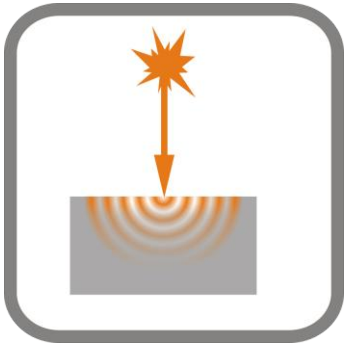


# FORACAM: A VERY PRECISE IMAGING METHOD FOR THERMAL METAL PROPERTIES CHARACTERIZATION AND FLAW DETECTION


EDEVIS GMBH
STUTTGART
GERMANY

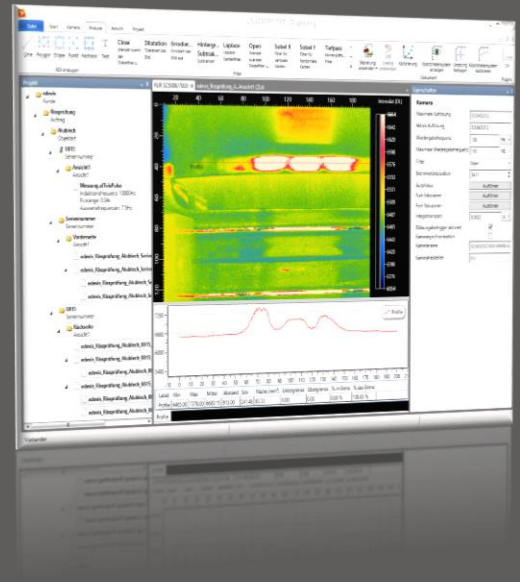
EDEVIS

# PRODUCTS

| | |
|---|---|
| OTvis | Optical excited Lockin-Thermography |
| PTvis | Pulse Thermography |
| LTvis | Laser Thermography |
| UTvis | Ultrasound Thermography |
| ITvis | Inductive excited Thermography |
| SHEAROvis | Laser-Shearography |
| ForaCAM | Photothermal radiometry NEW |
| LITe | Electro-Testing NEW |

## Software DisplayIMG 6

Image processing and excitation controller / real-time



**Infrared cameras**

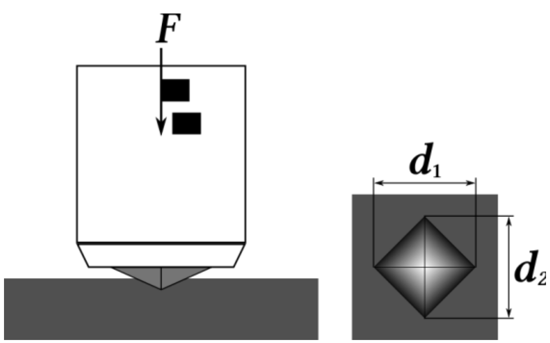
Cooled FPA and Micro-bolometer

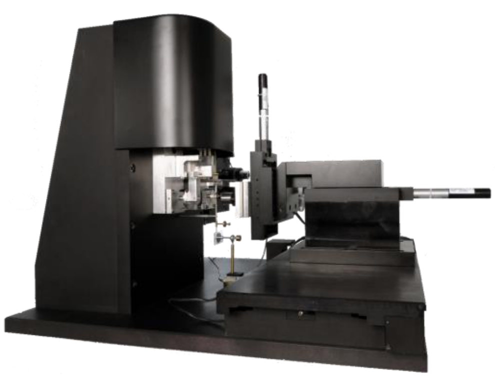
# APPLICATIONS

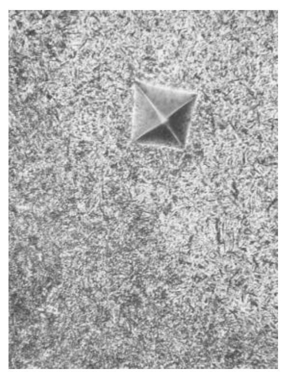
Measurement of hardness /hardness profile

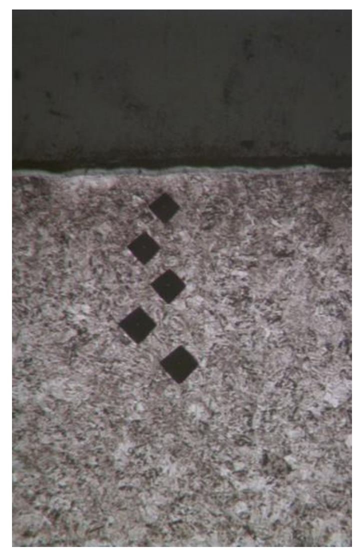
State of the art: indentation (Rockwell, Vickers, …)

- Time-consuming
- Destructive test







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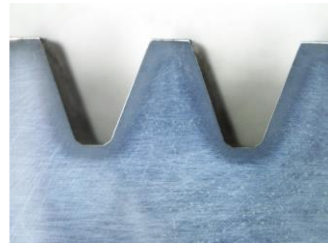
# APPLICATIONS

