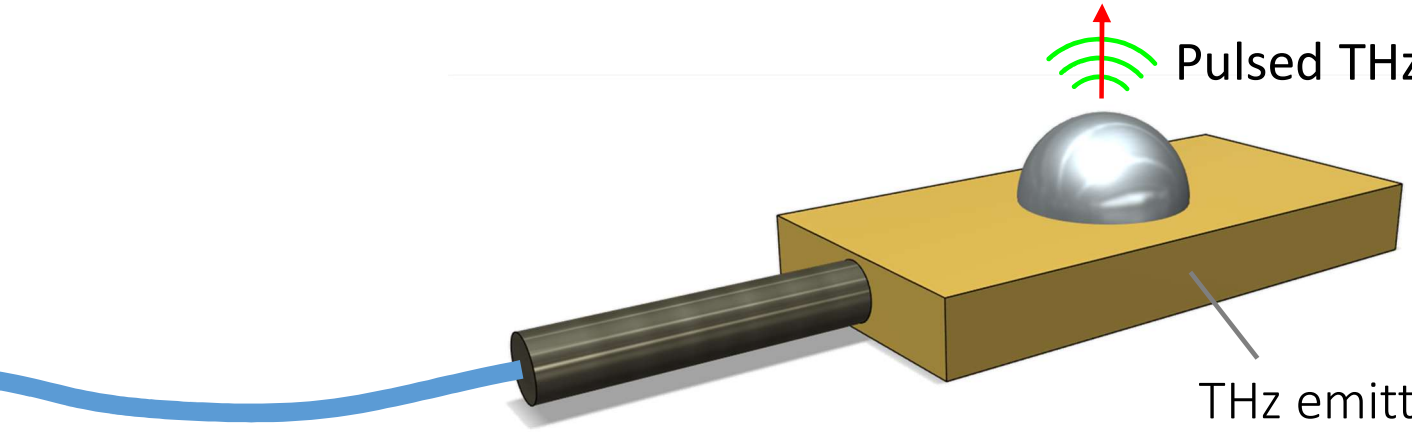
Modular configuration

With fiber-coupled THz TDS system: TeraFlash

THz source characterization

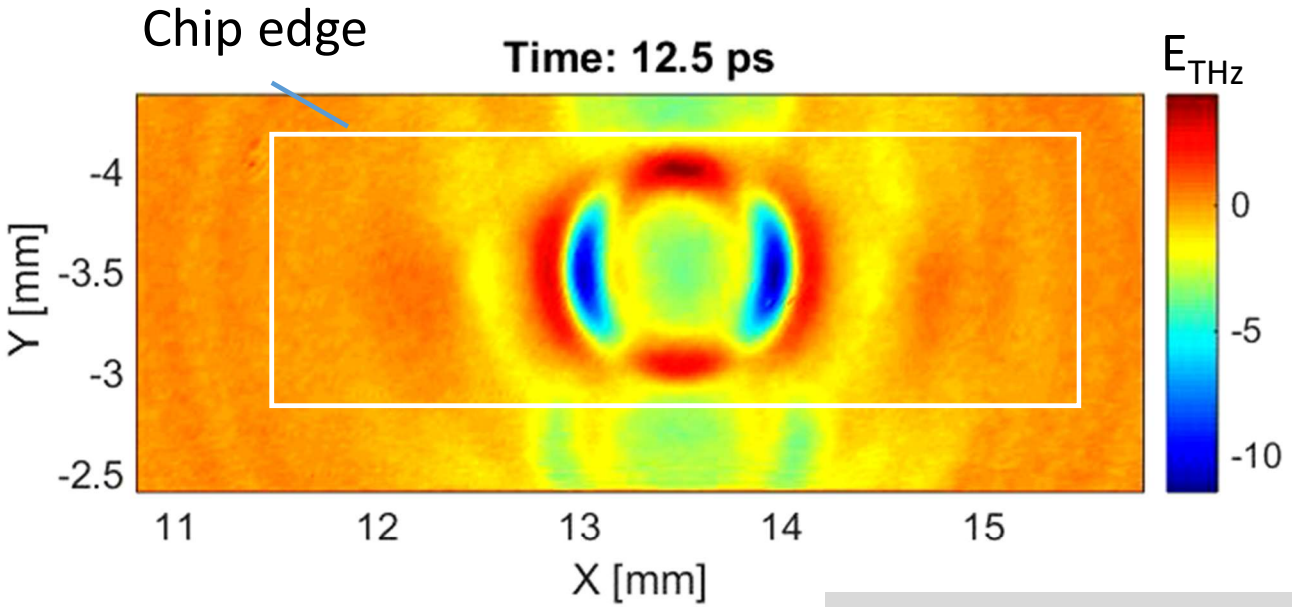
Measured with TeraFlash system & TeraSpike probe

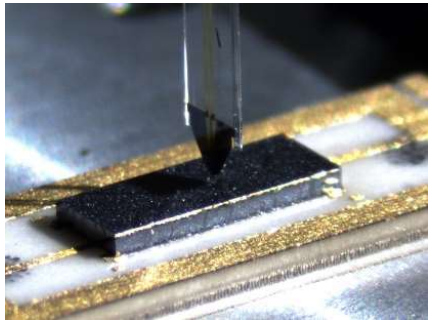
THz
microprobe
detector



THz source characterization

Measured with TeraFlash system & TeraSpike probe





*Measurement of 2,400,000 data points at **1333 data points per second**.*

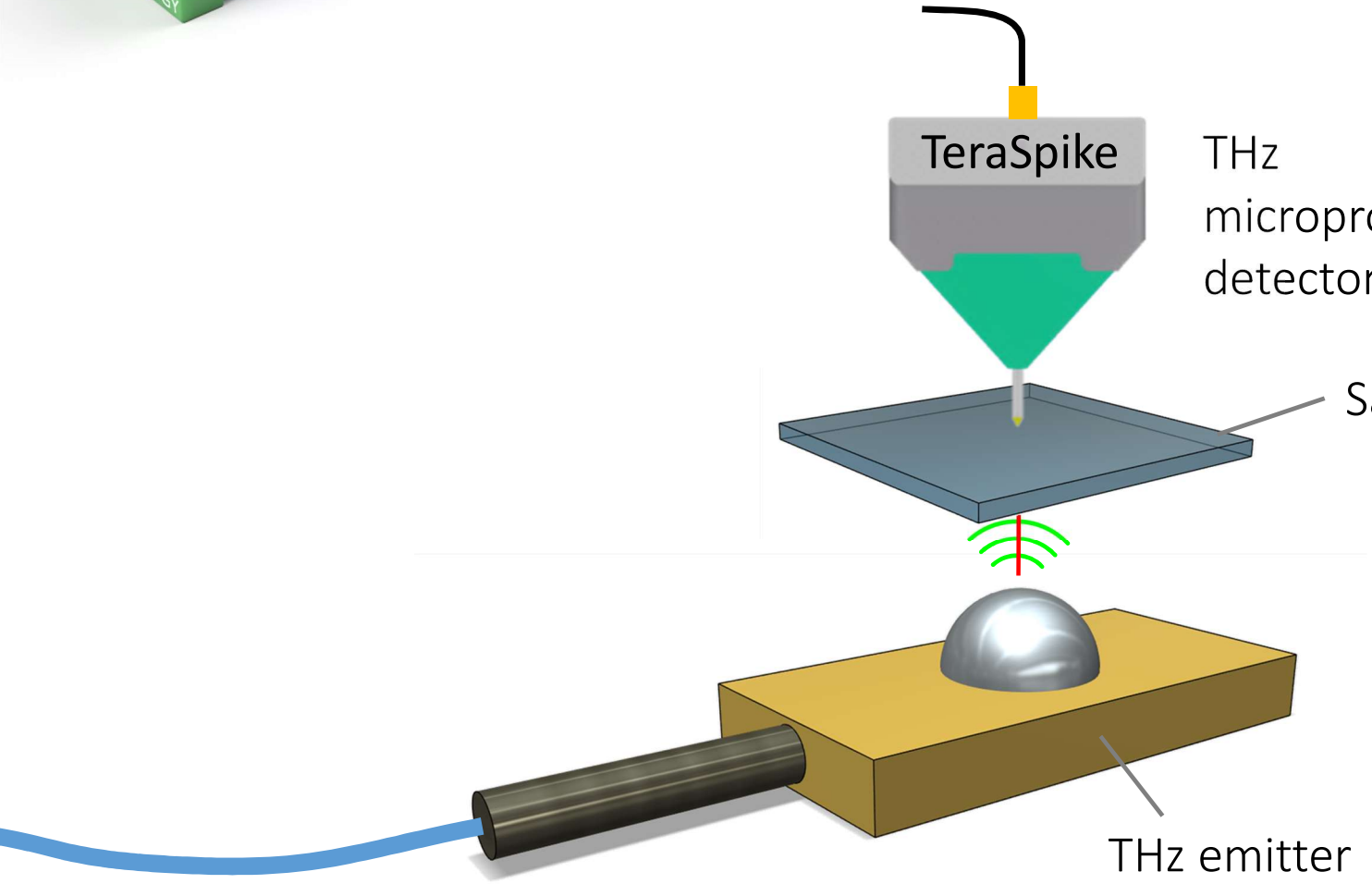
Toptica TeraFlash system and emitter chip provided by:

Fraunhofer HHI

Fraunhofer-Institut für Nachrichtentechnik, Heinrich-Hertz-Institut, HHI

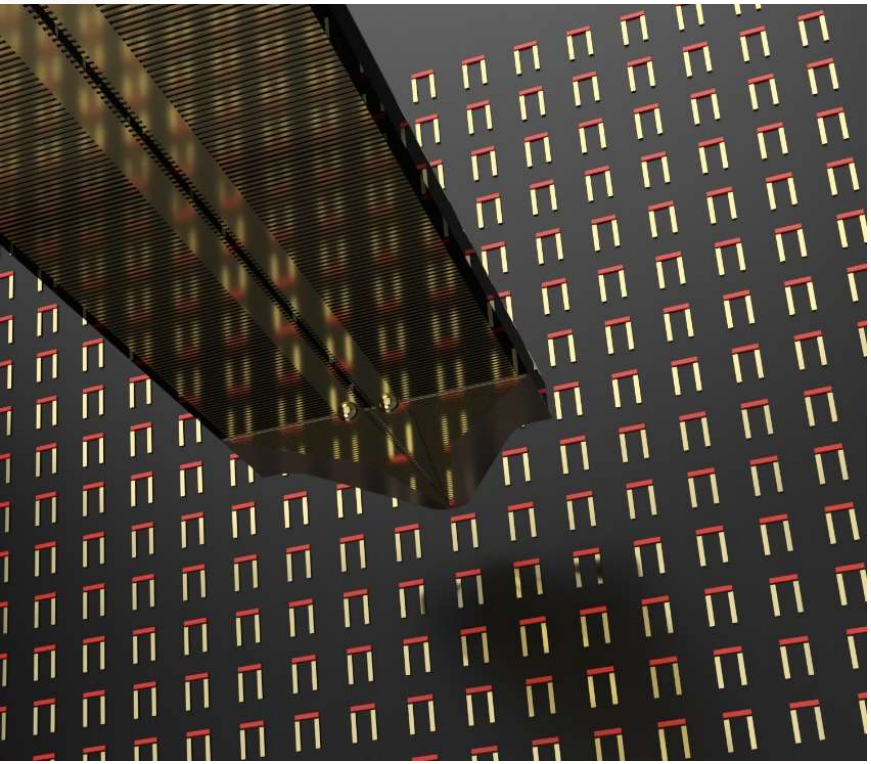
THz structure characterization

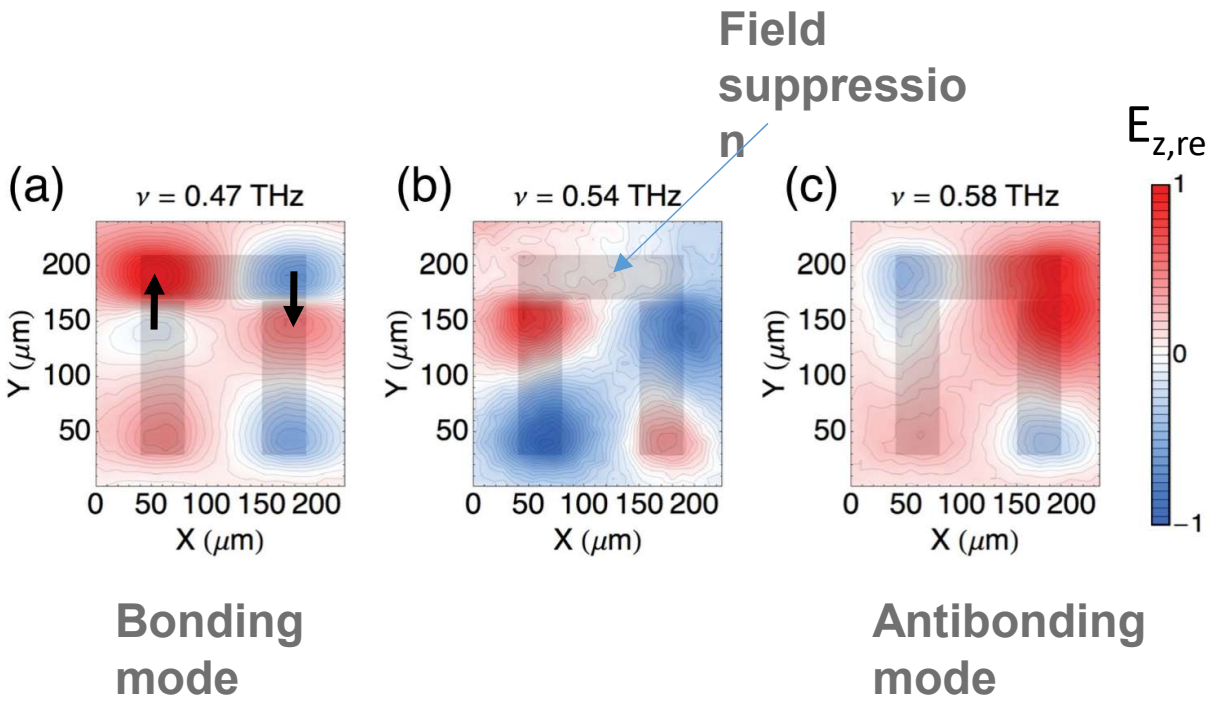
Measured with TeraSpike microprobe



Metamaterial characterization

Measured with TeraSpike microprobe



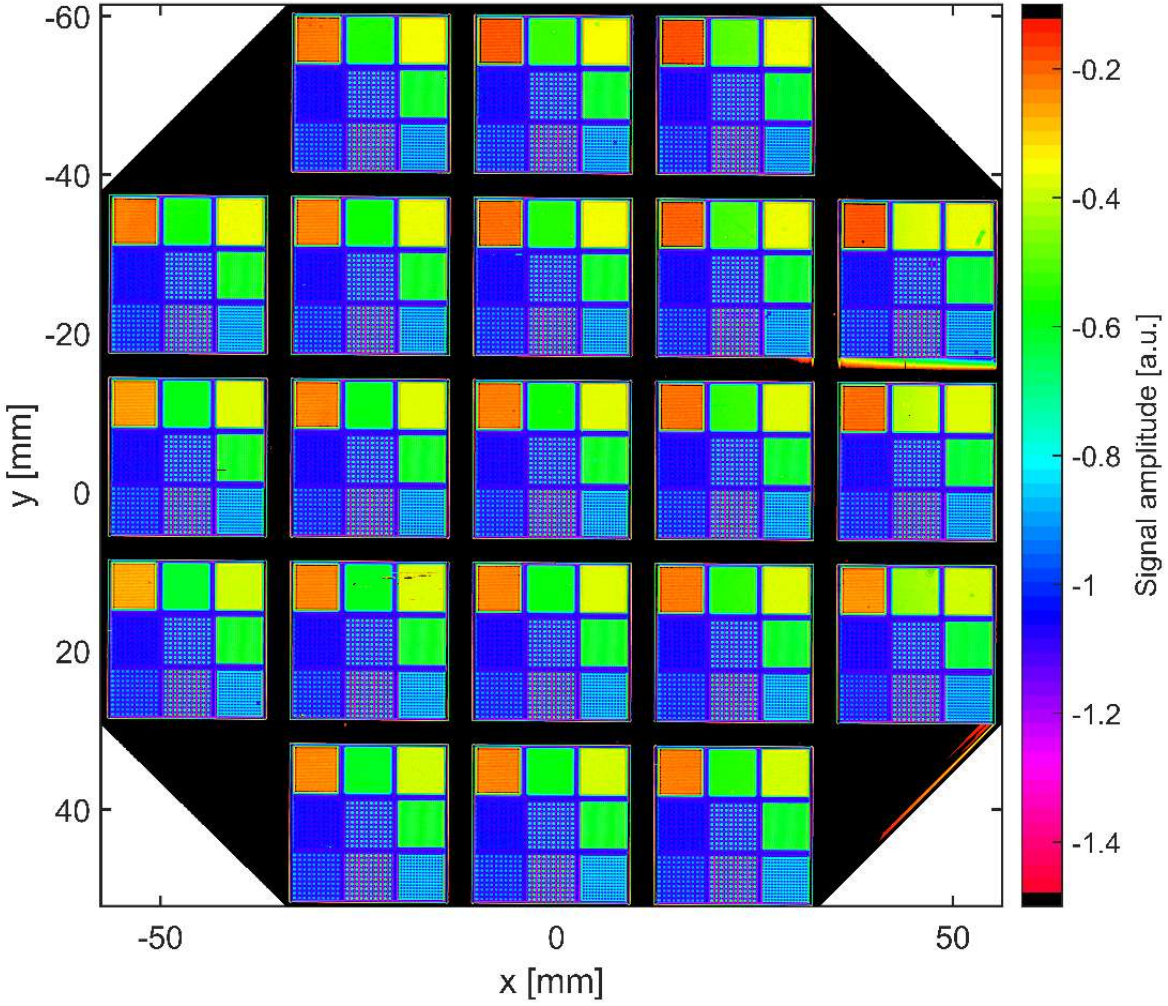


Visualizing near-field coupling in terahertz dolmens
A. Halpin, C. Mennes, A. Bhattacharya, and J. Gómez Rivas
Appl. Phys. Lett. 110, 101105 (2017)

