

# Thermal Imaging-Based Failure Analysis System - TIFAS<sup>®</sup>

Non-destructive failure detection and quality assessment



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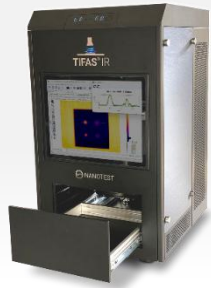
TIFAS | Thermal Imaging Failure Analysis System

Lab

## Pulse thermography

### TIFAS® IR lab

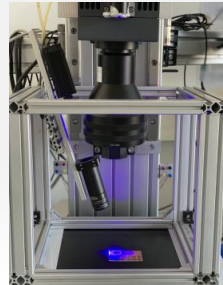
✦ Compact all-in-one benchtop pulse system



## Lock-in thermography

### TIFAS® LIT lab

✦ Compact all-in-one benchtop LIT system

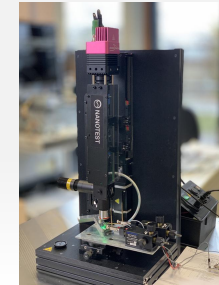


- ✦ LaserLIT
- ✦ E-LIT
- ✦ HaloLIT

## Thermoreflectance

### TIFAS® TR lab

✦ Compact all-in-one benchtop TR system



Inline

### TIFAS® IR inline

✦ Pulse system for production lines



### TIFAS® LIT inline

✦ Lock-in system for production lines



Mobile

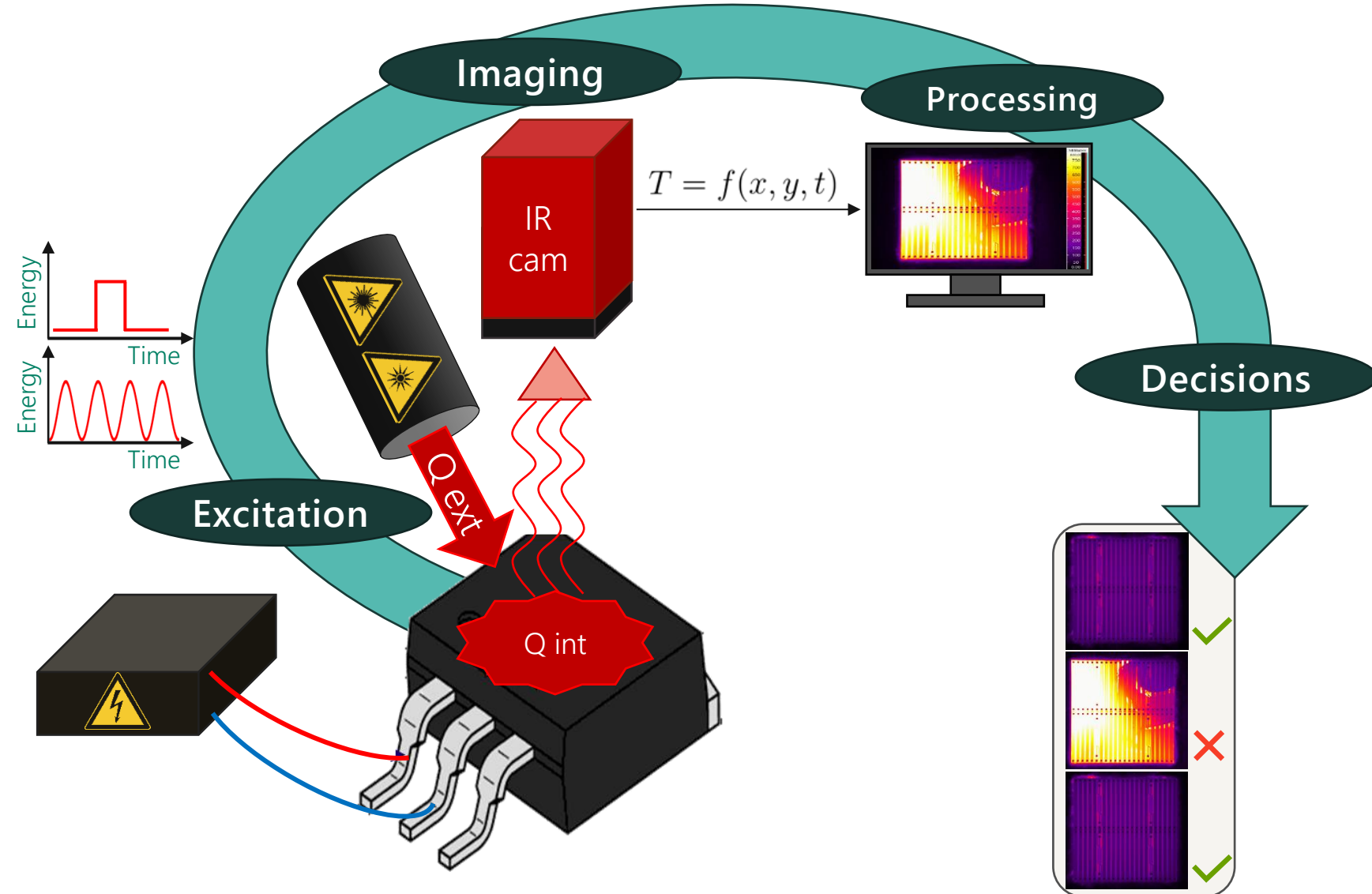
### TIFAS® IR mobile

✦ Mobile IR pulse system



## Process

- The basic principle is to heat the sample to be examined with a thermal excitation source (light, laser, electrical current).
- Thermal excitation can be carried out with a pulse or periodically.
- The resulting thermal contrast is detected by the IR camera.
- Recording oscillation temperature field using IR camera.
- The temperature images can be analysed using special software.



## Pulse Thermography

### Principle

- » Pulsed thermal excitation
- » Heat diffusion through specimen
- » Defects are barriers in heat path
- » Heat accumulations above defects
- » Result: sequence of IR images

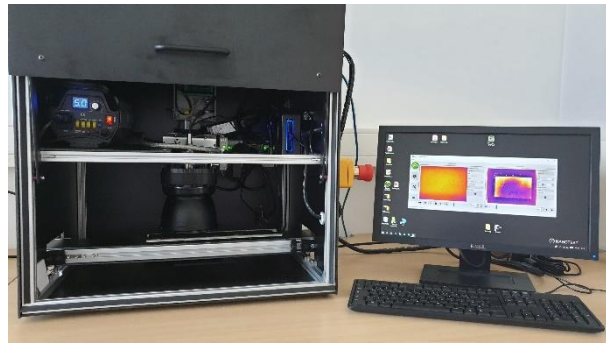
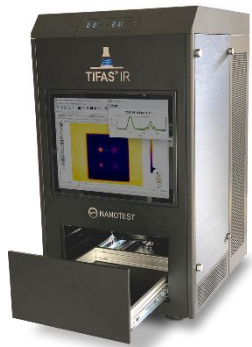
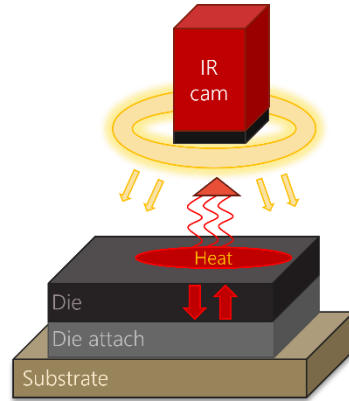
### Excitation Sources

- ★ Flash lamps
- ★ Joule Heating

### Features

- ★ Measurement time: <1 s ... 5 s
- ★ Pulse phase thermography
- ★ Thermal signal reconstruction

Fast



## Lock-in Thermography

### Principle

- » Modulated thermal excitation
- » Generation of thermal waves
- » Wave reflection on defects
- » Lock-in amplification of defect signals (reflected waves)
- » Result: amplitude and phase image

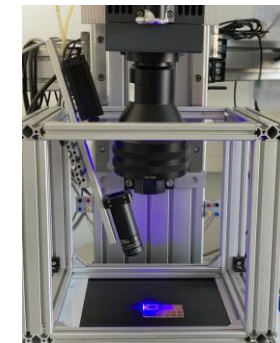
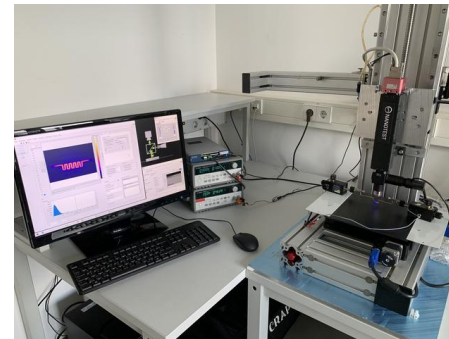
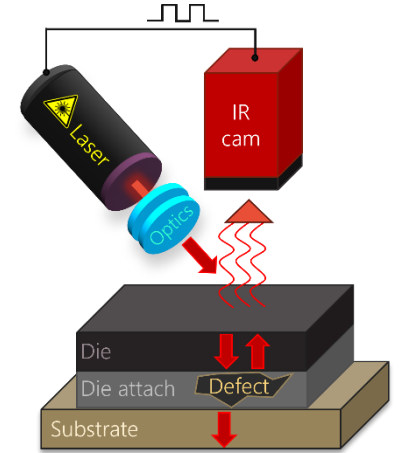
### Excitation Sources

- ★ Laser
- ★ Joule Heating
- ★ Eddy Current
- ★ LED/Halogen lamps

### Features

- ★ Measurement time: 1 s ... > 10 min
- ★ Depth resolution by frequency selection
- ★ Superior sensitivity due to lock-in amplification
- ★ Infrared based but also thermoreflectance based

Sensitive

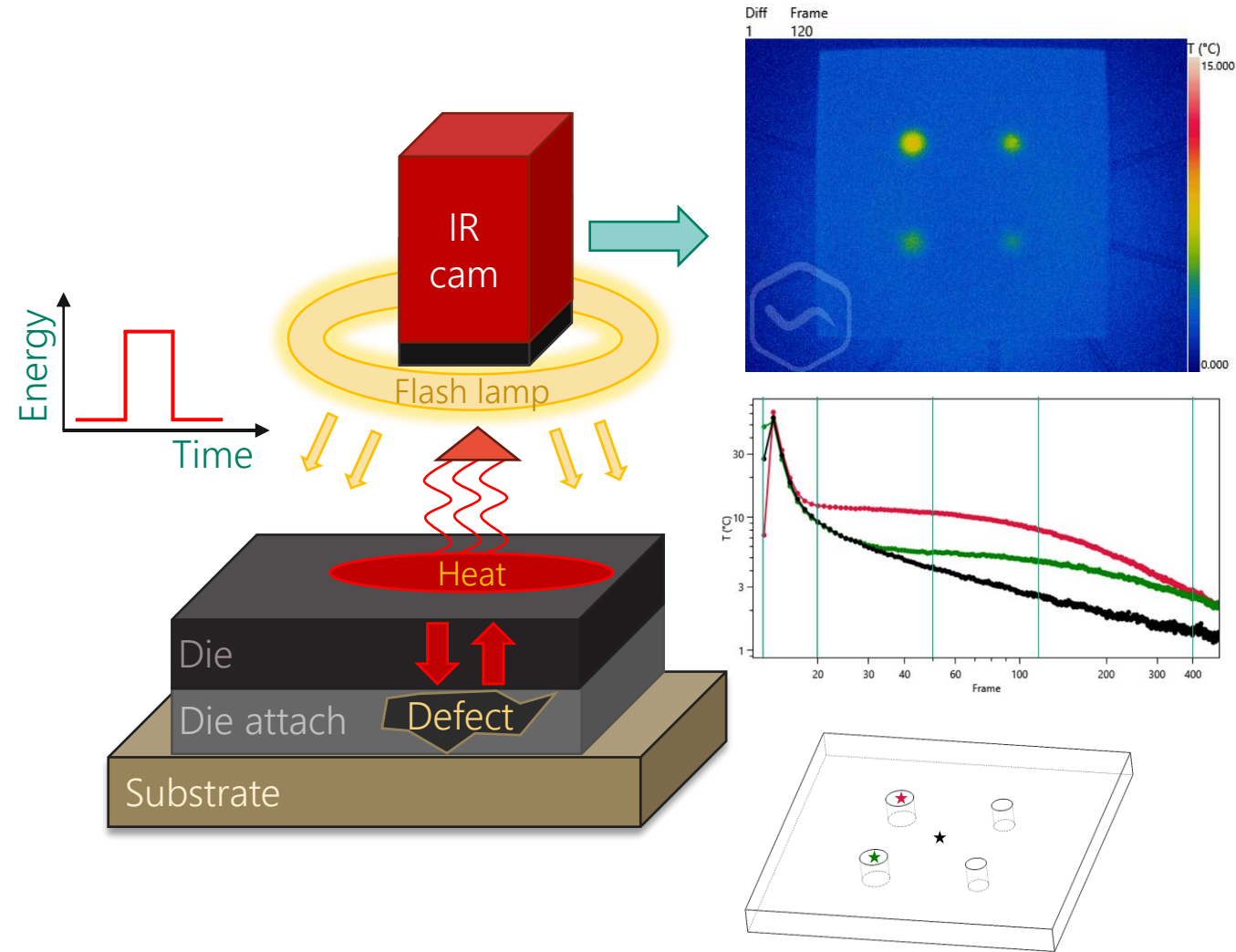


# TIFAS<sup>®</sup> IR

Thermal imaging failure analysis using pulse thermography

## Measurement principle

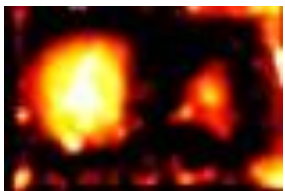
- » Pulse excitation with a flash lamp.
- » Analysis of thermal propagation over time.
- » Heat propagation is influenced by defects or irregularities in the volume.
- » Recording oscillation temperature field using IR camera.
- » Heat progression can be displayed graphically.
- » Short testing times.