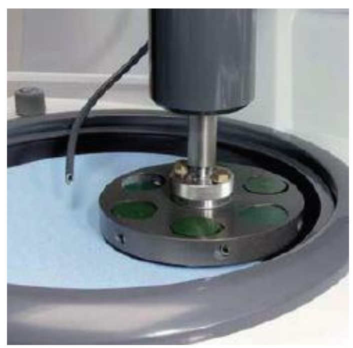
Measurement of carbonized depth



State of the art: metallography

- Time-consuming
- Destructive test

sampling

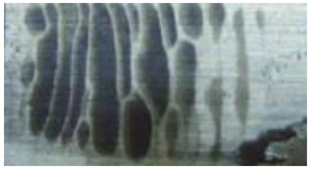


embedding, milling, polishing, etching

microscopy

# APPLICATIONS

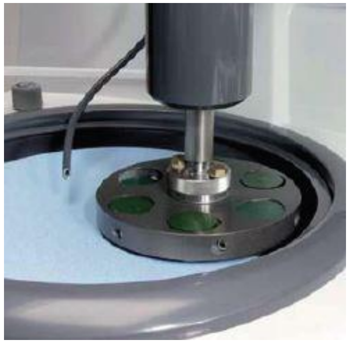
Detection of grinding burn



State of the art: metallography

- Time-consuming
- Destructive test

sampling



embedding, milling, polishing, etching

microscopy

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# TASK: INCREASE COST-EFFICIENCY

- Avoid sample preparation: save time to notice weak hardening process much earlier


- Non-destructive test: test object can still be used

- Inline measurements: 100% inspection instead of samples, avoid rejection of whole batches

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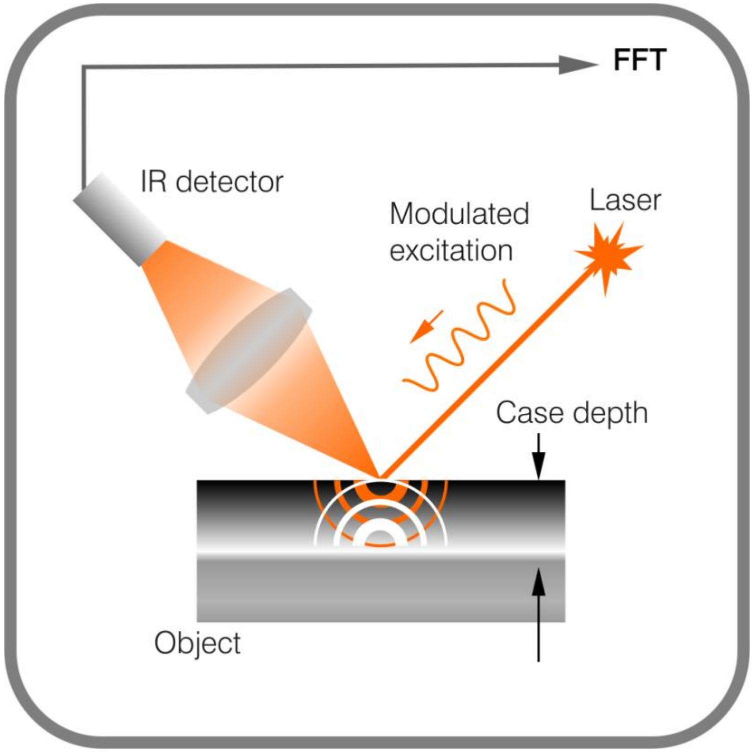
# SOLUTION: FORATHERM PHOTOTHERMAL RADIOMETRY