DIFFER
Dutch Institute for Fundamental Energy Research

Metamaterial characterization

Measured with TeraSpike microprobe

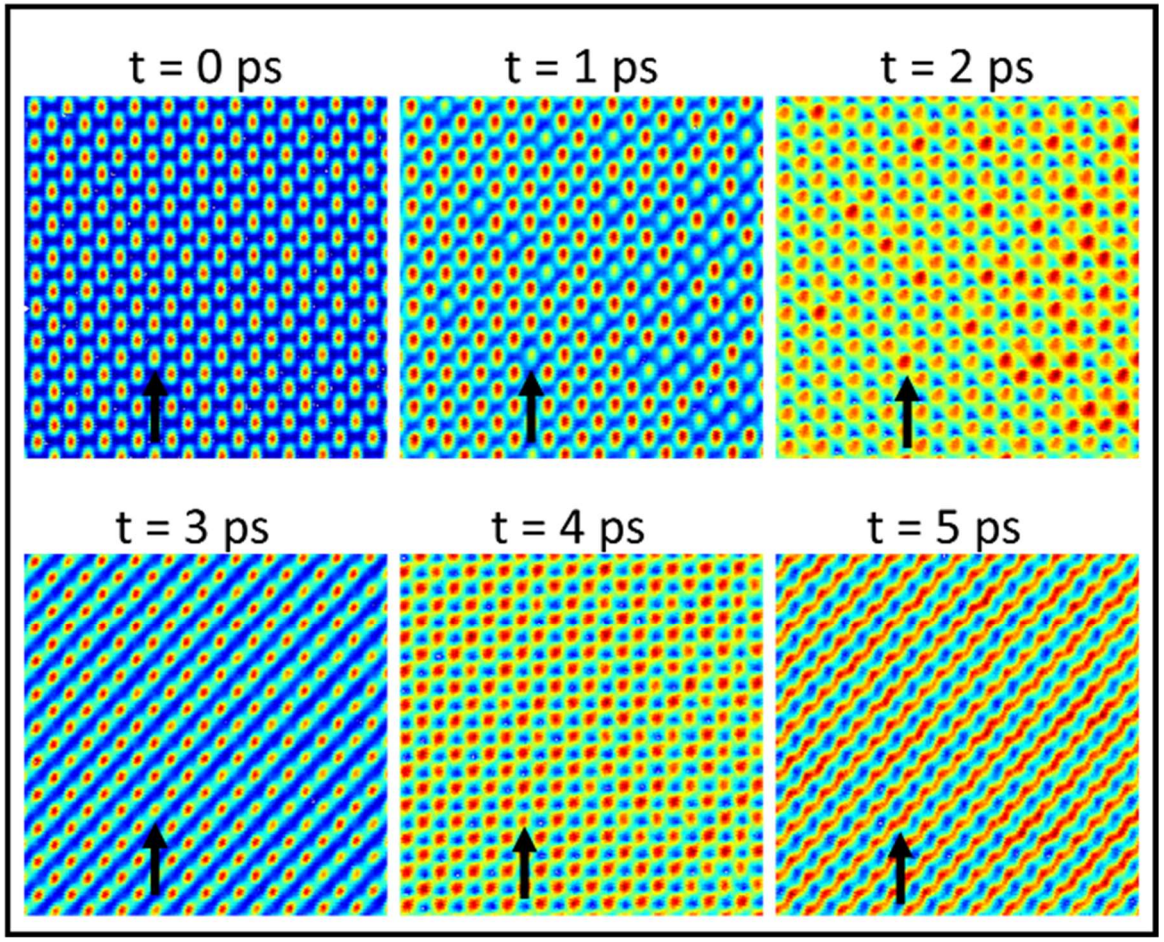


85000 resonators

THz structure characterization

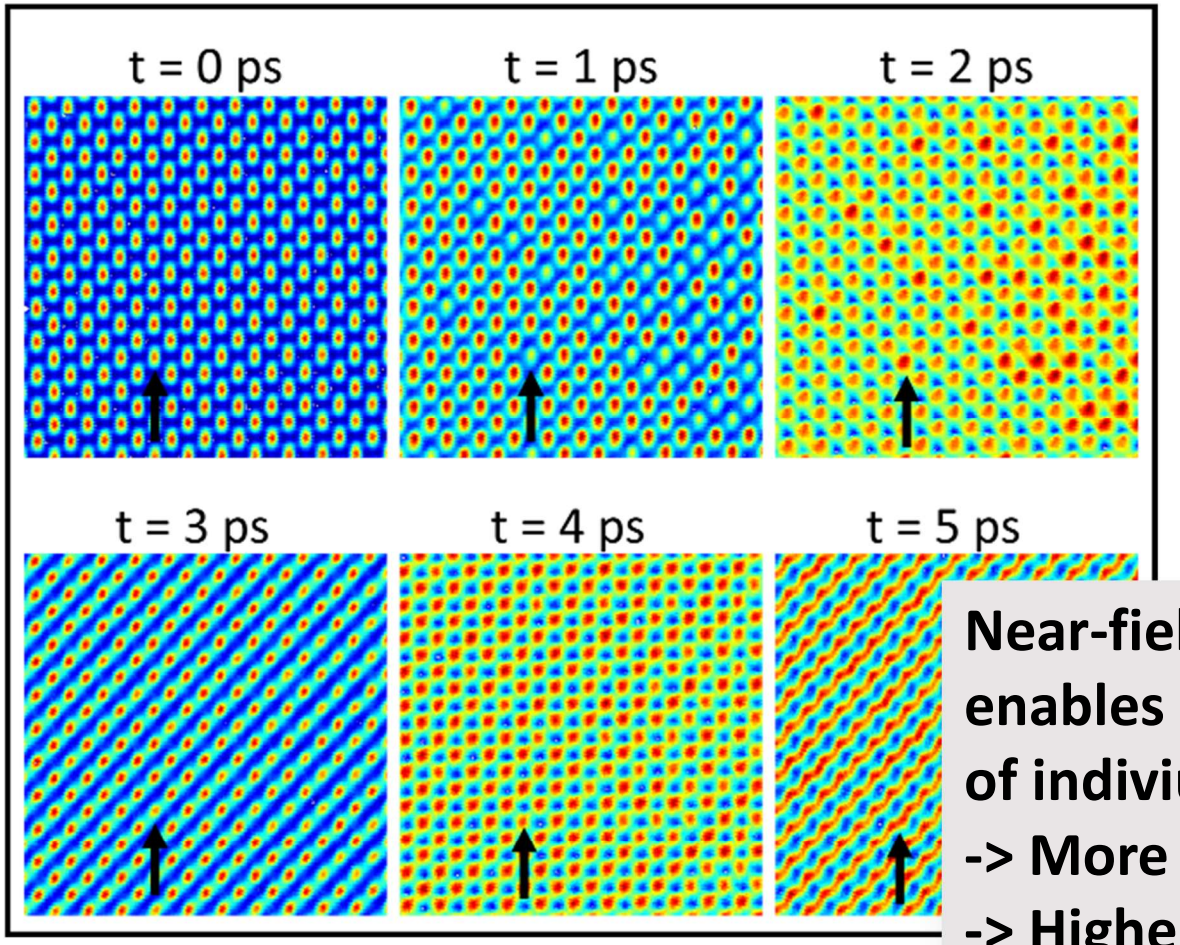
Measured with TeraSpike microprobe