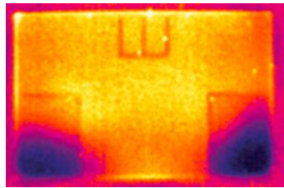
## Contactless failure analysis in a nutshell

### Features

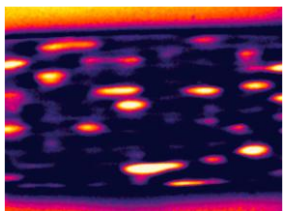
- » Complete pulsed infrared thermography-based failure analysis setup
- » Contactless and non-destructive
- » Short testing times, high throughput
- » Great variety of detectable defects
- » Comprehensive analysis software
- » Adaptable to special needs



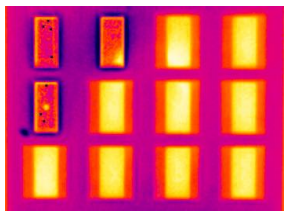
Voids in solder die attach layer



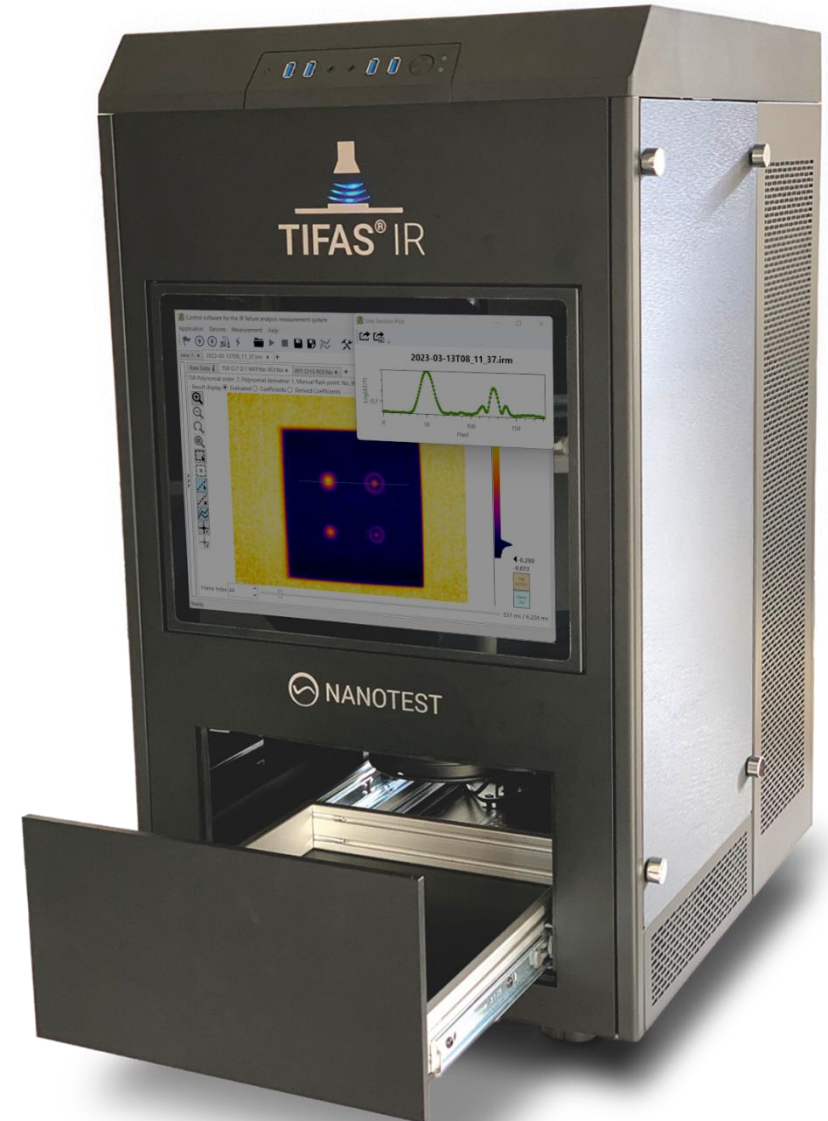
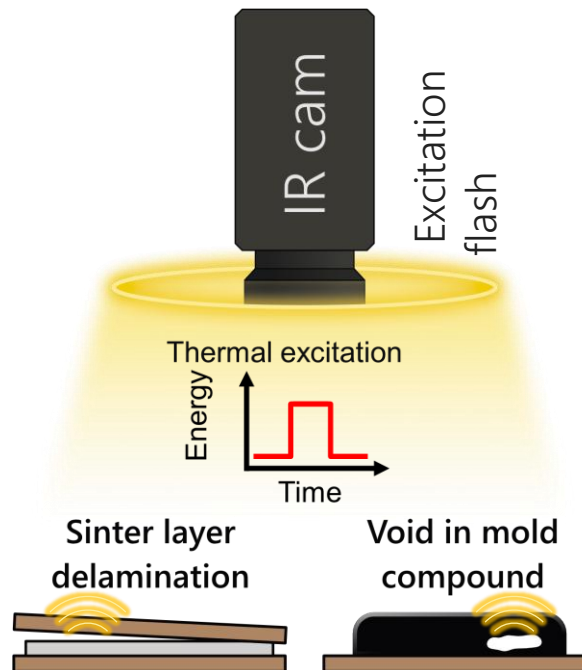
Delamination in sintered power module



Voids in carbon fiber reinforced polymer



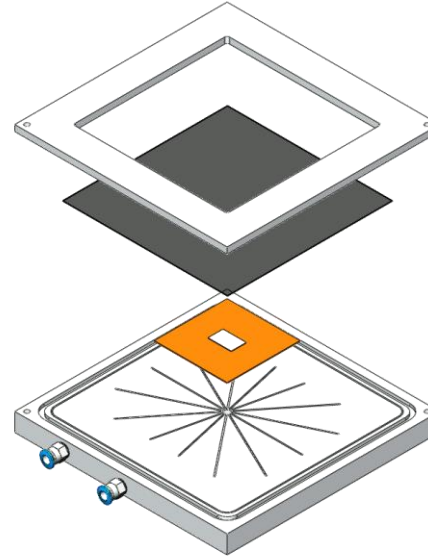
Voids in molding compound



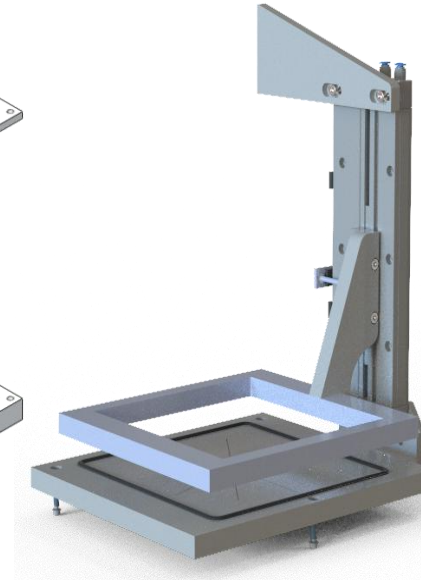
## Functionality

- » Temporary lamination of the specimen with a high-emissivity foil.
- » Reduce of reflection losses of the excitation power on metallic surfaces and increase emissivity of the specimen.
- » Temporary lamination of the specimen with a high emissivity foil.
- » Suitable thermal attachment between foil and specimen by vacuum.
- » Residue-free removal of foil after sample examination.
- » Fully integrated into TIFAS® IR lab system.
- » Two types of VacBlack® - foils: 50 µm & 30 µm thickness.

## Principle



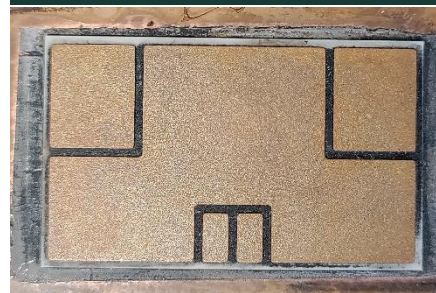
## Standard size



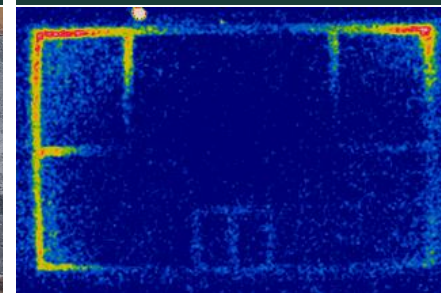
## Large size



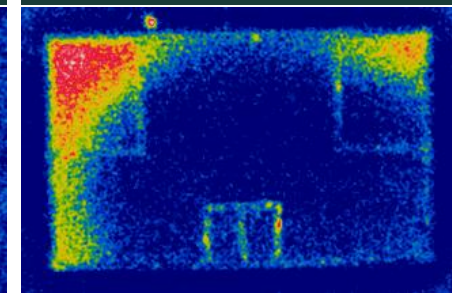
## Photo



## No foil



## With foil



# TIFAS<sup>®</sup> IR lab – Use cases

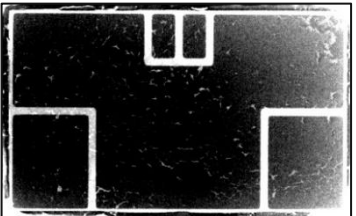
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Thermal imaging failure analysis system for lab-scale applications



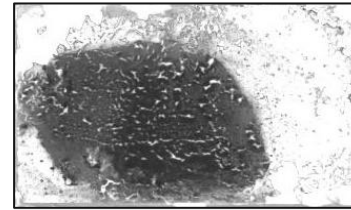
## Visual inspection

- Delamination between sinter layer and DCB
- Undetectable by visual inspection
- Further process steps are lost money
- **No failure found**



## X-ray techniques

- Fast
- Delamination almost not detectable
- High costs and safety requirements
- **Failure found (poor contrast)**



## Scanning acoustic microscopy

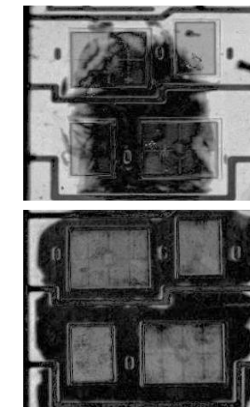
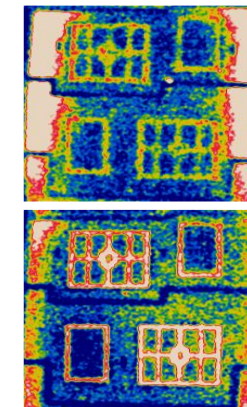
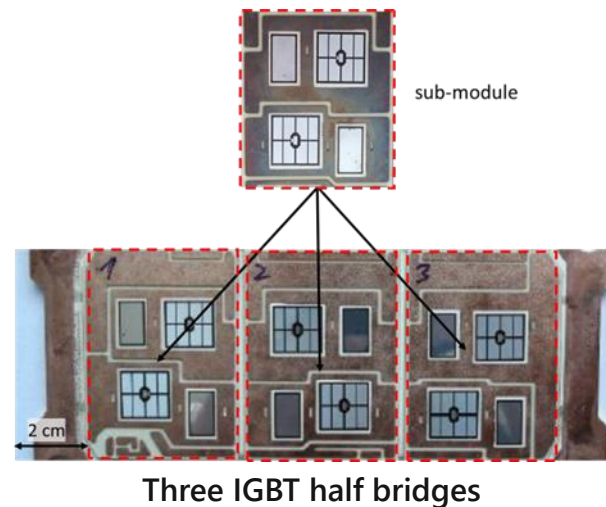
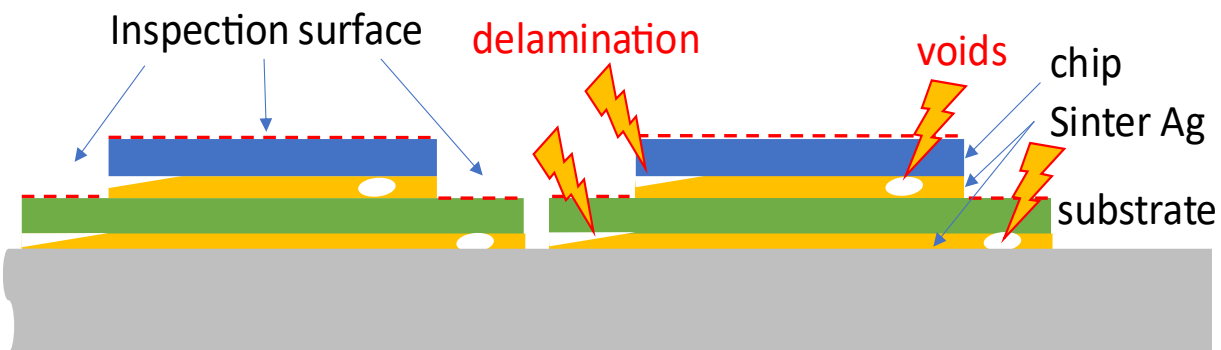
- Water needed as coupling medium
- Slow
- Moderate to high costs
- **Failure found**



## IR-thermographic techniques

- Fast and direct (thermal phenomena)
- Detection of voids and delamination
- Moderate costs
- **Failure found**