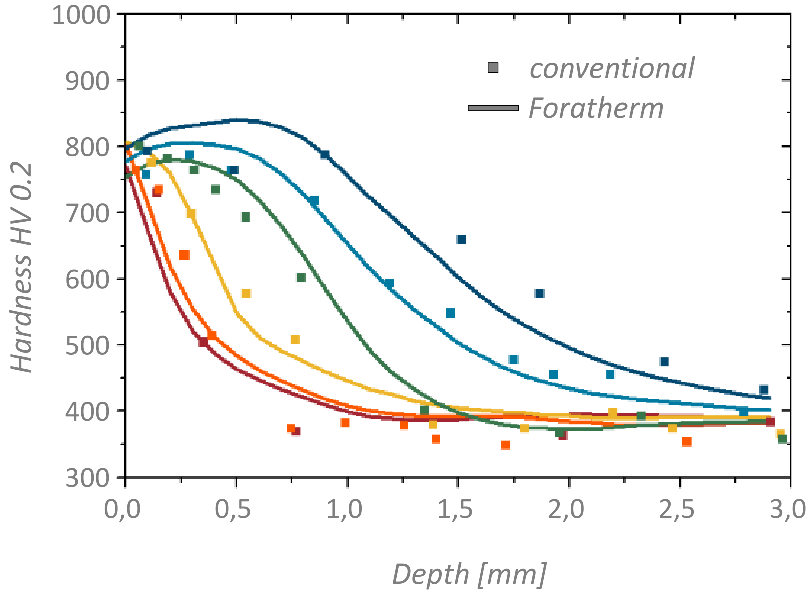


Determination / detection of

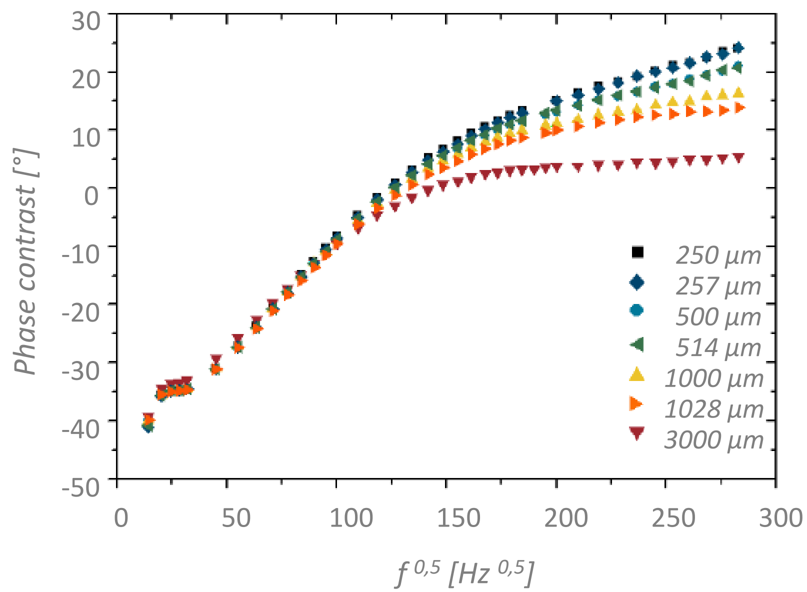
- layer thicknesses
- case hardness depths
- nitriding depths
- hardness profiles
- porosity contents
- grinding burn
- hidden corrosion

# FORATHERM: EXAMPLES

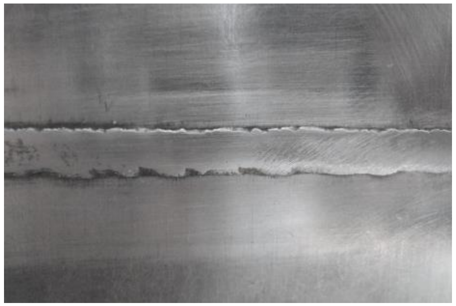
Non-contact determination of hardness profile
(after calibration with reference body)



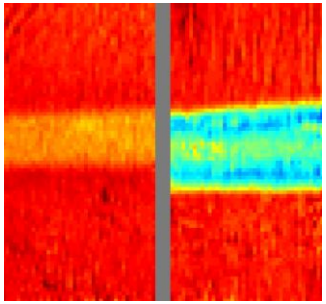

Non-contact determination of Invar layer thickness on silicon substrate



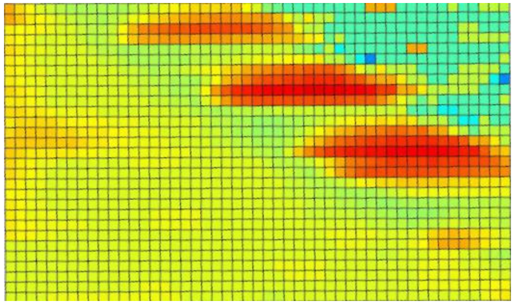
# FORATHERM: EXAMPLES WITH SCANNING



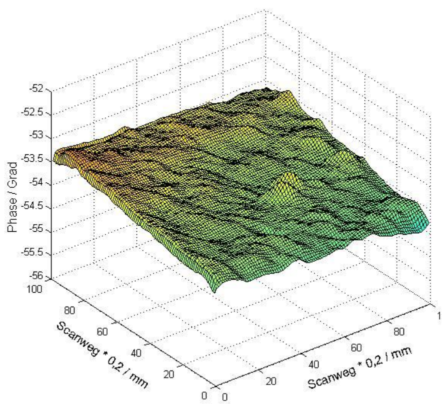
Welding seam



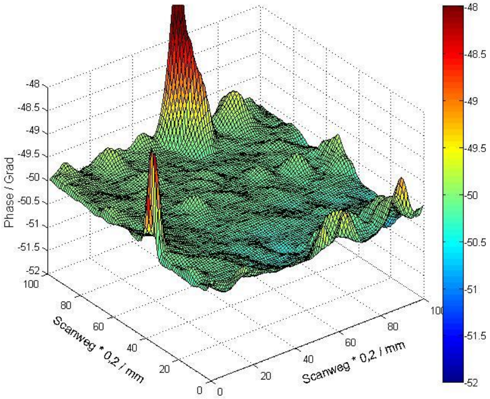
annealed / not annleaded



Grinding burn




without grinding burn




with grinding burn

# FORATHERM PHOTOTHERMAL RADIOMETRY

## Advantages

- Non-contact
- Non-destructive
- Inline-testing is possible
- Faster than materialographic analysis