Resonator
covered with
a dielectric layer



THz structure characterization

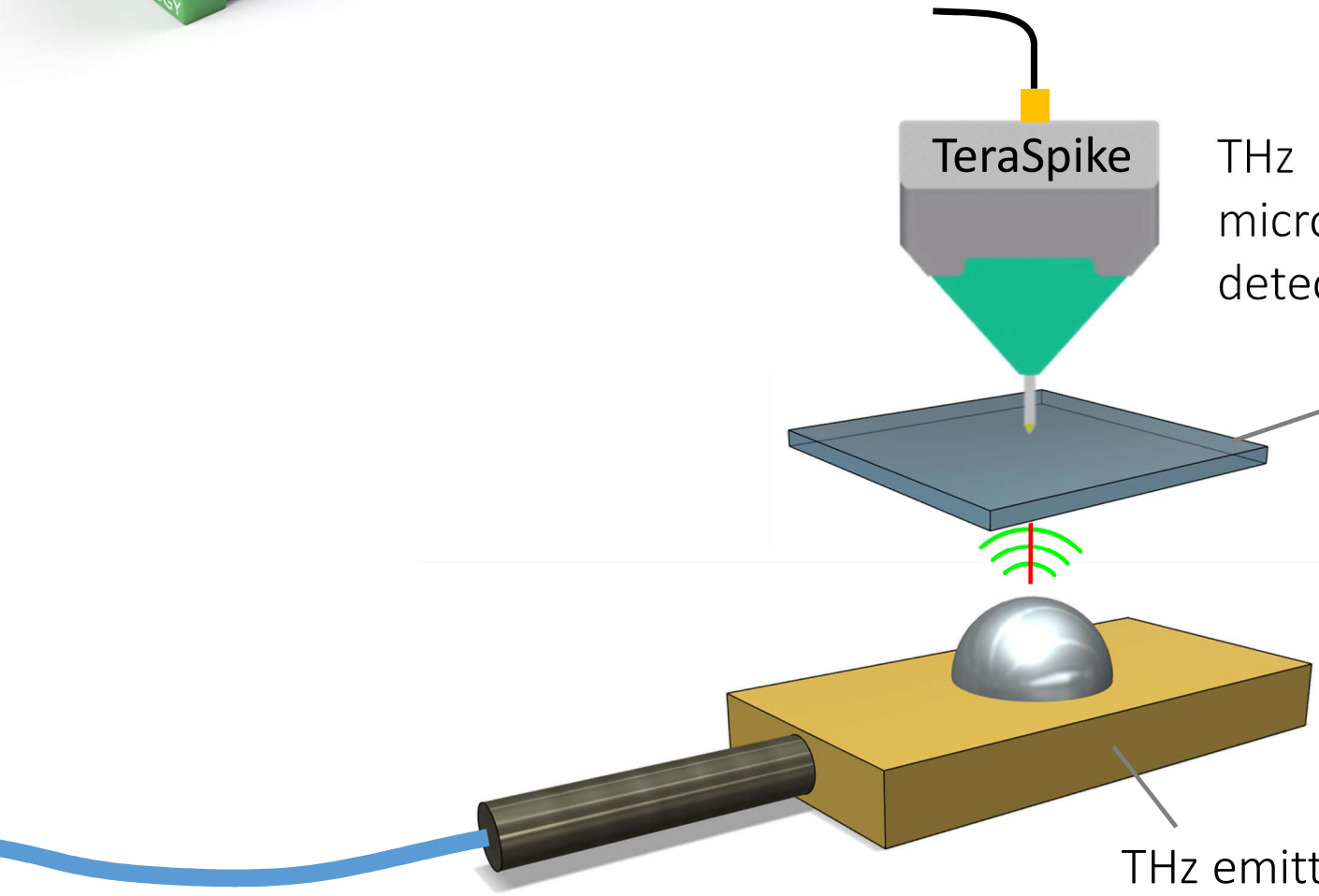
Measured with TeraSpike microprobe



Near-field detection enables single read-out of indiviual resonators.
-> More information
-> Higher sensitivity