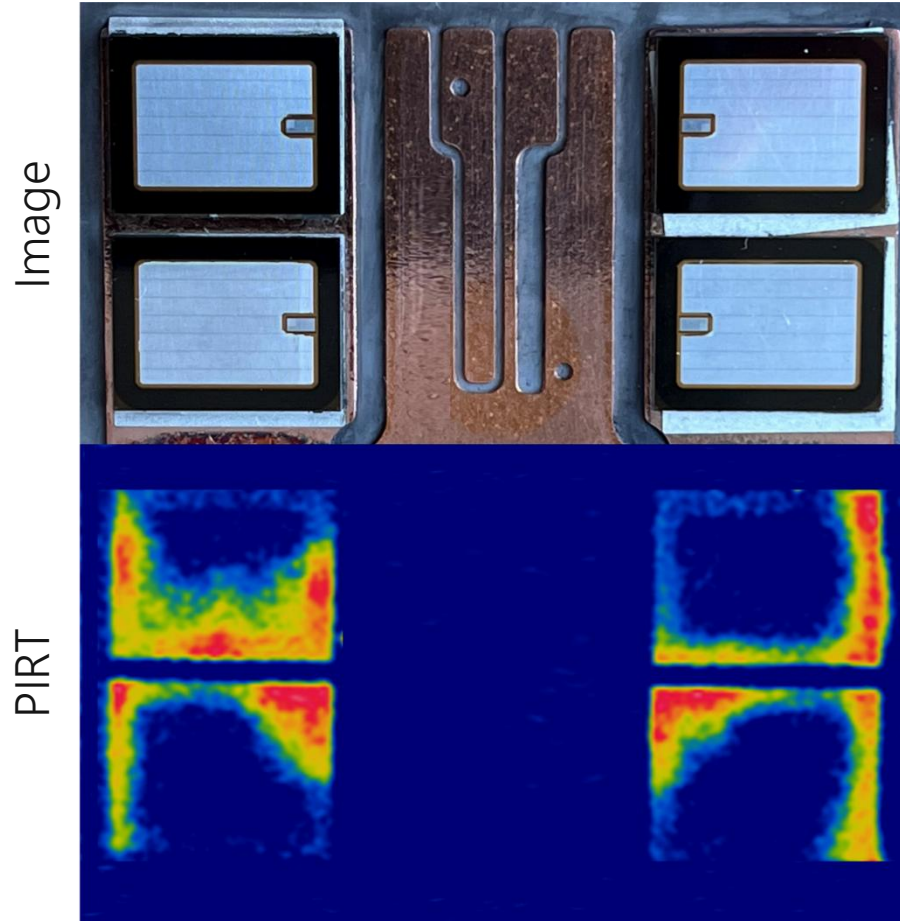
## Process monitoring silver-sintering of power modules



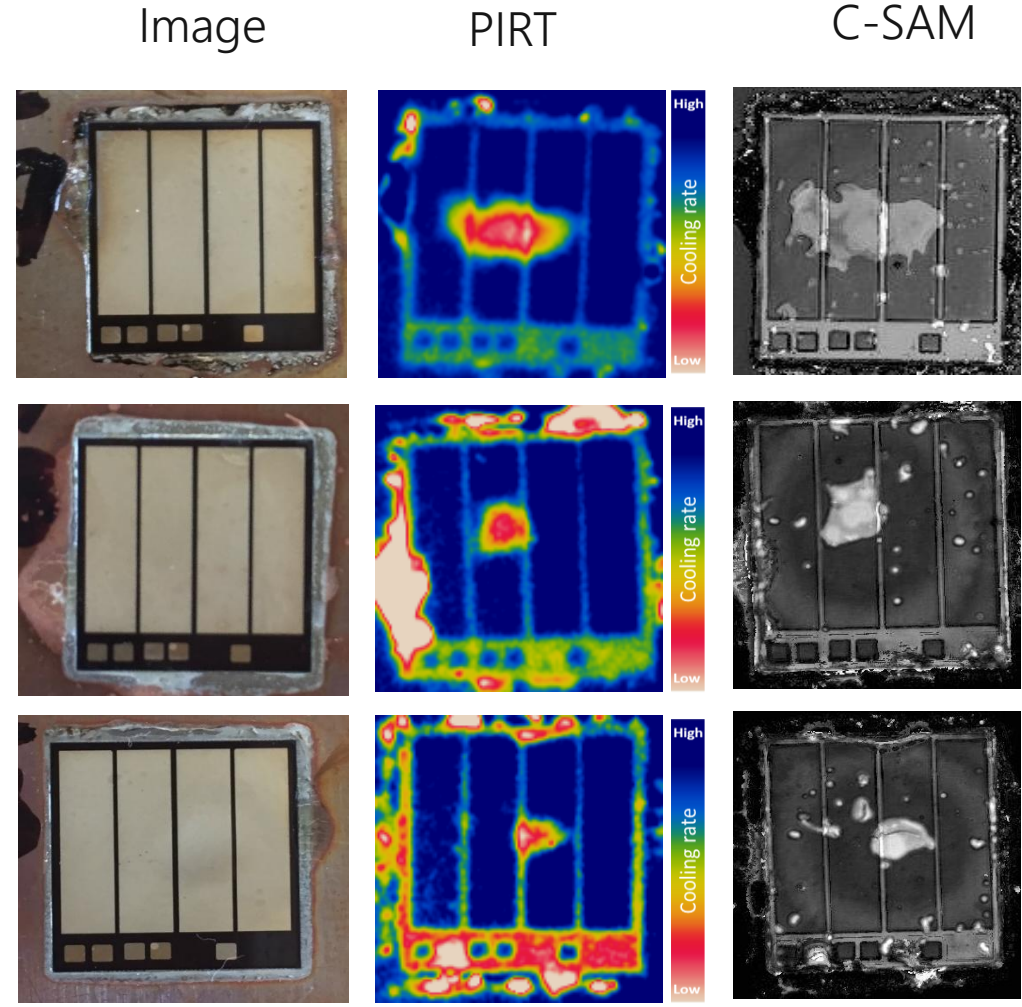
PIRT

C-SAM

- » Higher thermal conductivity and reliability of silver sinter layers  
→ replacement of the solder layer by sinter layer
- » Typical failures: delamination, voids
- » Analysis time: 700 ms / sub-module → Total analysis time 2.1 s

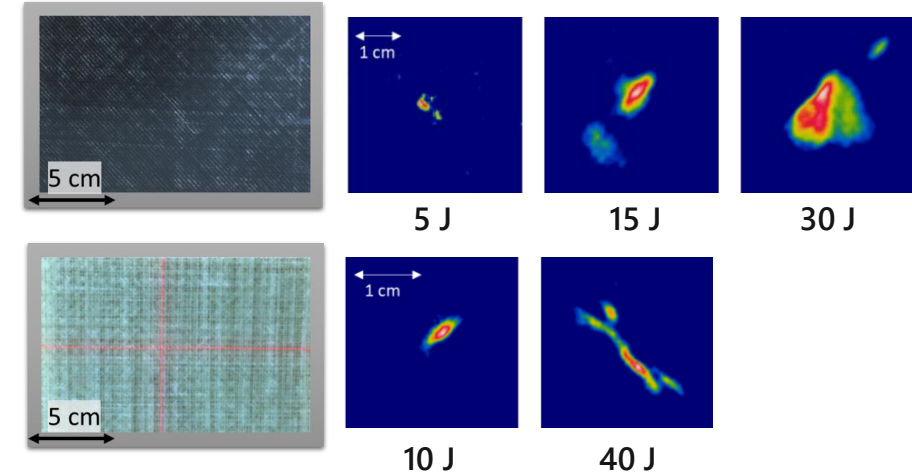
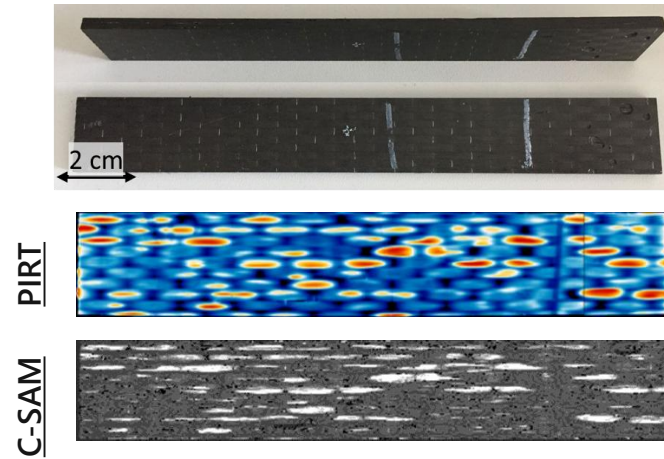
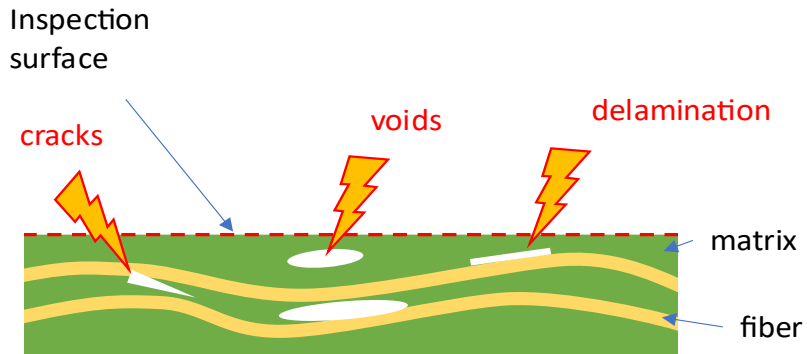


sintered



soldered

## Failure detection during the process and in field



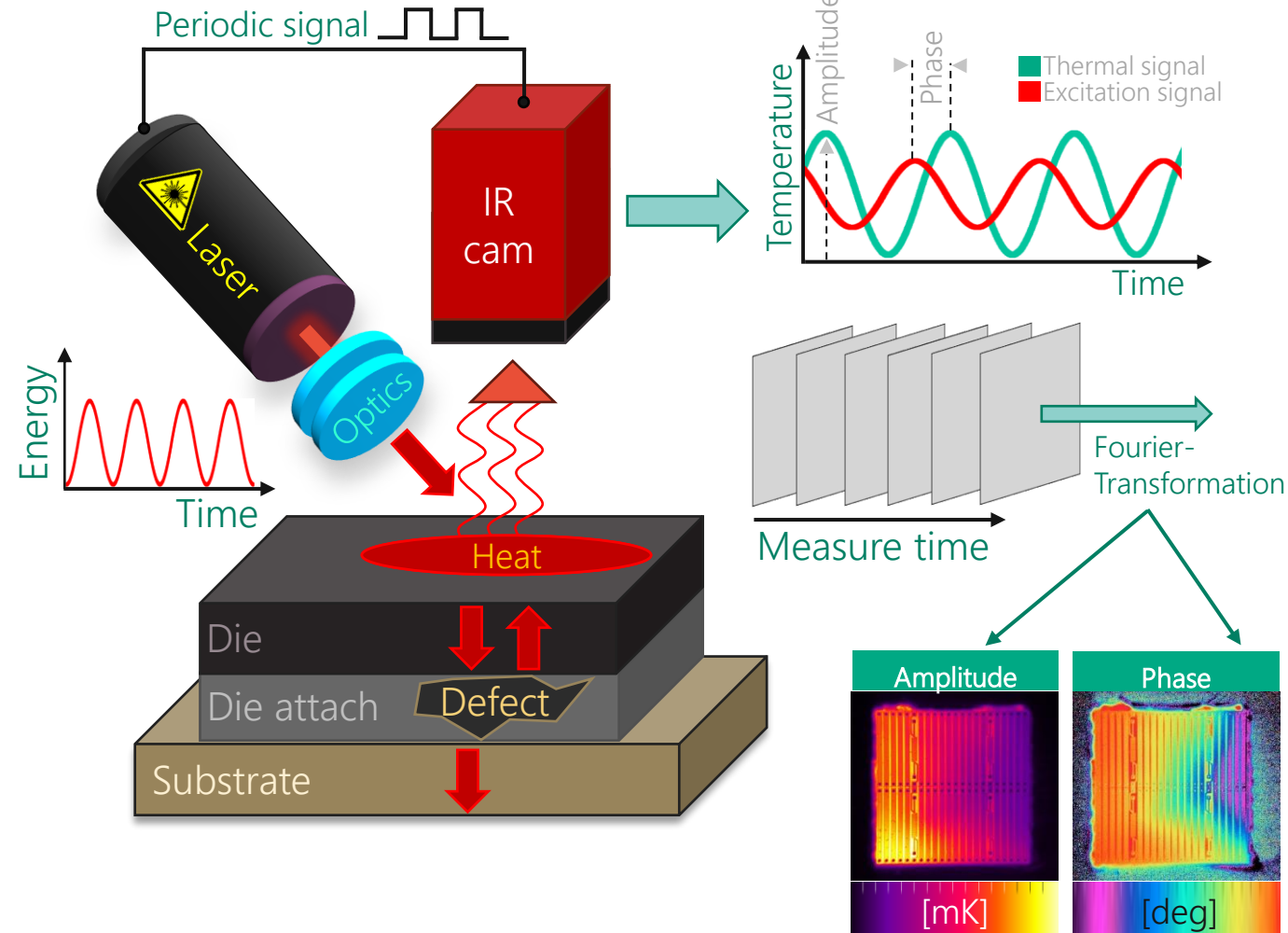
- » The mechanical integrity is crucial
  - » Defect detection during processing or in-field
  - » Analysis time
    - > measurement time  $\approx 1 \dots 10$  s
    - > subsequent postprocessing
- Total analysis time ca. 20 s

# TIFAS<sup>®</sup> LIT

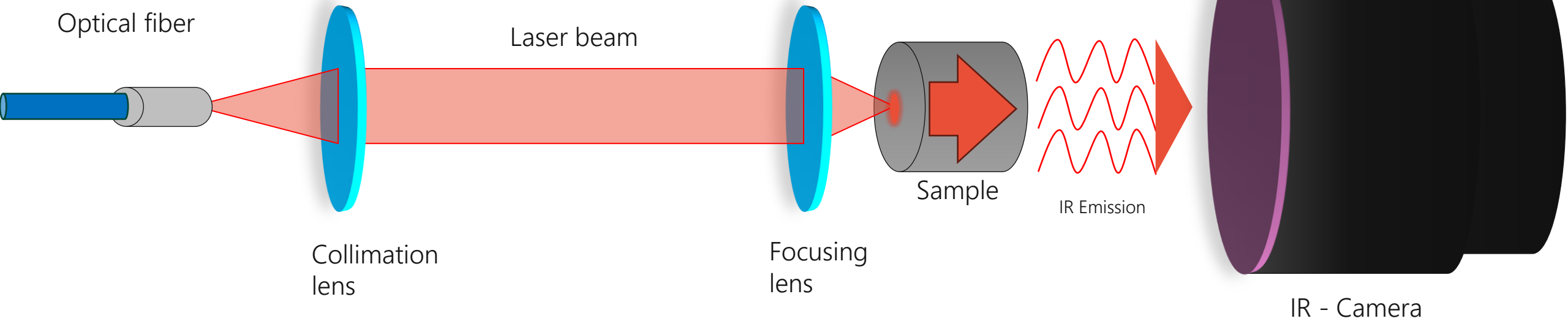
Thermal imaging failure analysis using lock-in thermography