## Drawbacks

- Detectorsize 1 Pixel: Imaging requires time consuming scanning of sample or sensor head

# 1 PIXEL IS ENOUGH?

## Why not using an infrared camera?

- Metals have a high thermal diffusivit
  Very high frame rates needed

- Layers like grinding burn are very thin:
  Extremely high frame rates needed
- Signals levels are very small:
  Perfect temporal synchronization needed

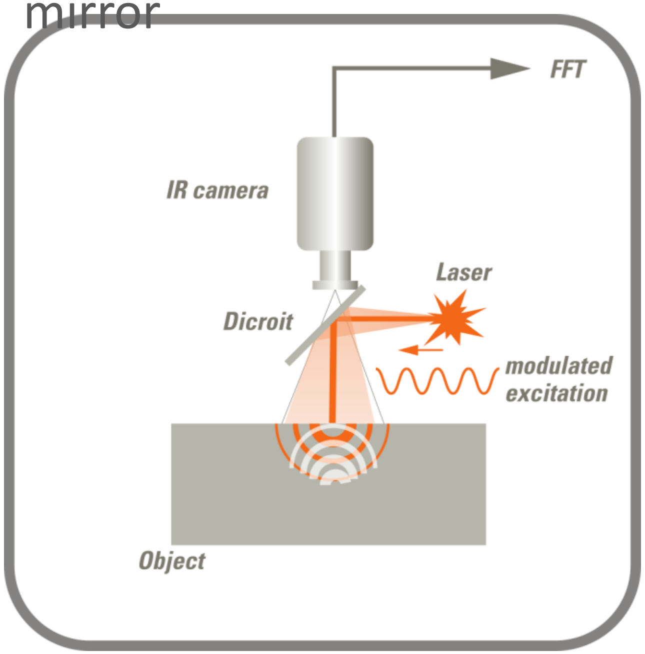

- FLIR X8500sc, 180Hz
- Subwindowing

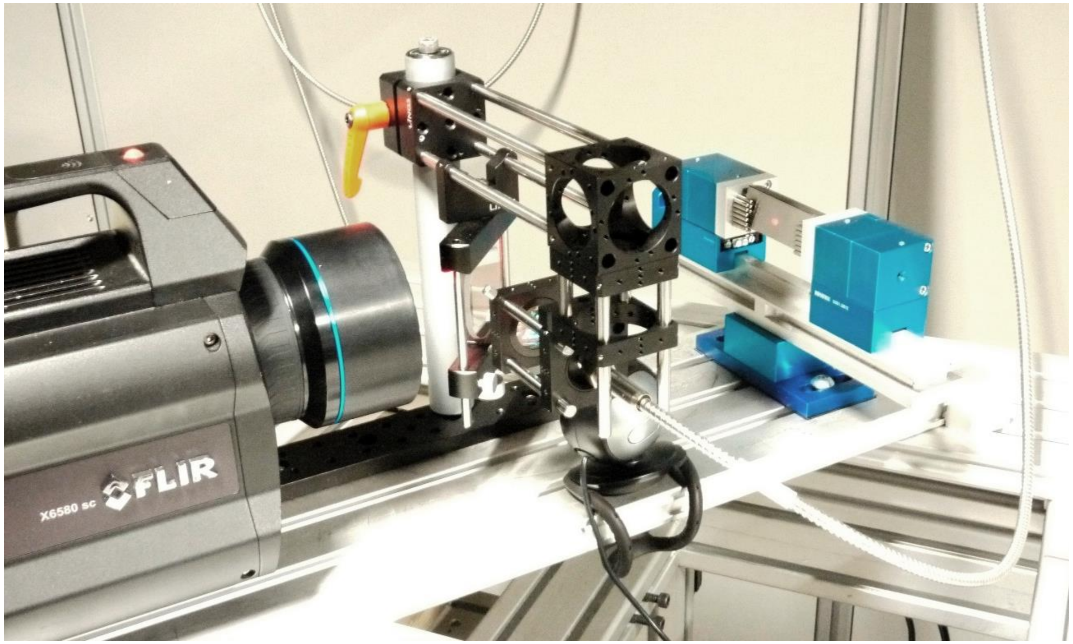

- FLIR X6900sc, 1003Hz
- Subwindowing
- Subsampling

- edevis signal generator ESG
- edevis software DisplayIMG

# FORACAM SETUP

Collinear setup of IR camera and excitation laser with dicroitic mirror




Advantages:

- Measurement spot position independent from working distance
- No geometrical constraints between camera & lens and laser excitation