THz structure characterization

Measured with TeraSpike microprobe



Transmitted THz field

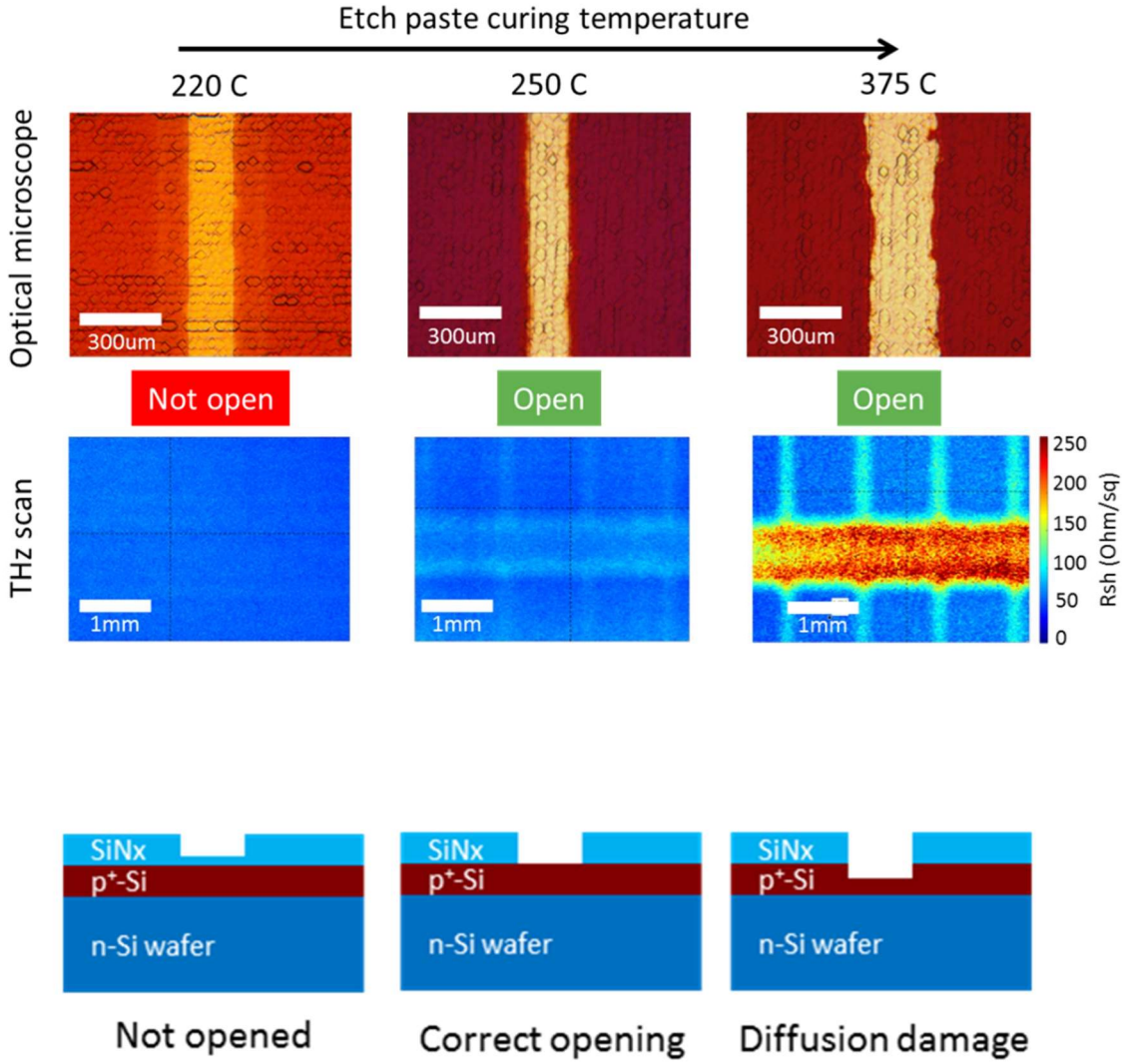
Material Properties:
Sheet resistance

Dielectric layer opening control on doped Si surfaces

Non-destructive Solar cell process inspection

Measured by:

ECN



Dielectric layer opening control on doped Si surfaces

Non-destructive Solar cell process inspection

Measured by:

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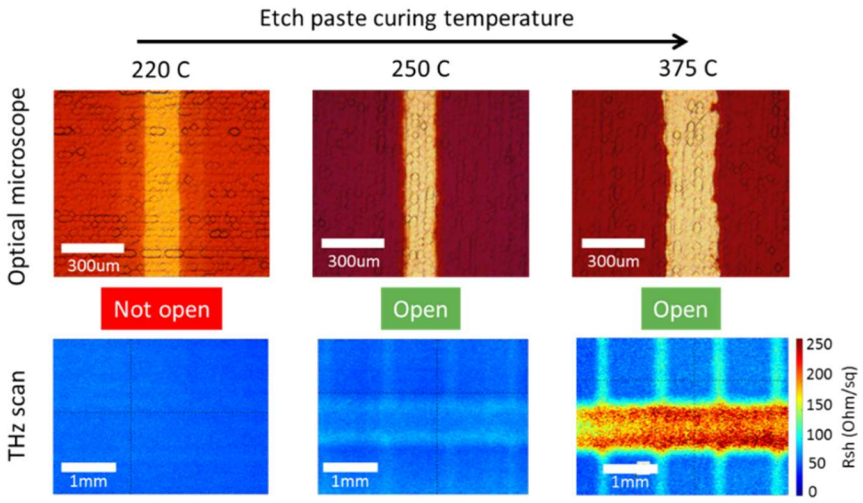


Conclusion:

The THz NF sensor is the **first tool** offering the required

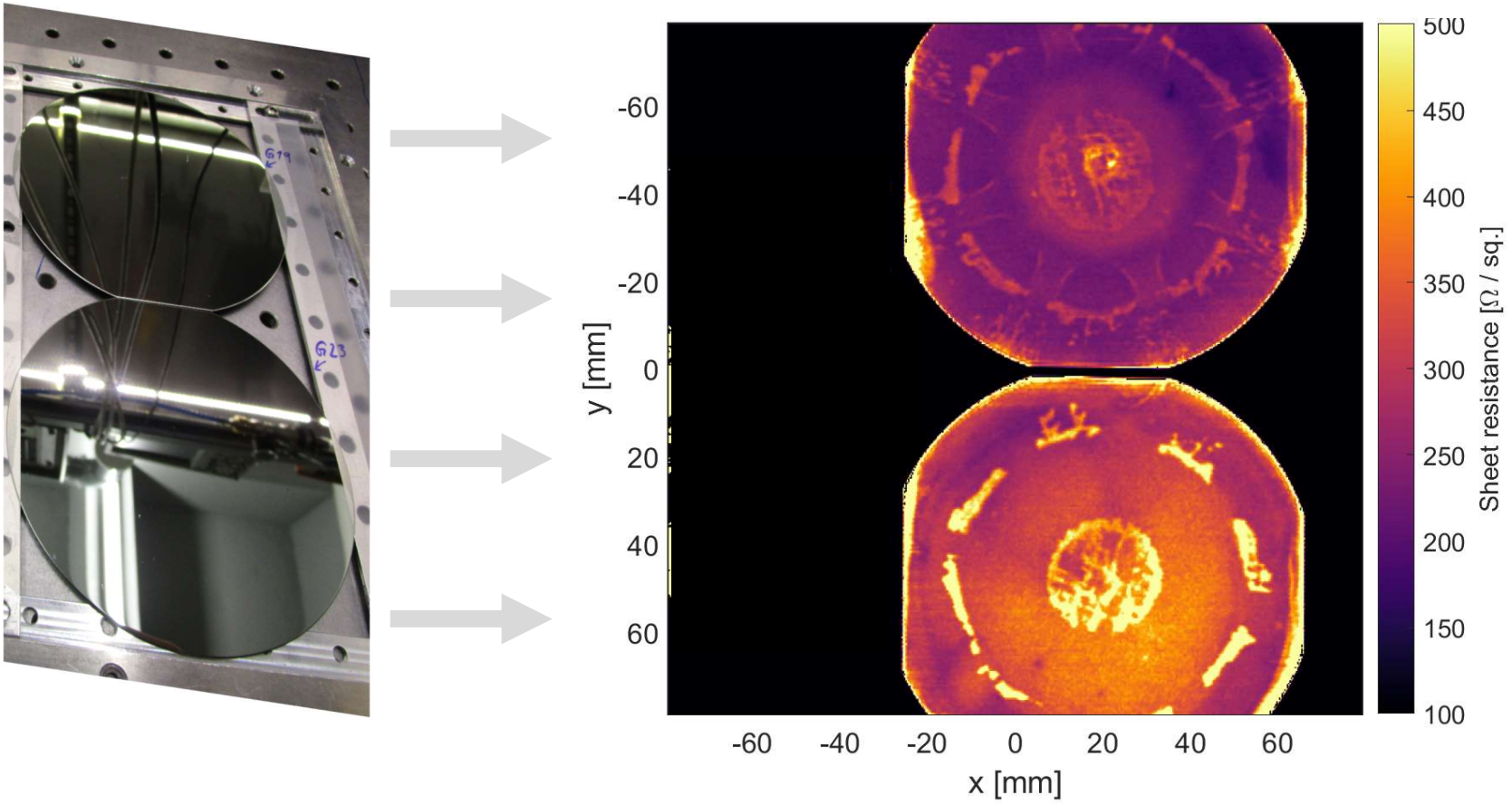
- **spatial resolution**
- **large area access**
- **and selectivity to doping layer.**