## Measurement principle

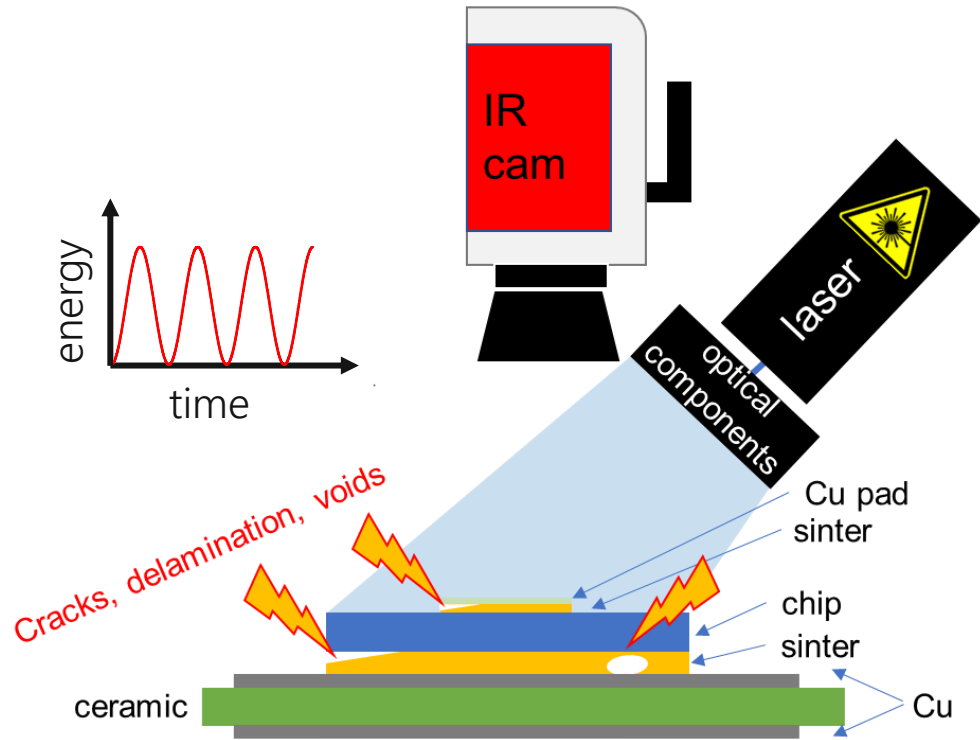
- » Active laser lock-in thermography (L-LIT).
- » Periodical thermal excitation with light.
- » Propagation of thermal waves through the device under test.
- » Wave reflection on interfaces/defects.
- » Recording oscillation temperature field using IR camera.
- » Lock-in amplification of signals.
- » Result: amplitude and phase images.
- » Complex image includes amplitude and phase information.
- » Lasers currently available:
  - »  $\lambda = 878 \text{ nm}$ , 45 W
  - »  $\lambda = 450 \text{ nm}$ , 12 W



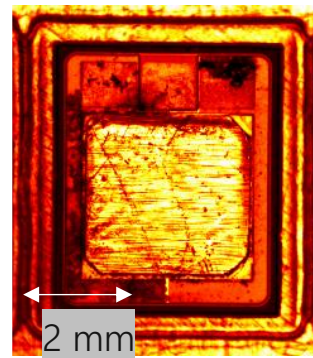
## Transmitted light setup for L-LIT



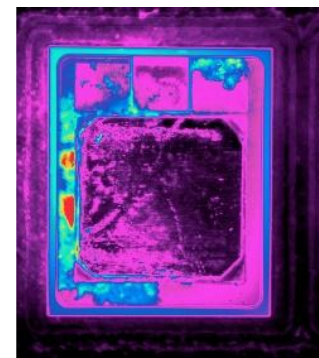
- » A modulated laser illuminates the rear side of the sample.
- » The laser wavelength is chosen to penetrate the material effectively.
- » Thermal waves are generated internally and propagate toward the front surface.
- » An IR camera captures the resulting thermal response from the front side.
- » Defects (e.g., voids or delamination) disturb heat flow, visible in phase and amplitude images.
- » Ideal for thin or semi-transparent materials or when using IR cameras with short working distances.



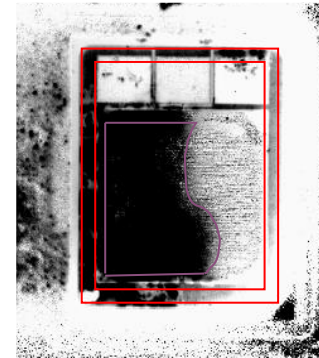
Live Image



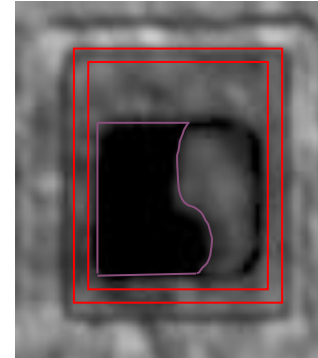
Amplitude Image



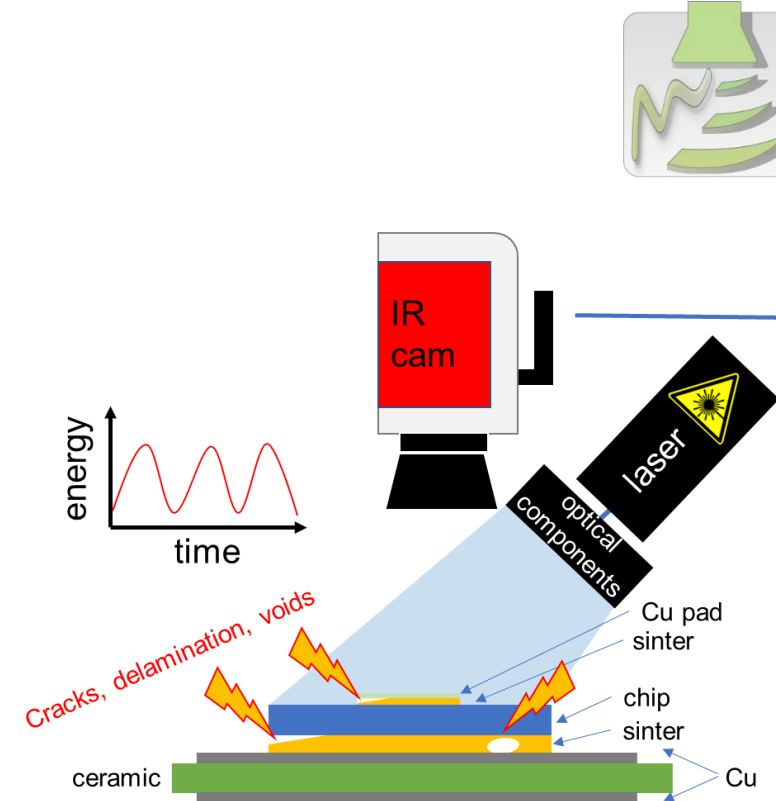
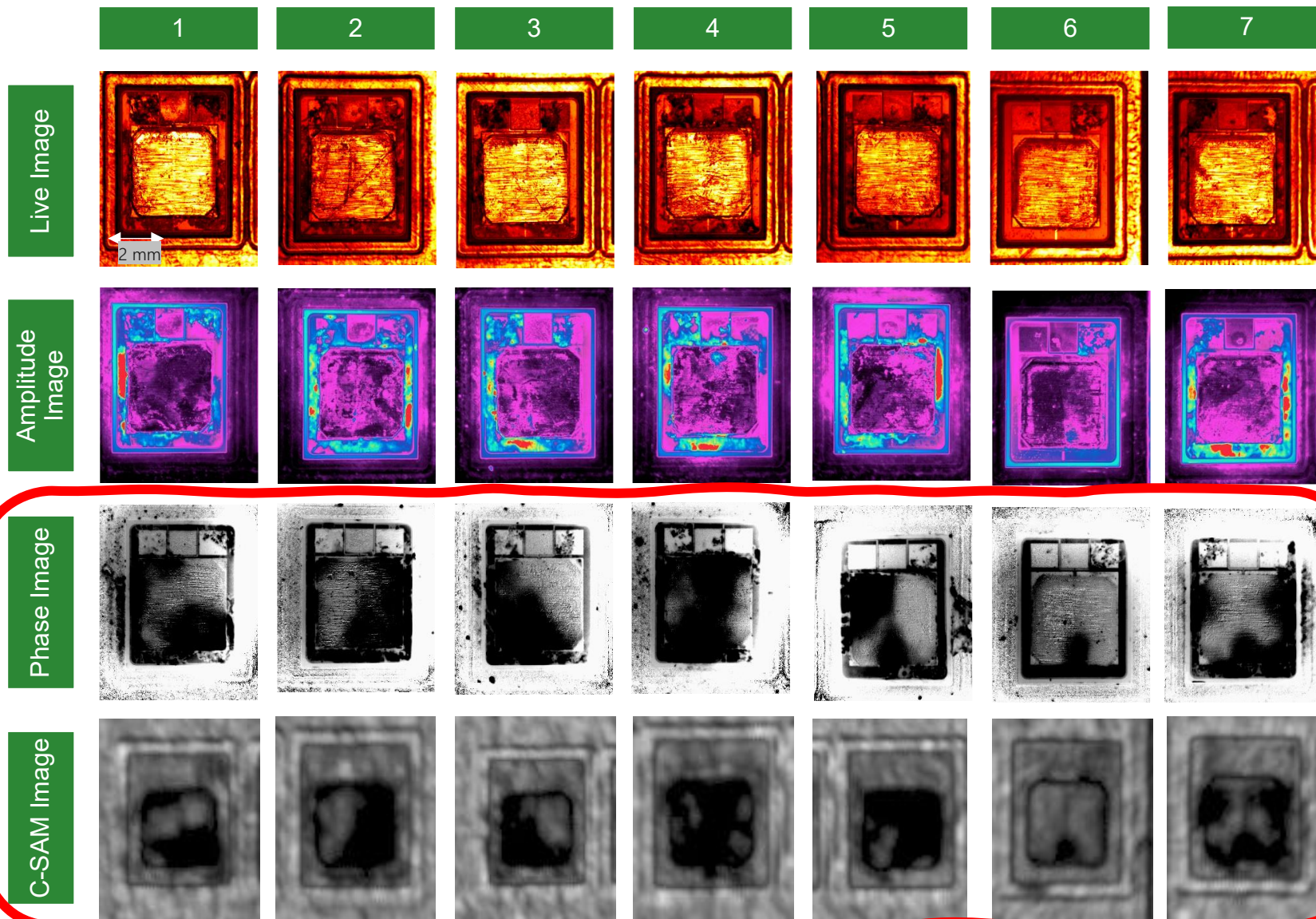
Phase Image



C-SAM Image



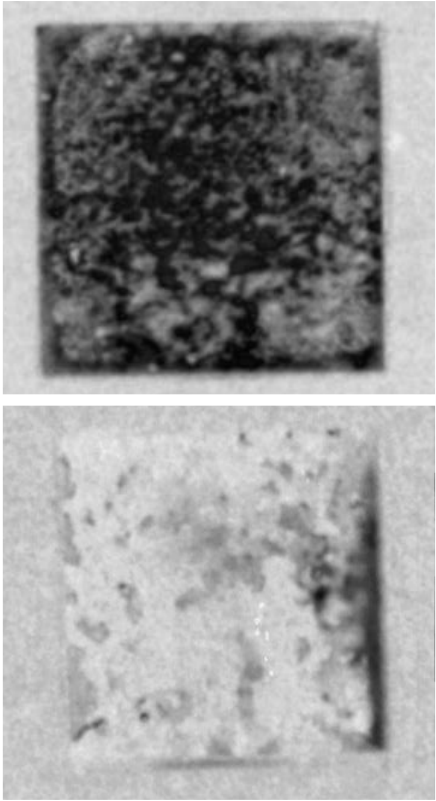
S. Panahandeh, D. May, C. Grosse-Kockert, B. Wunderle and M. Abo Ras, Laser Lock-in Thermography for Inspection of Silver-Sintered Die Attaches, 16th Quantitative InfraRed Thermography Conference, 4 – 8 July 2022, Paris, France, 10.21611/qirt.2022.2008,