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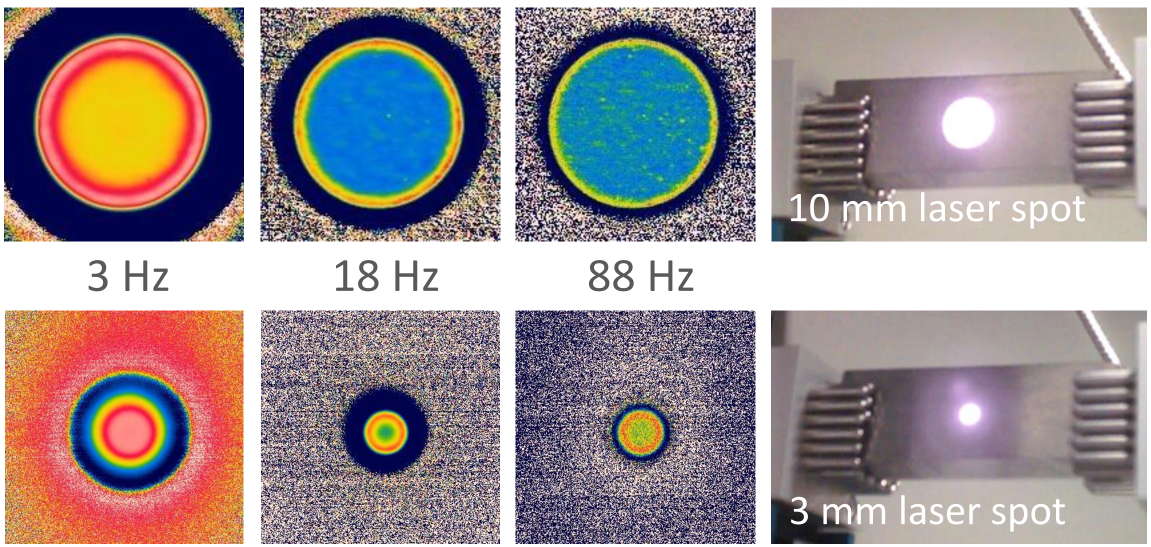
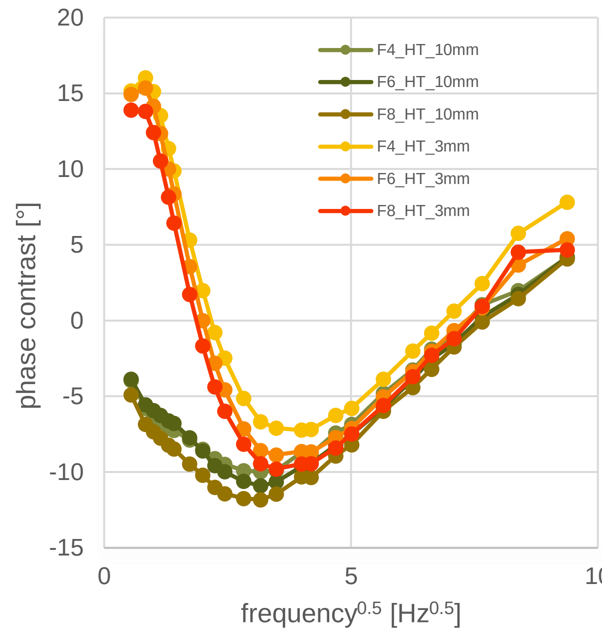
# FORACAM

Case hardened specimen, tested at different modulation frequencies




10 mm spot size: phase signal 1D heat flow -> lower phase contrast

3 mm spot size: phase signal influenced by 3D heat flow -> higher phase contrast due to lateral heat flux effects

⇒ Spot size should be optimized

⇒ For imaging, array of laser spots can be used

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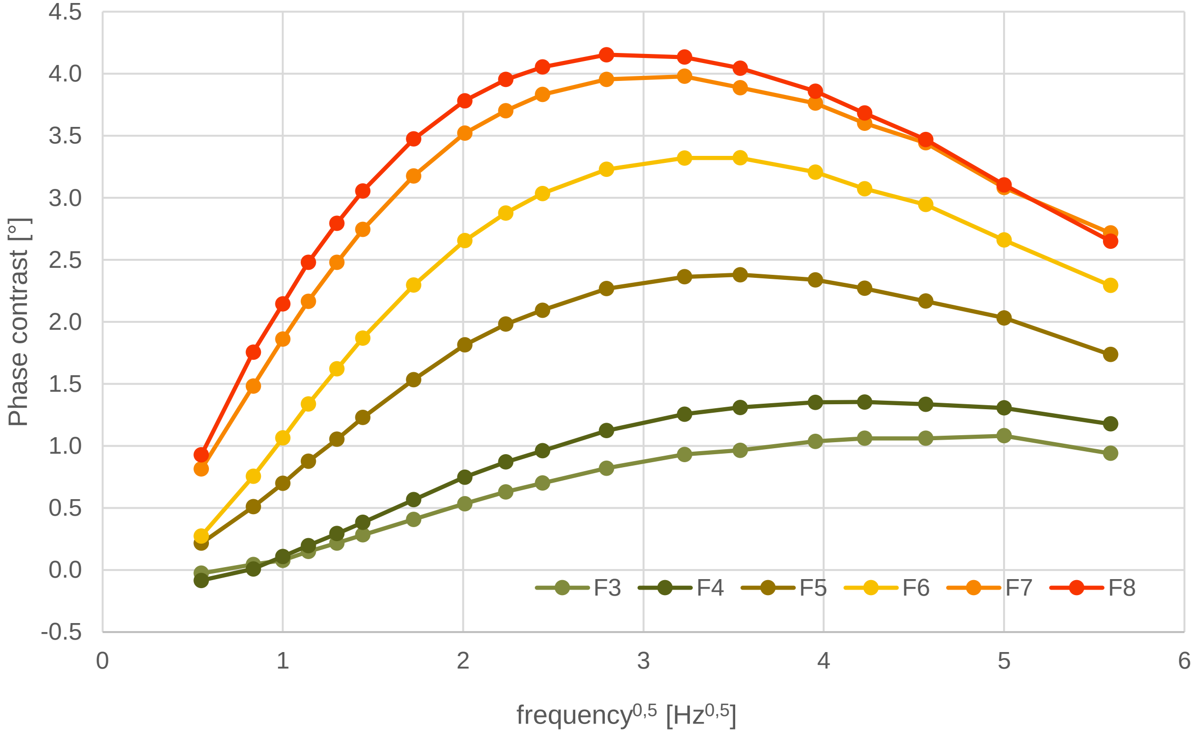
# FORACAM CASE-HARDENING CHARACTERIZATION