The THz microprobe can also reveal:

- **Sheet resistance, Carrier mobility**
- **Photoconductivity, Carrier lifetime**

Graphene on Germanium-Wafers

Sheet resistance imaging

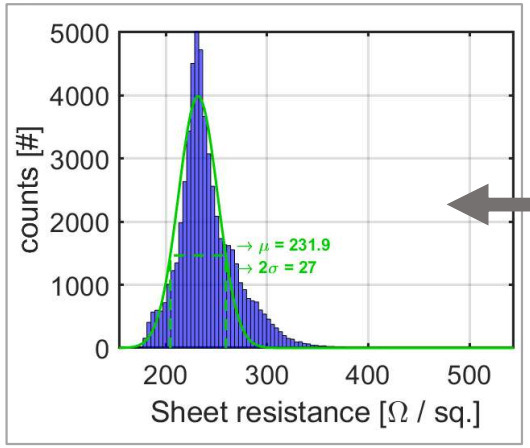


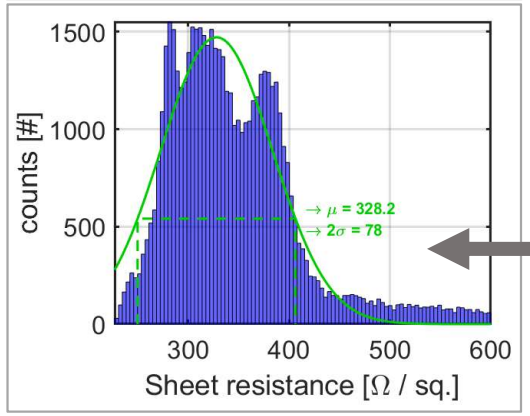
Wafers courtesy of:

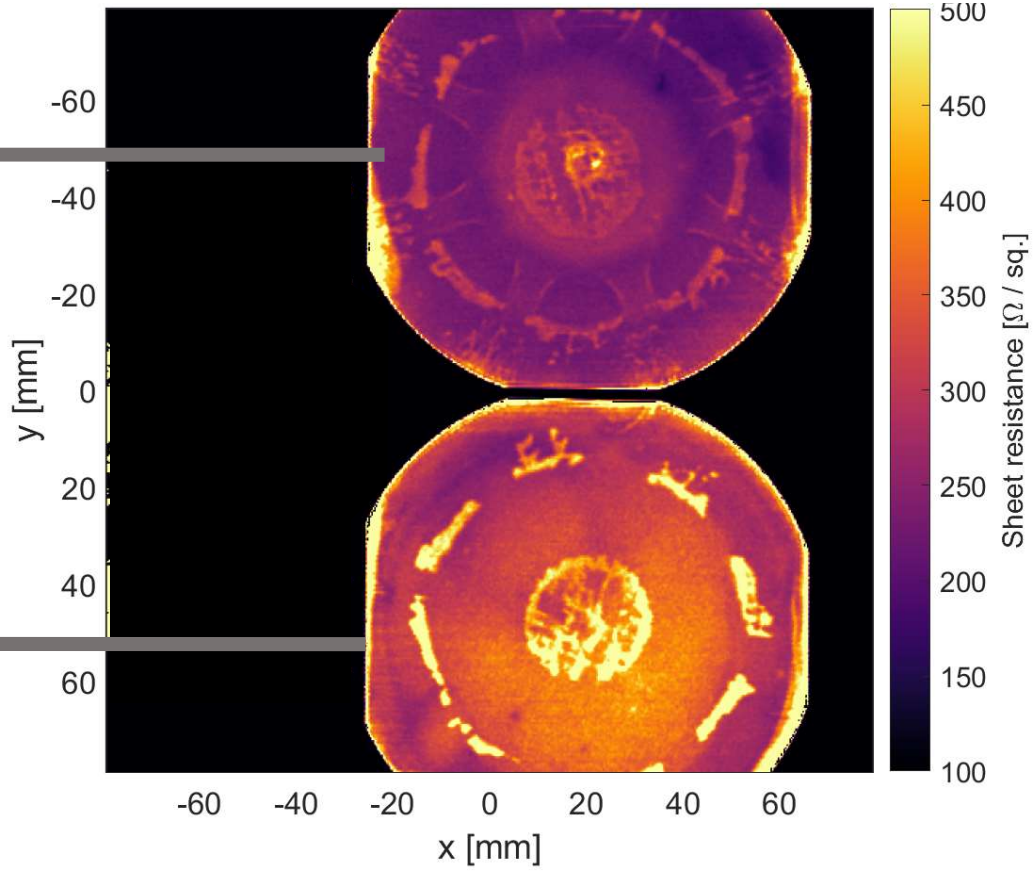
Microelectronics Research Center
THE UNIVERSITY OF TEXAS AT AUSTIN

Graphene on Germanium-Wafers

Sheet resistance imaging





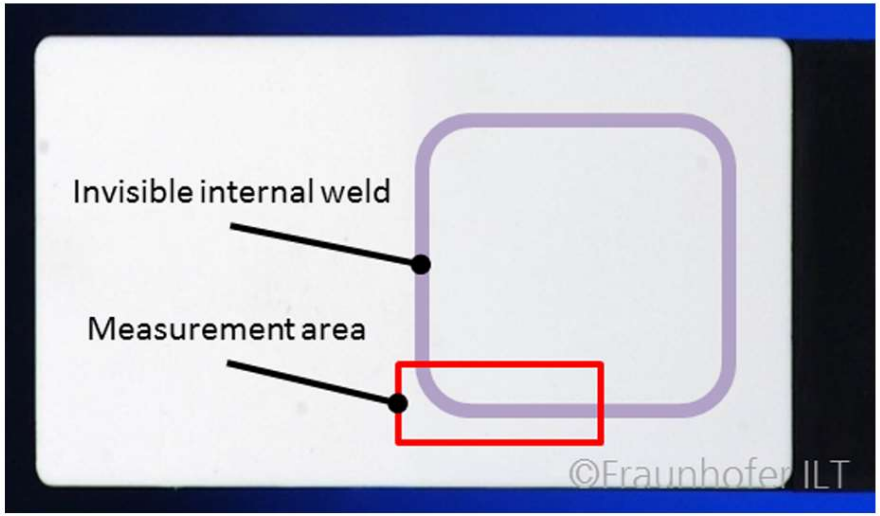


Wafers courtesy of:

Microelectronics Research Center
THE UNIVERSITY OF TEXAS AT AUSTIN

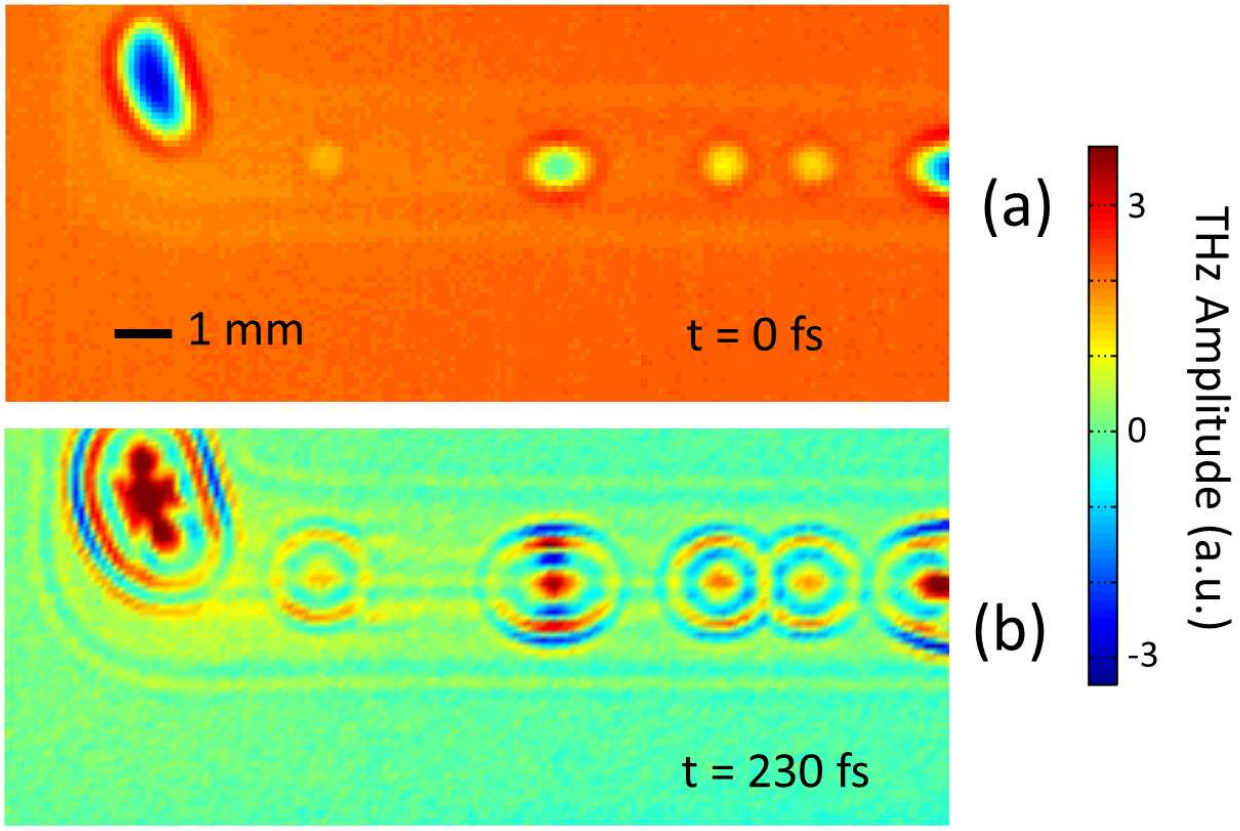
Non-destructive testing

Laser plastic weld inspection



THz microprobing is especially important for plastics which cannot be inspected through light from other spectral ranges.