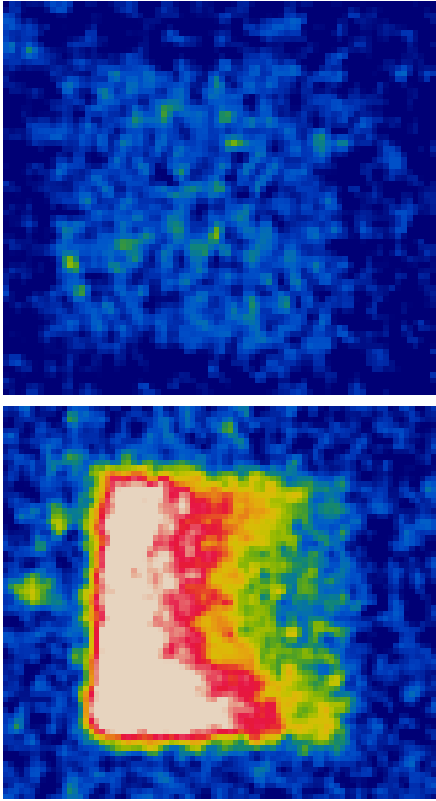
Sample Photo



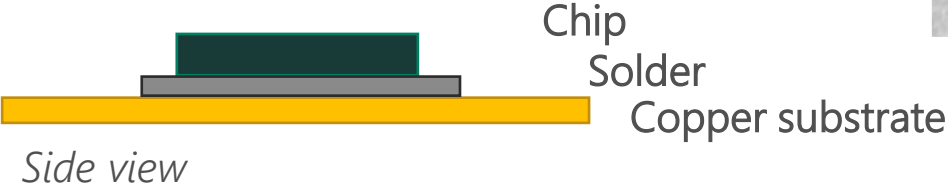
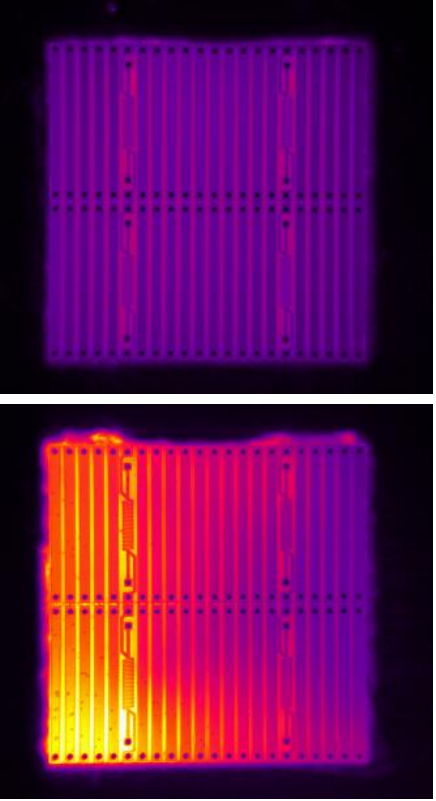
C-SAM

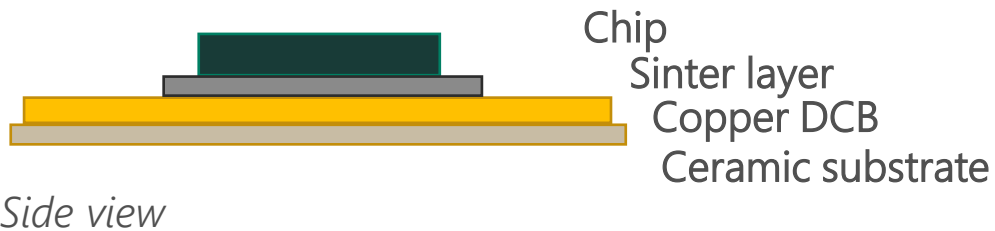
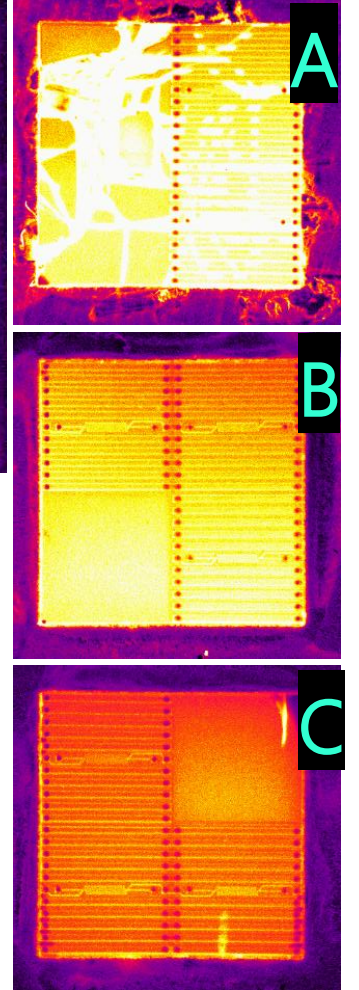
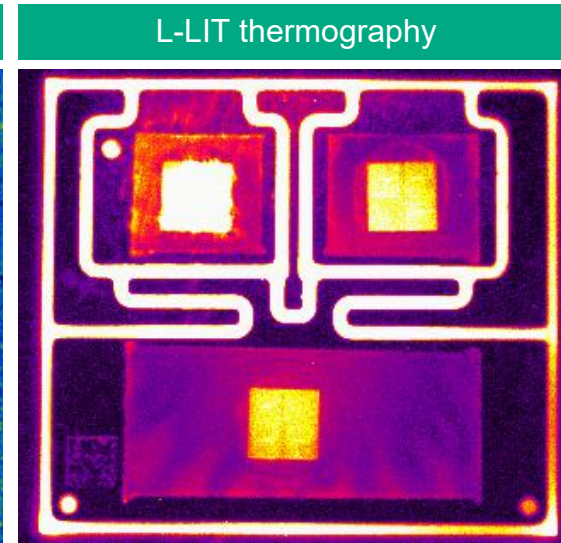
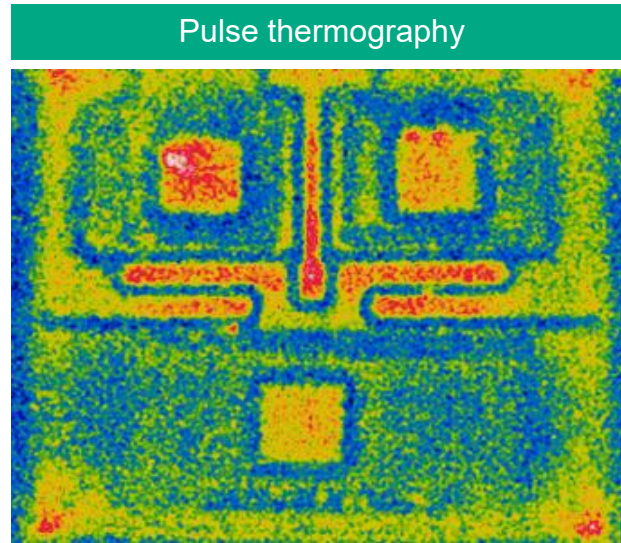
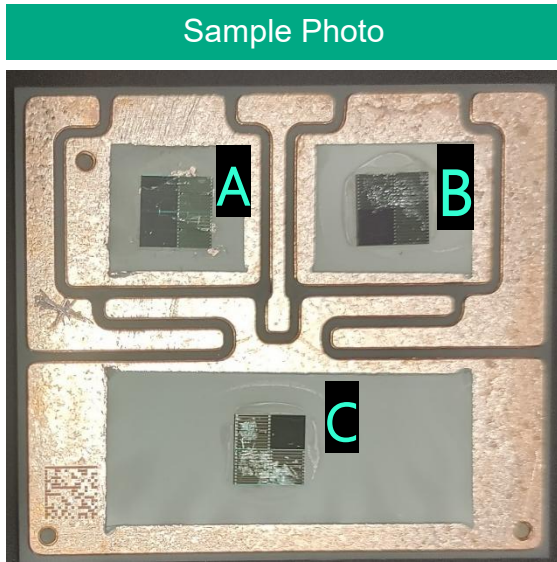


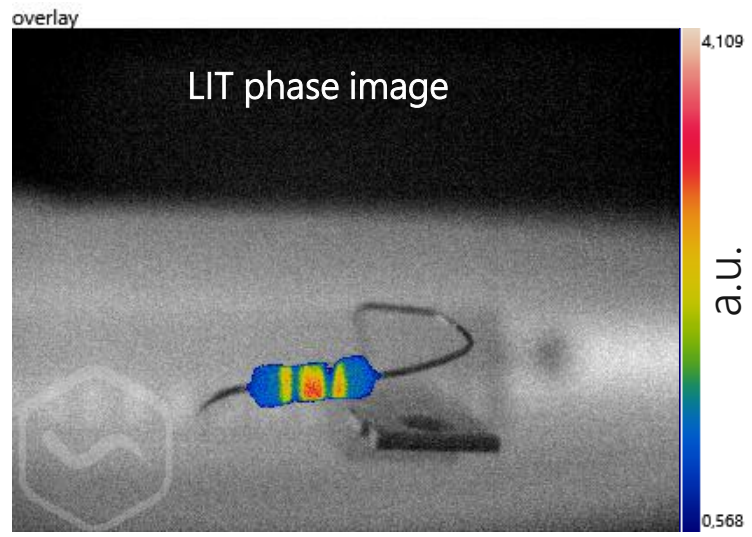
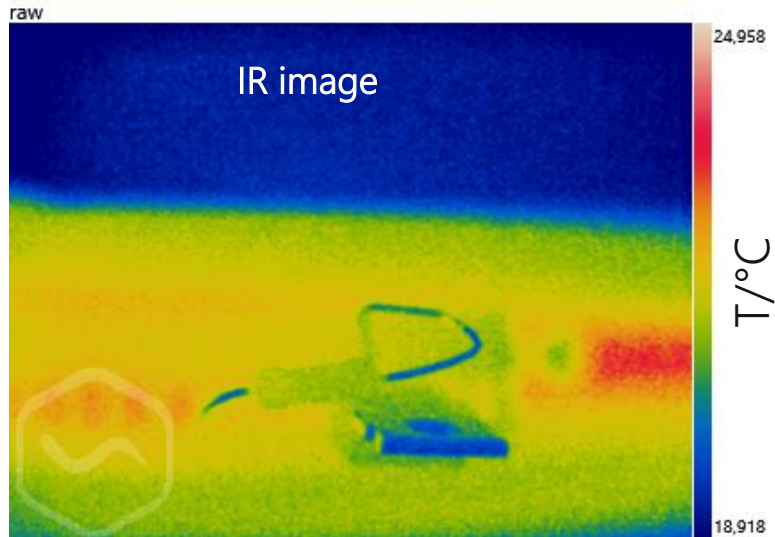
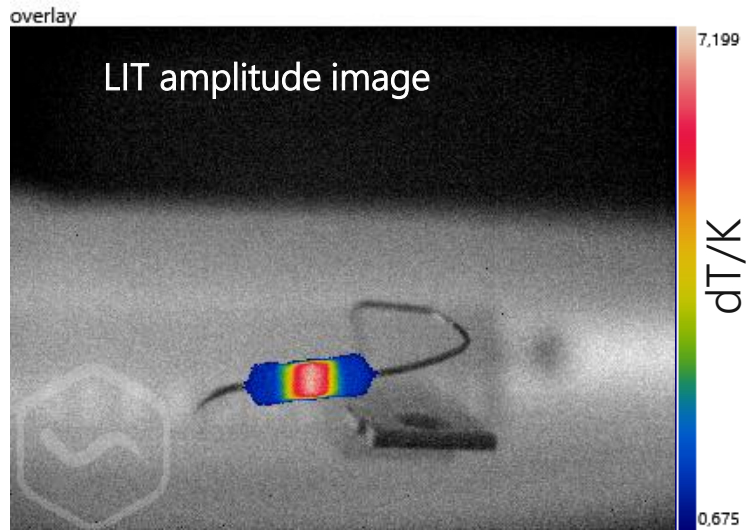
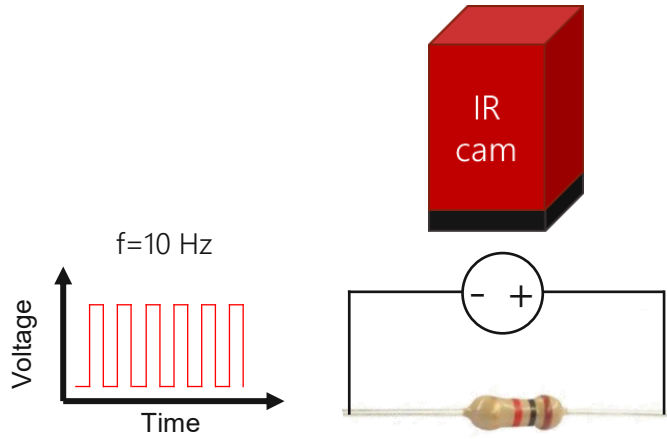
Pulse thermography

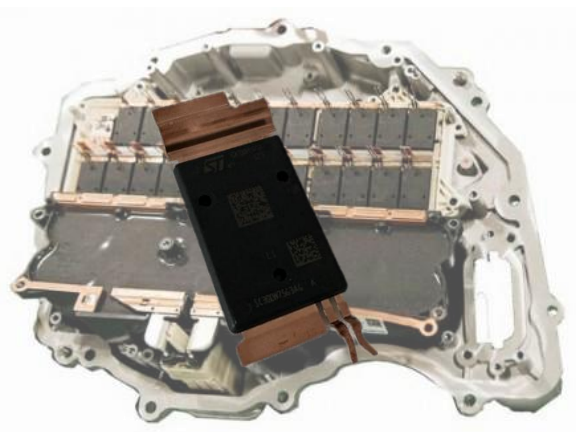


L-LIT thermography

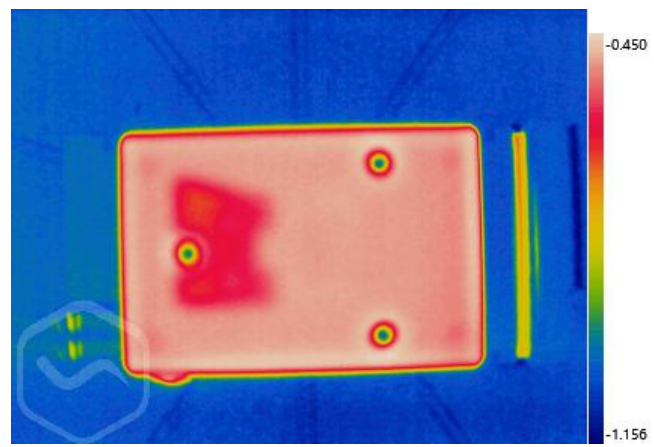




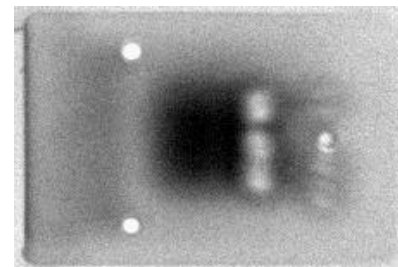
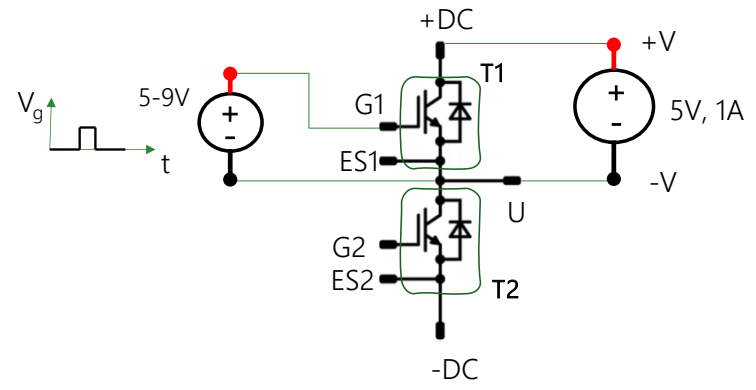