Case hardening depths of 16MnCr5 samples between 0.3 and 2.0 mm




CHD:

F3 0.3 mm

F4 0.5 mm

F5 0.8 mm

F6 1.0 mm

F7 1.3 mm

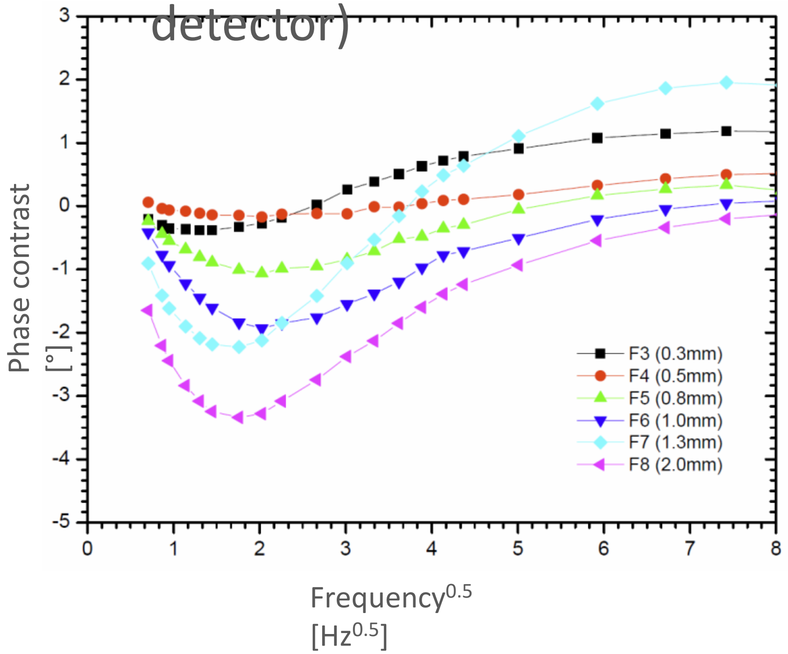
F8 2.0 mm

Strong signal change -> CHD can be determined quantitatively (requires calibration)

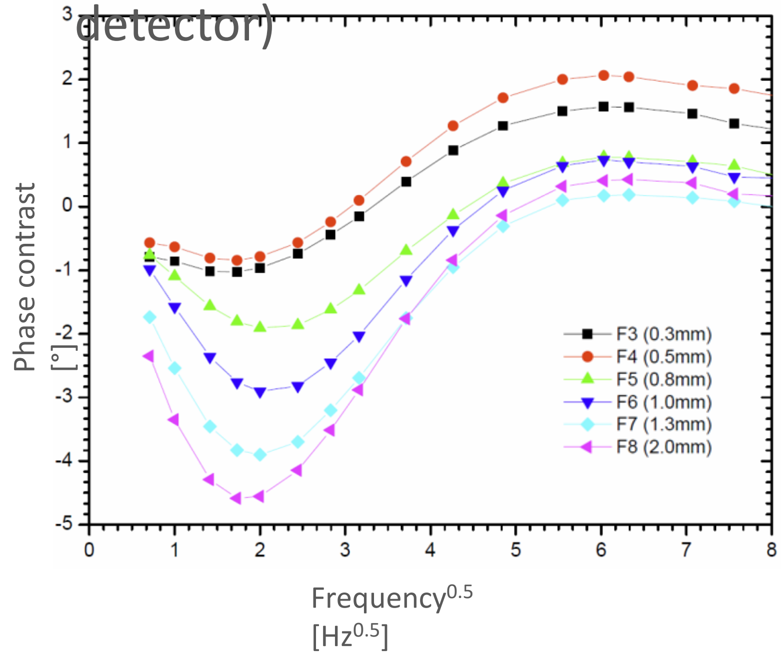
# FORACAM VS FORATHERM

Case hardening depths of 16MnCr5 samples between 0.3 and 2.0 mm

ForaTherm (1 point detector)