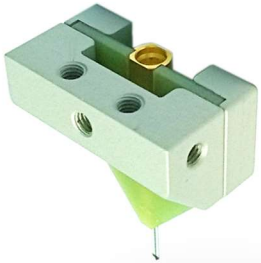
THz microprobe measurement data

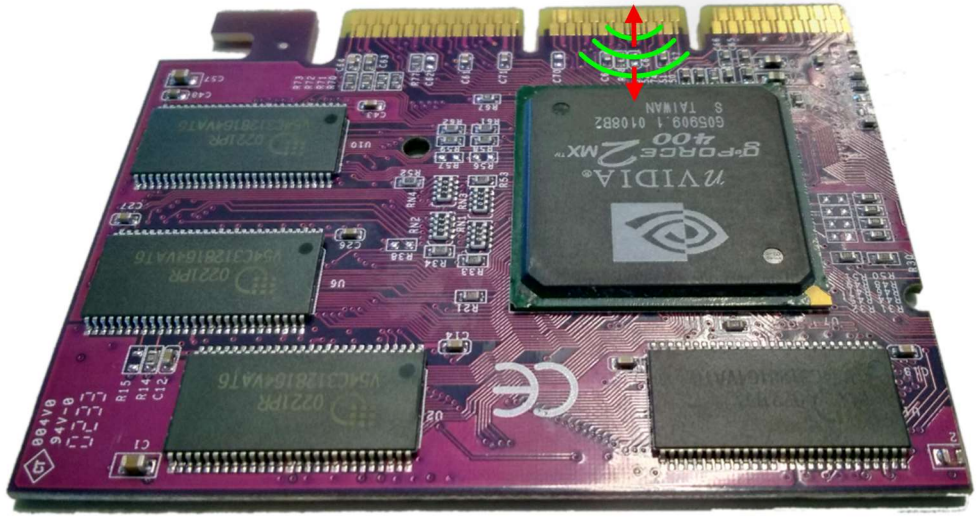


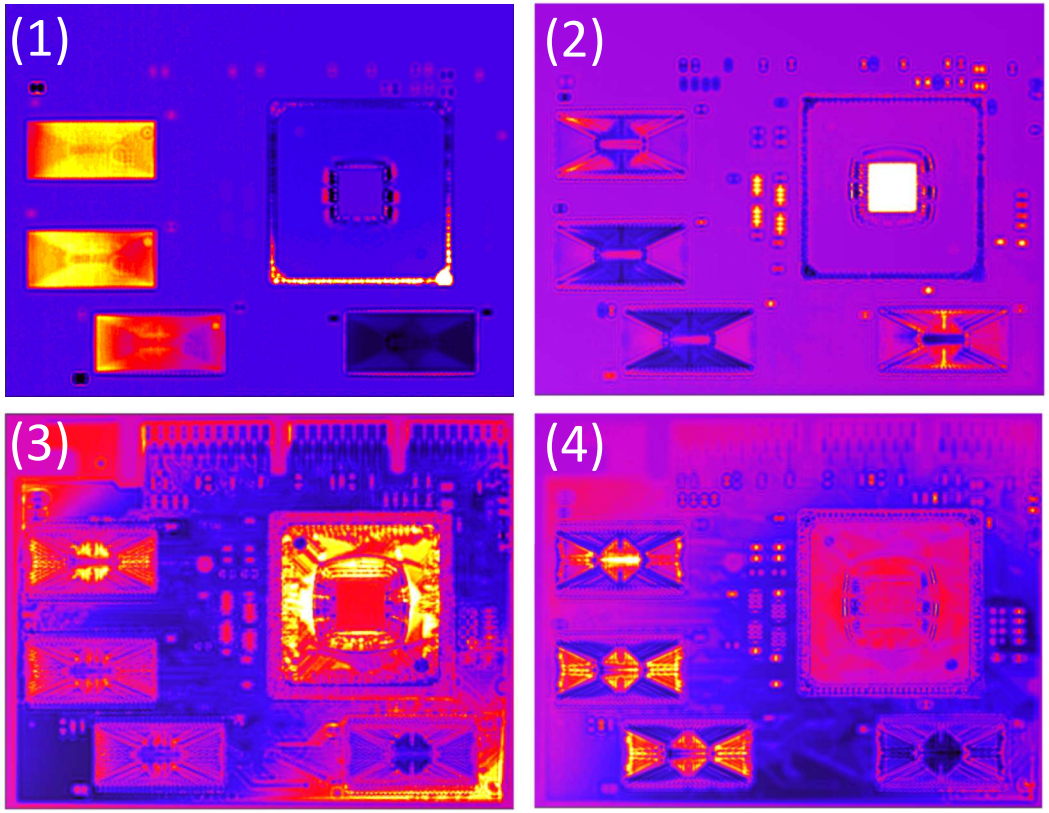
Non-destructive testing

Chip package inspection

Near-field transceiver microprobe



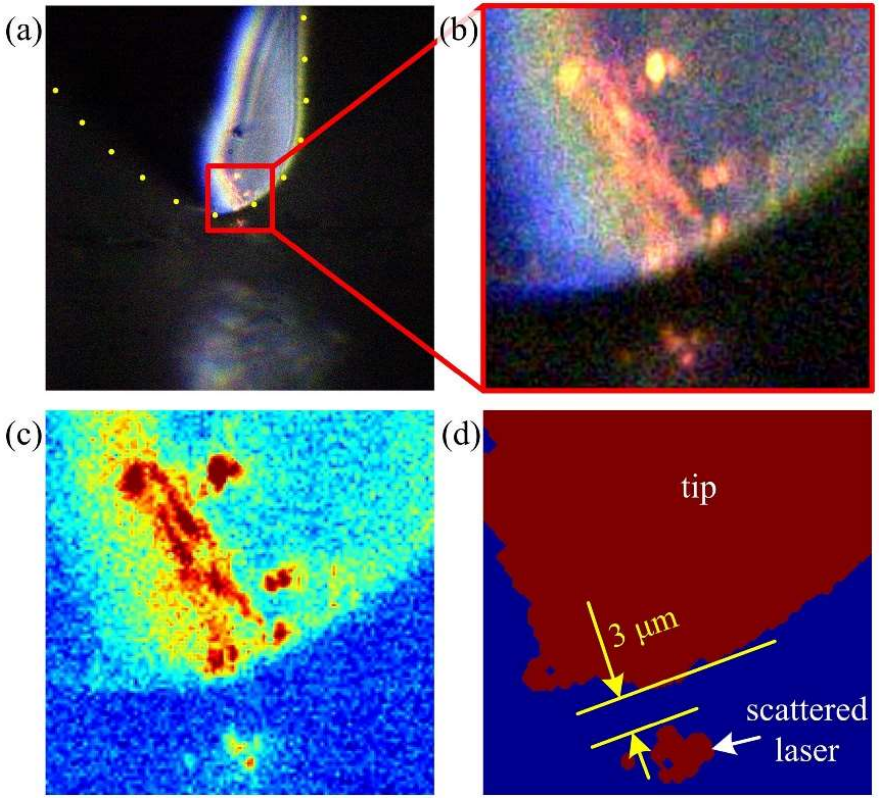




THz images corresponding to different depths

Biological applications

Imaging of brain tissue



BIOTECHNOLOGY PROGRESS

Society for Biological Engineering

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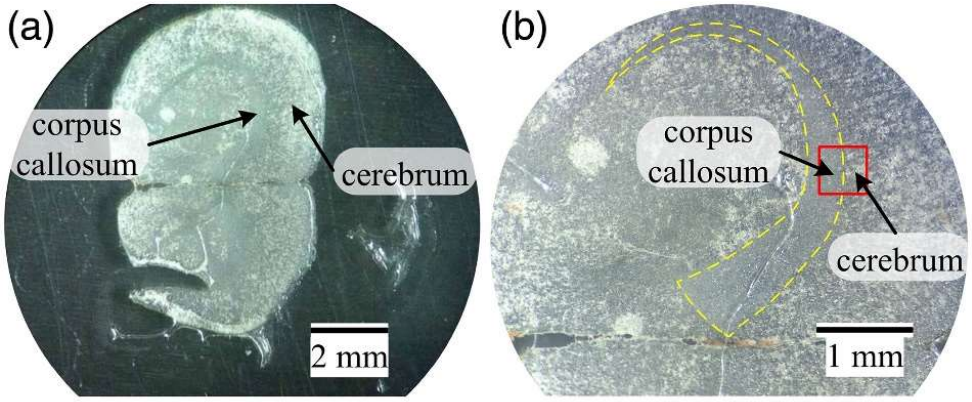
RESEARCH ARTICLE | Full Access

Imaging brain tissue slices with terahertz near-field microscopy

Guoshuai Geng, Guangbin Dai, Dandan Li, Shengling Zhou, Zaoxia Li, Zhongbo Yang, Yuehong Xu, Jiaguang Han, Tianying Chang, Hong-Liang Cui, Huabin Wang

First published: 10 November 2018 | https://doi.org/10.1002/btpr.2741 | Citations: 1



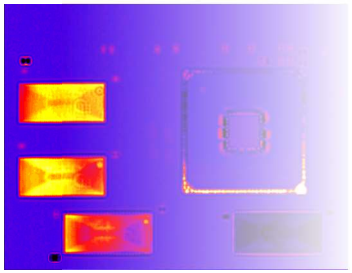
Conclusion

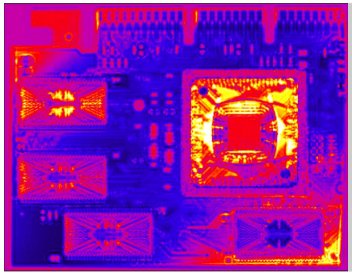
Terahertz microprobe technology …

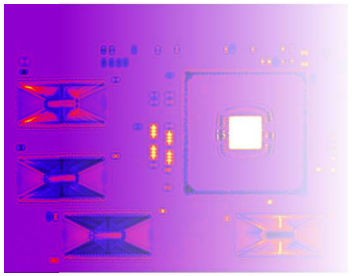
- … is going **beyond the capabilities** of standard (free-space) Terahertz inspection.

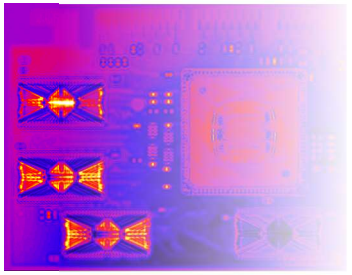
- … enables Terahertz-based **non-destructive** **contact-free** inspection
  - at **micron-scale** resolution,
  - on **large wafer-scale areas** and
  - at **high measurement speeds**.

- … Near-field information is more information!









Terahertz Microprobe-enabled Near-Field Imaging for non-destructive testing applications

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Thank you for your attention!