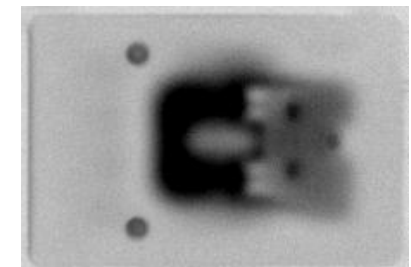
TIFAS IR pulse thermography



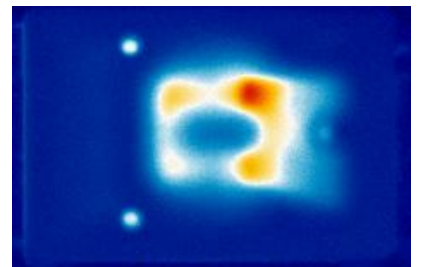
TIFAS electrical LIT



Complex

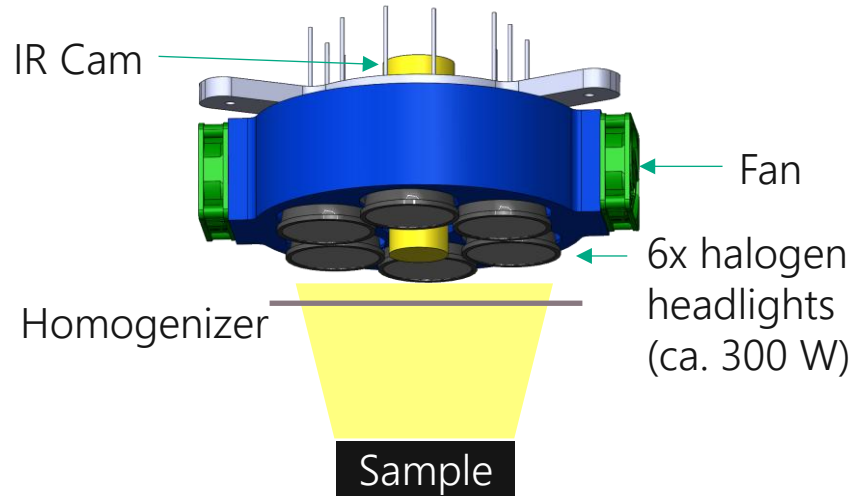


Phase



Amplitude

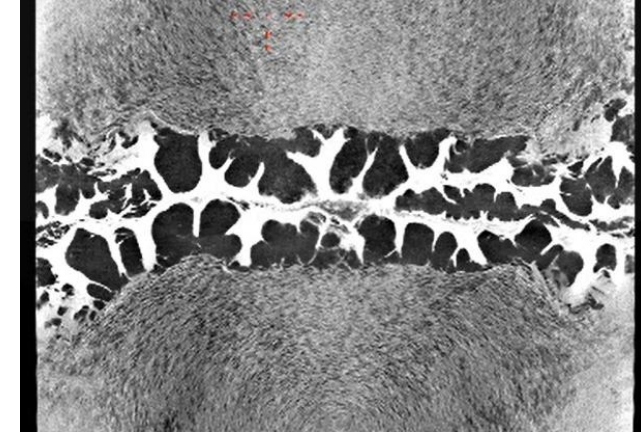
(Source: Tesla Model 3 Inverter with SiC Power Module from STMicroelectronics report, System Plus Consulting, 2018)



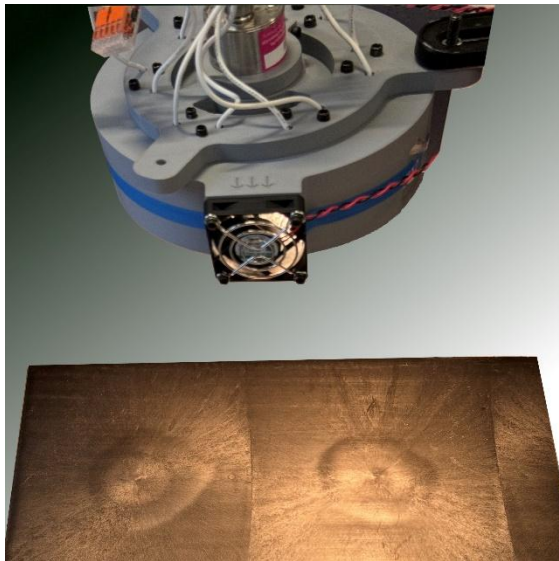
Use case: foamed plastic sheets



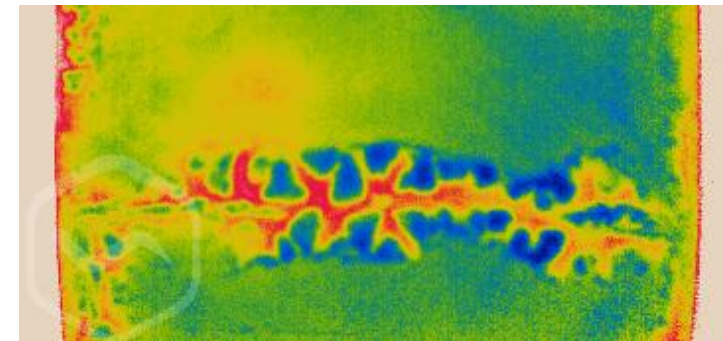
Photo\*



CT-Scan by FhG IMWS



Experiment: Sample during measurement



Lock-in-thermography (phase)



\* Samples are special demo-samples from ElringKlinger AG, results obtained within the project InThelekt funded under grant number 19I22005D by the Federal Ministry for Economic Affairs and Climate Action (Germany).

## Features

- » Fast and easy
- » 100% contactless + non-destructive
- » Works without spray-coating
- » Single layers up to full modules
- » Detection of various hidden defects
- » Thermally relevant (in contrary to SAM)
- » Automated decision making ready

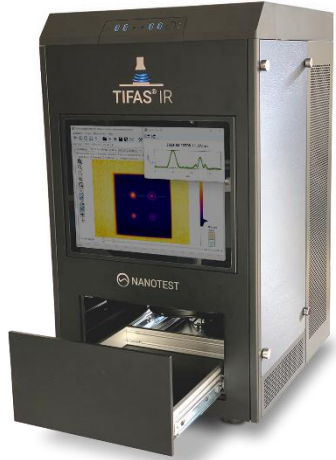
## Limits

- » Failure size requirement (size  $\geq$  depth)
- » 3D structures require spray-coating
- » Spatial resolution limited by IR wavelength
  - + Blur from heat spreading

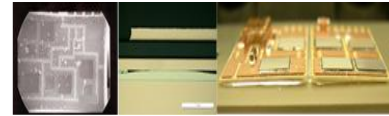
# TIFAS<sup>®</sup> IR inline

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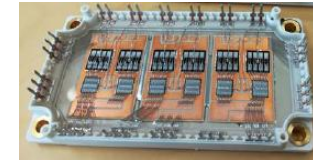
Thermal imaging-based failure analysis system for production lines



## Fields of application



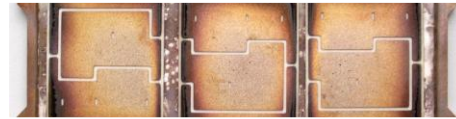
Solder interconnections



Power electronics



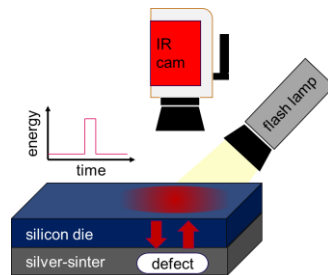
Innovative & sustainable industries



Sinter interconnections

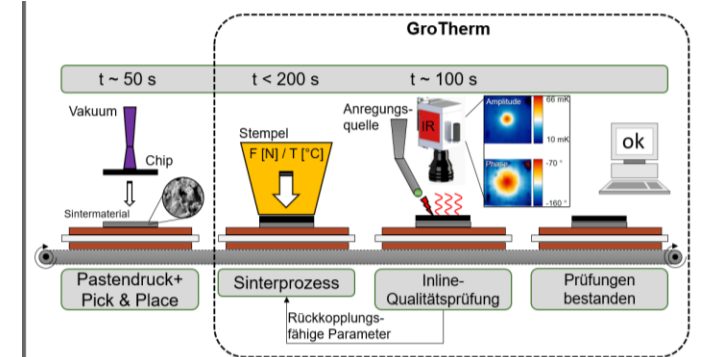
## Method

### Pulsed IR Thermography



- fast
- non-destructive
- low cost
- unexploited potential

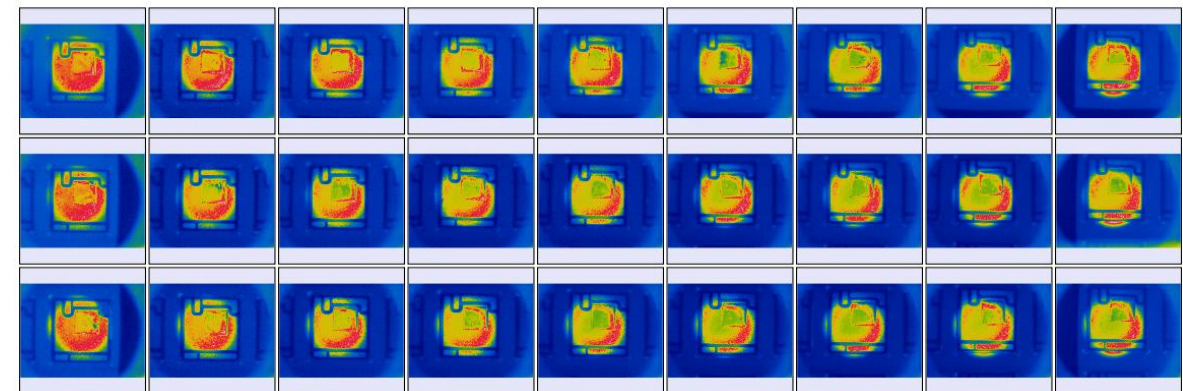
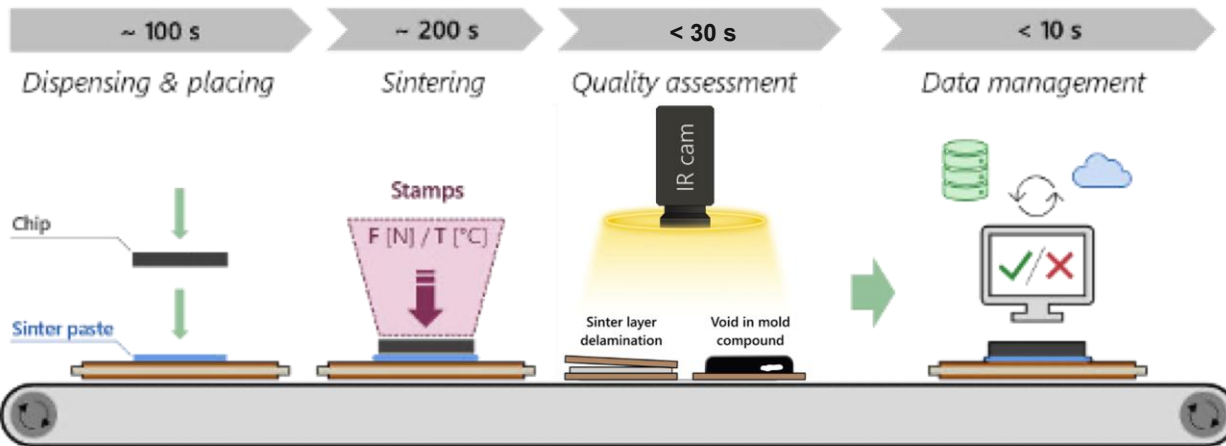
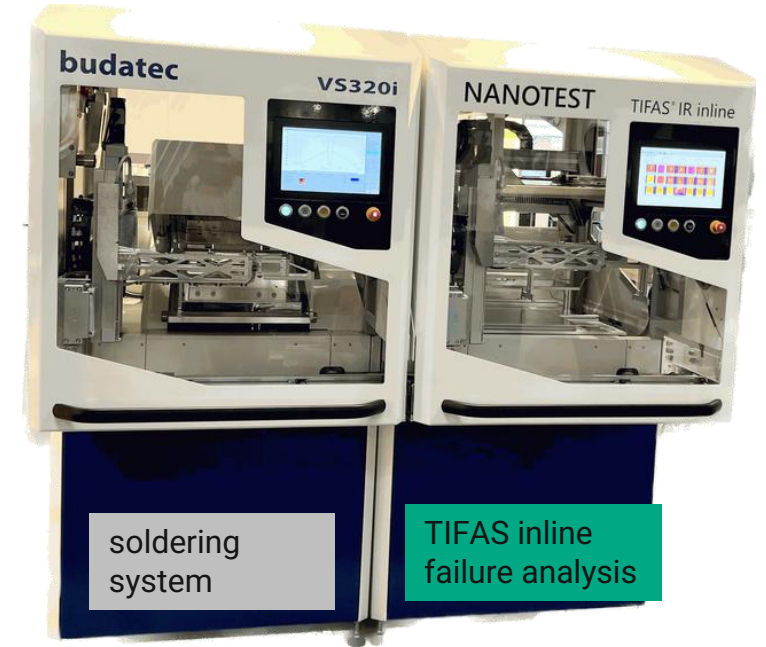
## Production lines