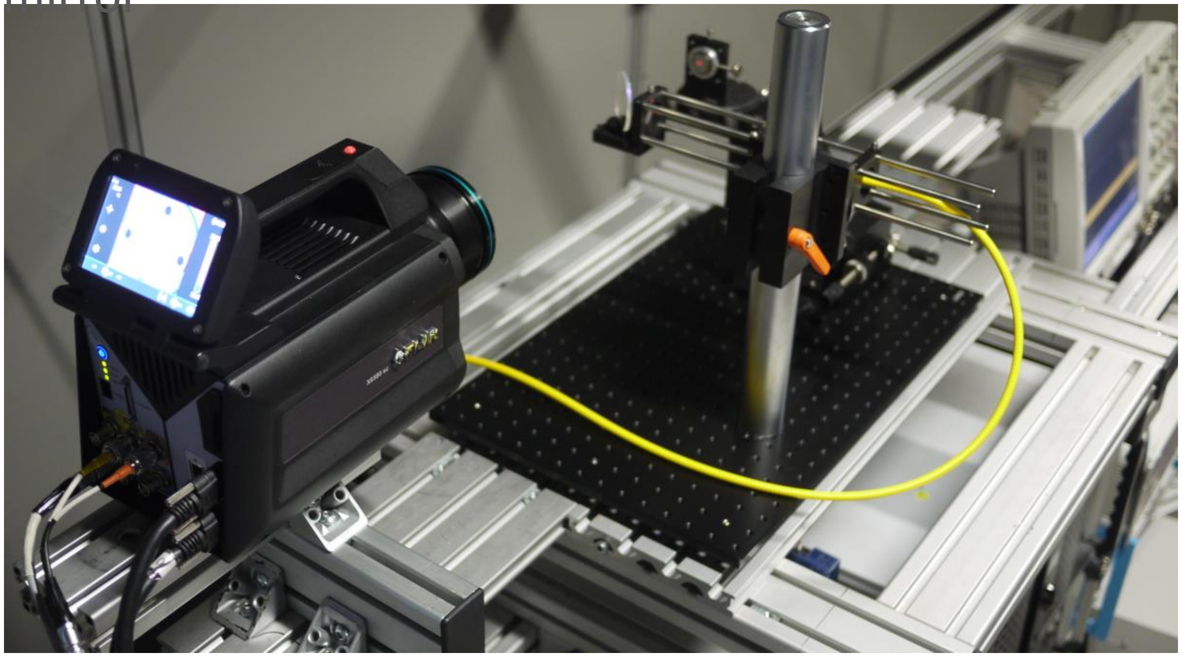

ForaCAM (focal plane array detector)




ForaCAM is even more sensitive!

# FORACAM GRINDING BURN DETECTION

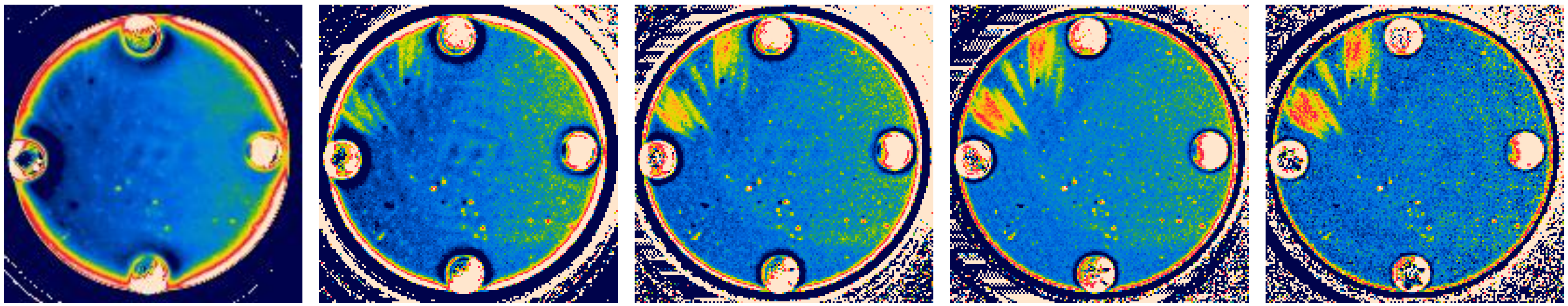
Collinear setup of IR camera and excitation laser with dicroitic mirror



Frame rate 900 Hz
Subwindow 160 x 160 pixel
IFOV 125 µm
Measurement field 20 x 20 $mm^2$
Laser power 200 W