## Intelligent non-destructive 100% inline failure analysis

### Features

- » 100% inspection in production lines, full automation
- » Short testing times, high throughput
- » Complete infrared thermography-based failure analysis setup
- » Contactless and non-destructive
- » Great variety of detectable defects

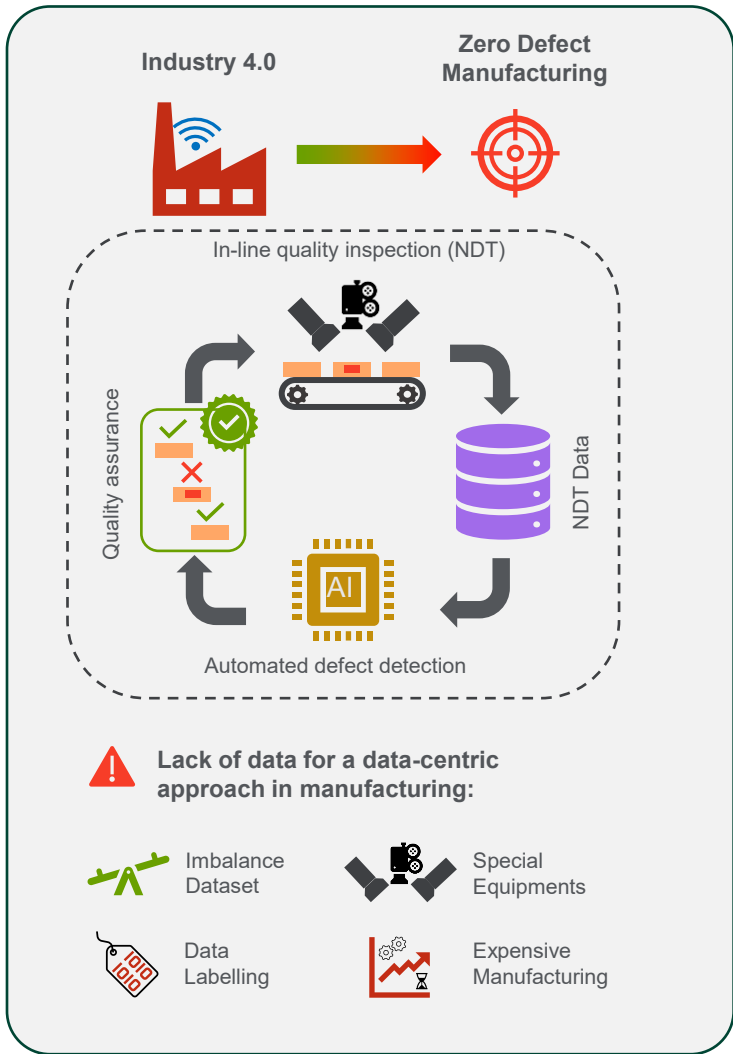


3x9 Measurements in a system tray

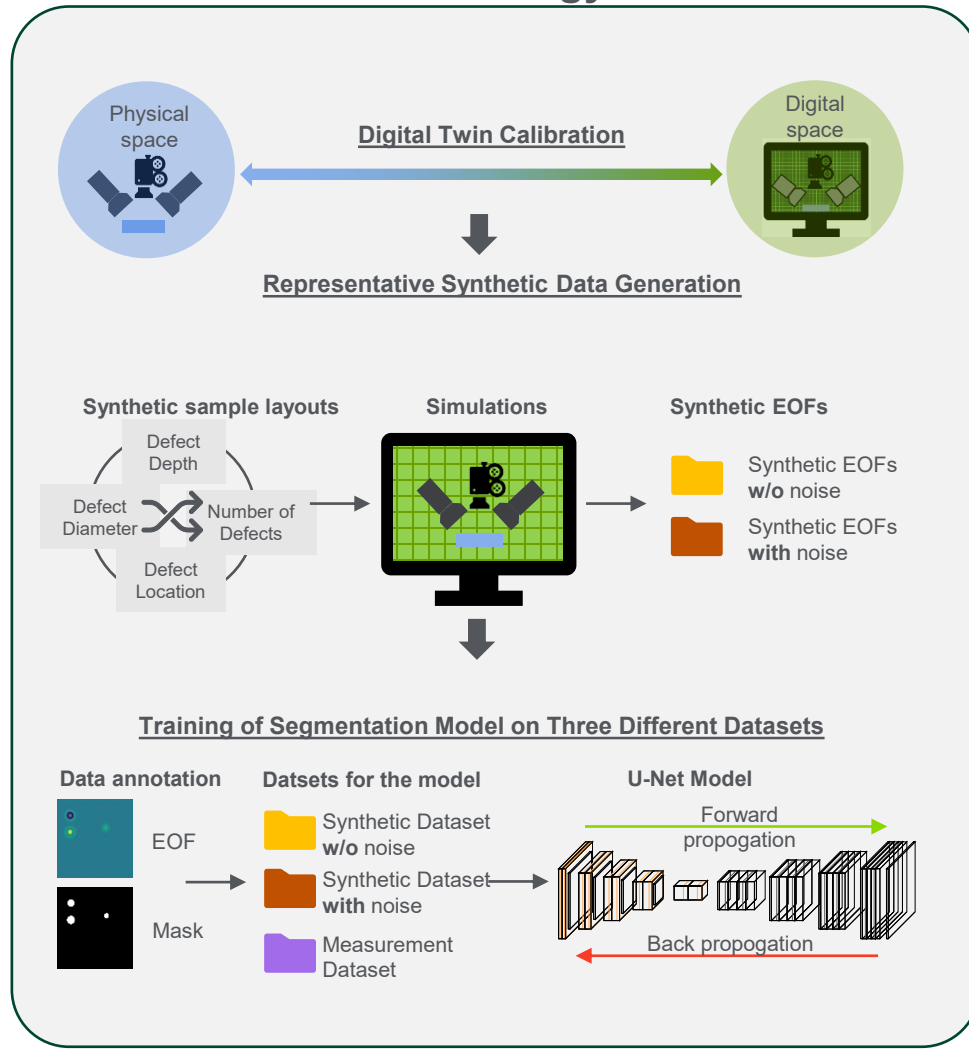


<https://www.youtube.com/watch?v=EZfxSXH0w0M>

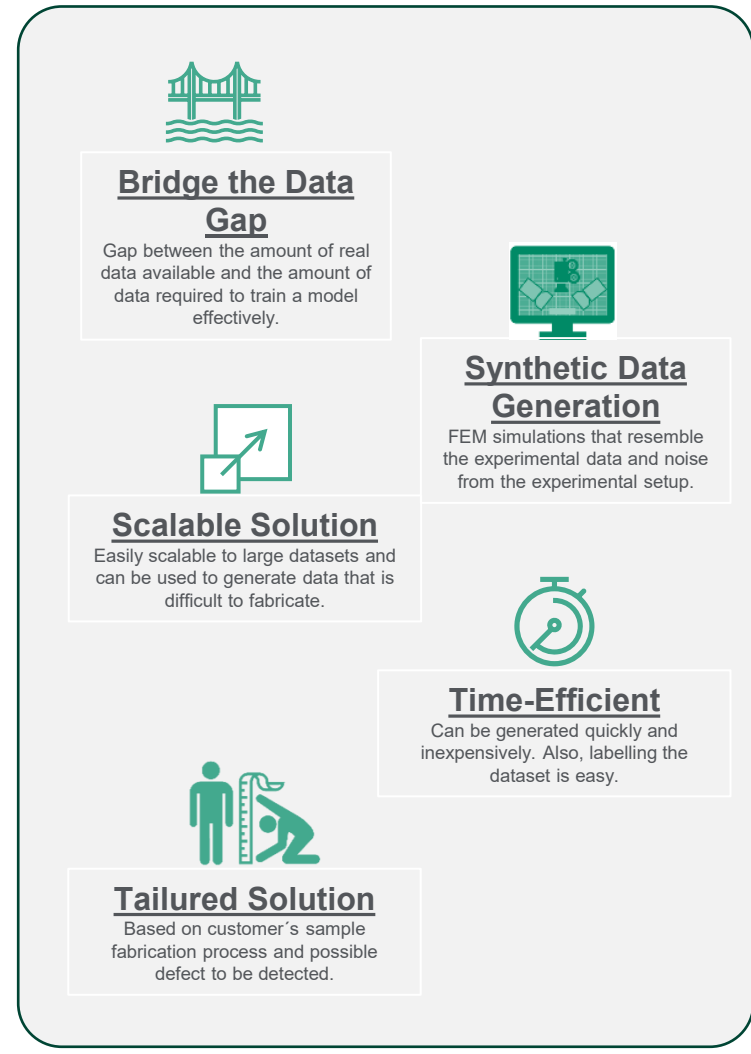
## Motivation



## Methodology



## Conclusion



# TIFAS<sup>®</sup> IR mobile

Thermal imaging failure analysis system for mobile applications

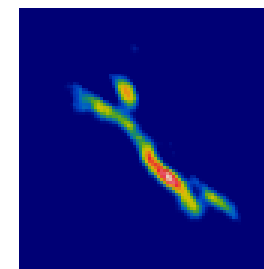
## Contactless failure analysis in a nutshell for mobile applications

### Features

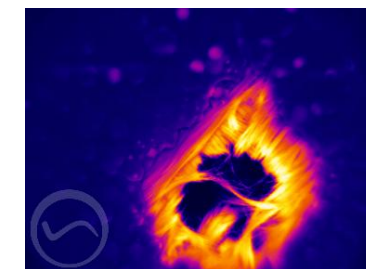
- » Mobile infrared thermography-based failure analysis setup
- » Contactless and non-destructive maintenance of components
- » Great variety of detectable defects
- » Comprehensive analysis software
- » Example: non-destructive testing of fiber composites and bonded joints



Impact defect



Lightning strike defect



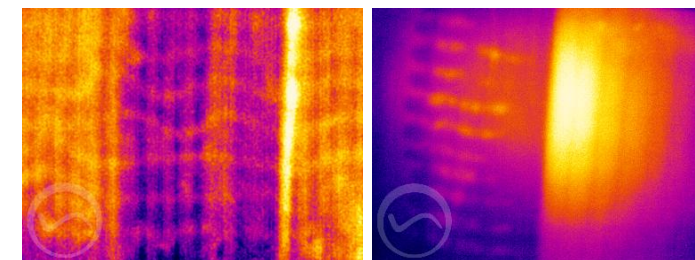
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ZfP heute | Berlin 2020 p 54-55  
M. Kaczmarek, M. Müller, Zerstörungsfreie  
Bauteilprüfung von großflächigen, glasfaserverstärkten  
Schienenfahrzeug-Komponenten

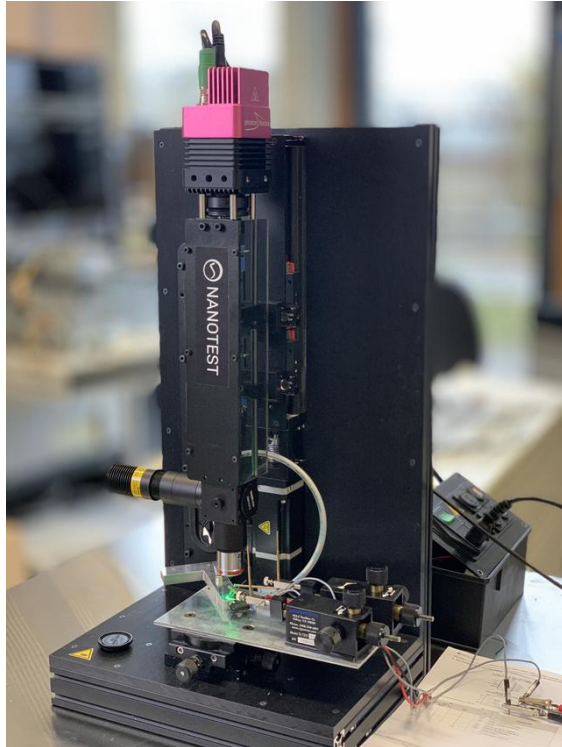


Inner structure of a wind turbine blade

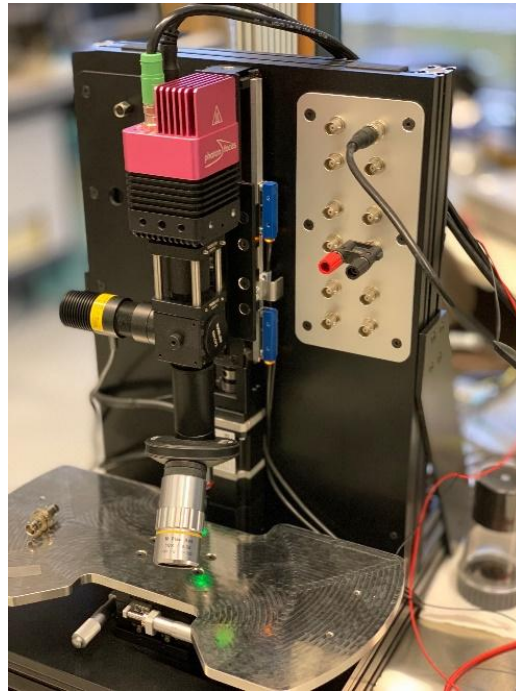
# TIFAS<sup>®</sup> TR

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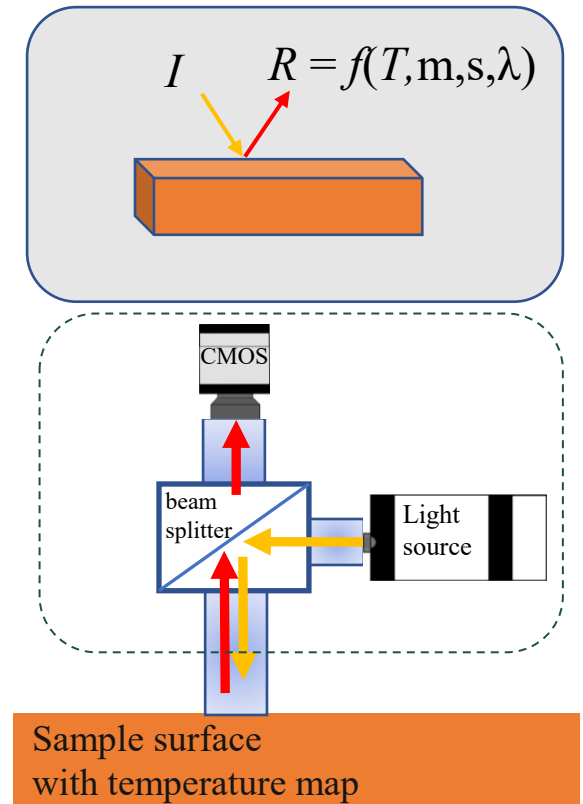
Thermal imaging failure analysis using thermo-reflectance



Lab scale platform



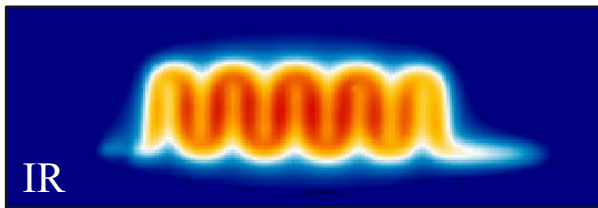
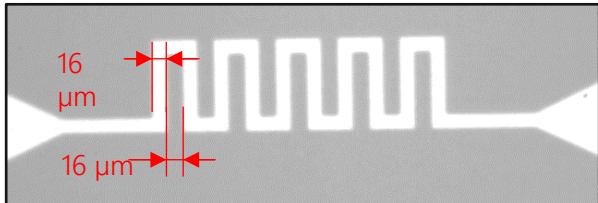
TIFAS TR



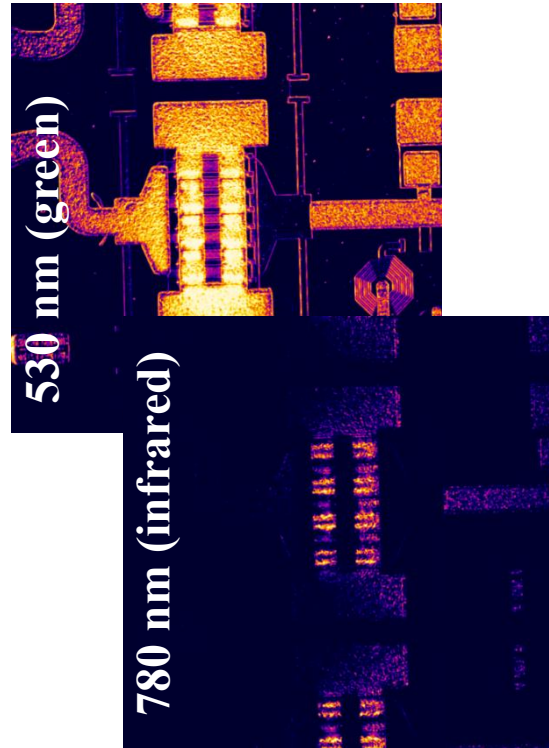
$$\frac{\Delta R}{R} = \left( \frac{1}{R} \frac{\partial R}{\partial T} \right) \Delta T = C_{TR} \Delta T$$

Advantages: imaging on reflective surfaces, higher lateral resolution, selective per material

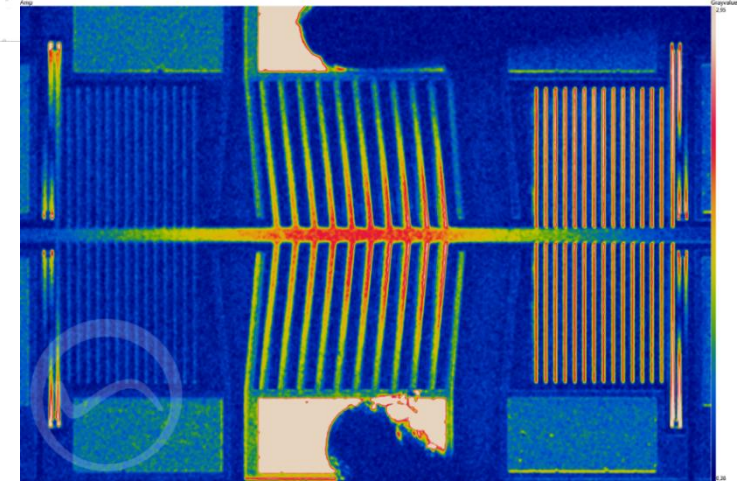
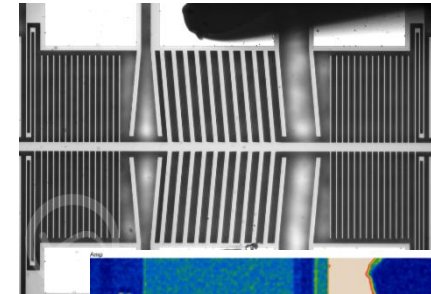
Metal test structures

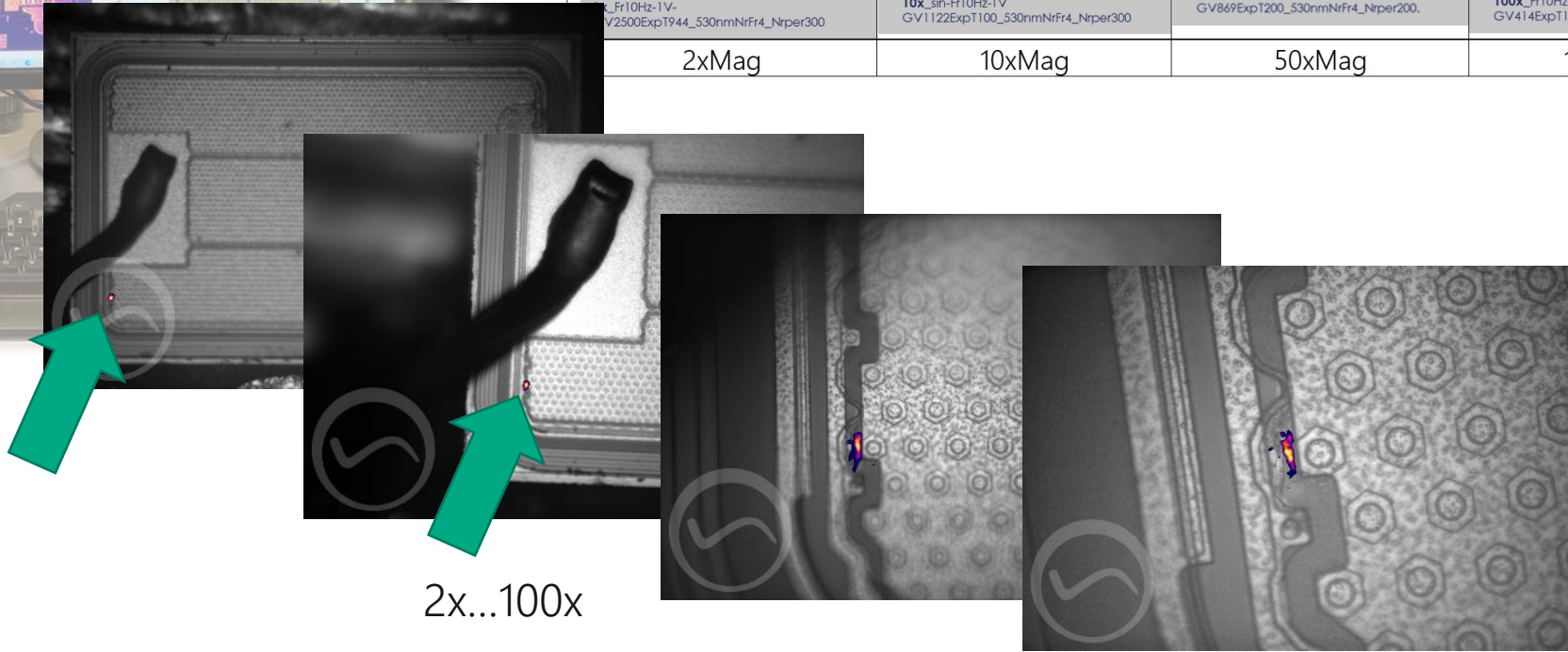
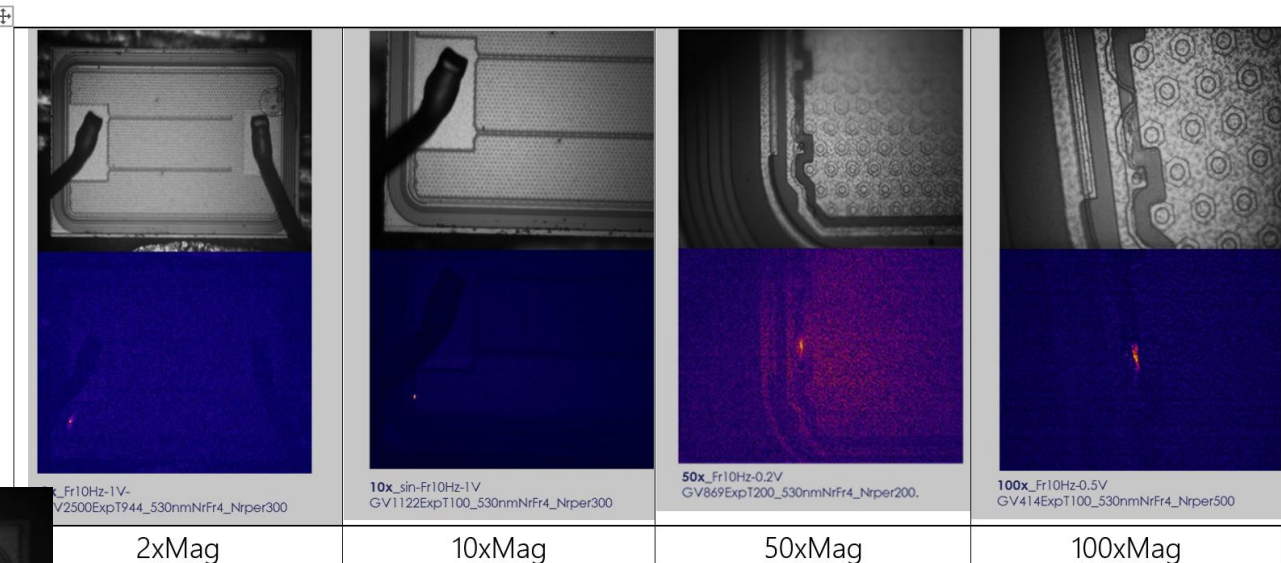
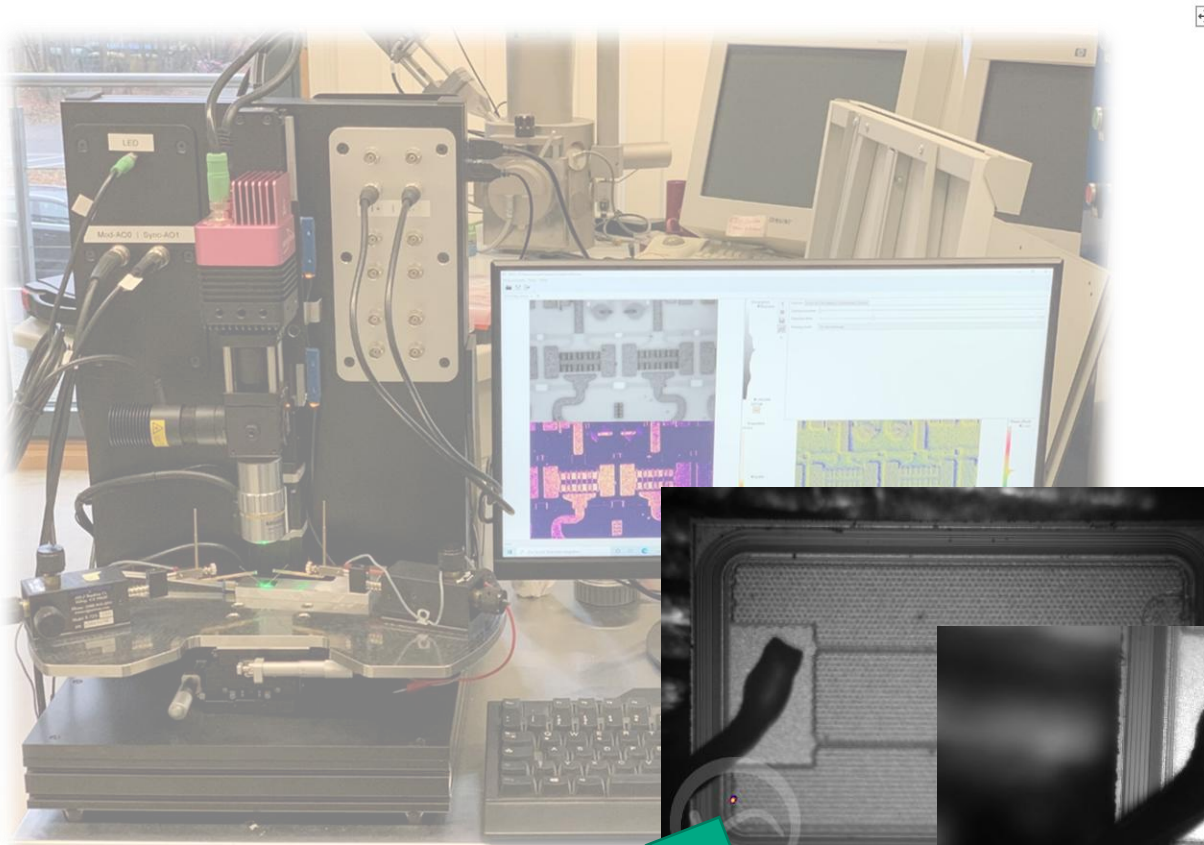


HEMT device (active)



MEMS actuator device







[nanotest.eu/tifas](https://nanotest.eu/tifas)

[nanotest.eu](https://nanotest.eu)

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