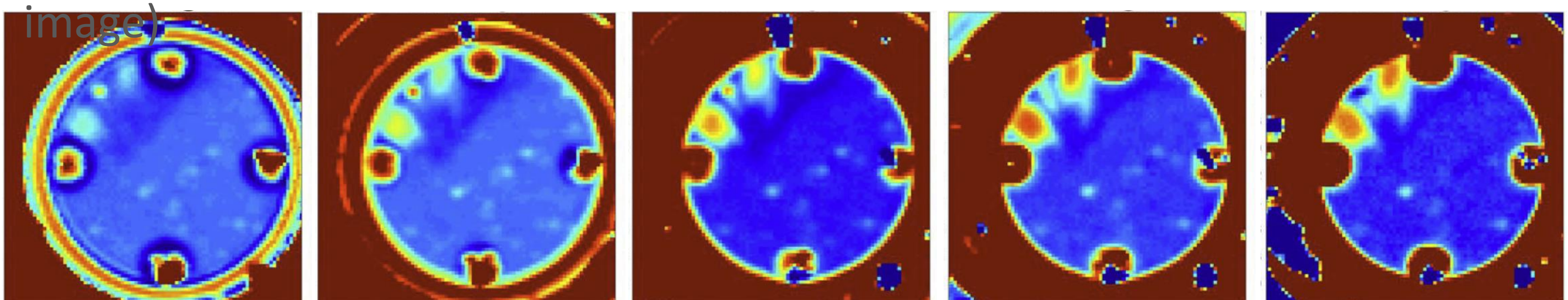
# FORACAM GRINDING BURN DETECTION

Foracam Specimen 1 (measurement duration: 30s per image)



10 Hz | 39 Hz | 82 Hz | 150 Hz | 225 Hz

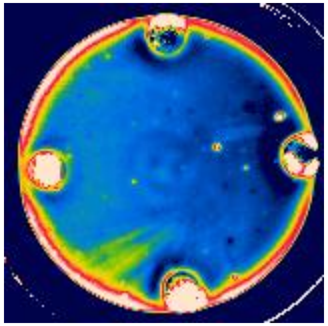
Foratherm Specimen 1 (scanned, measurement duration ca. 60min per image)

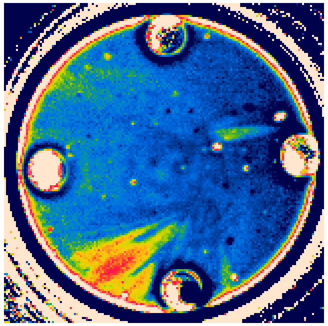


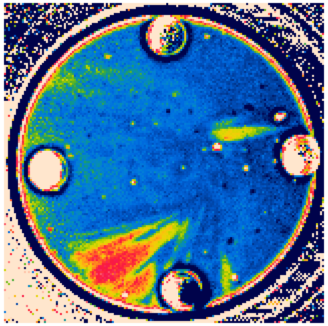
23 Hz | 65 Hz | 205 Hz | 405 Hz | 905 Hz

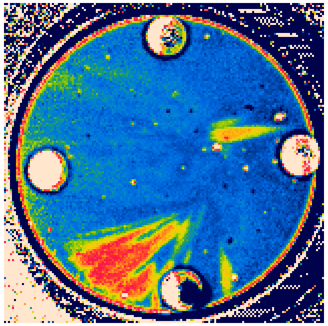
# FORACAM GRINDING BURN DETECTION

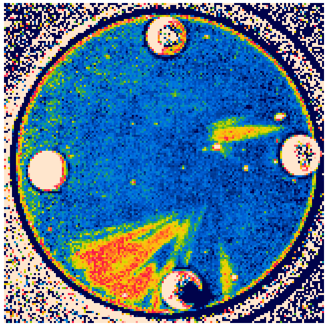
Foracam Specimen 2 (measurement duration: 30s per image)


10 Hz

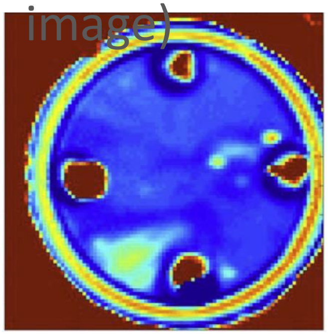

39 Hz

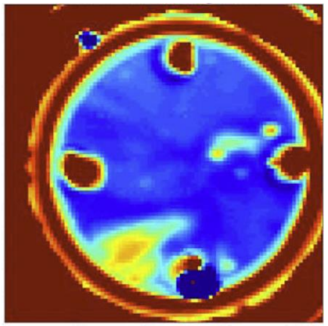

82 Hz

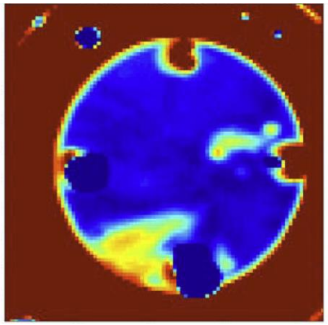

150 Hz

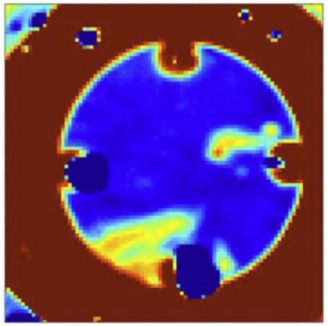

225 Hz

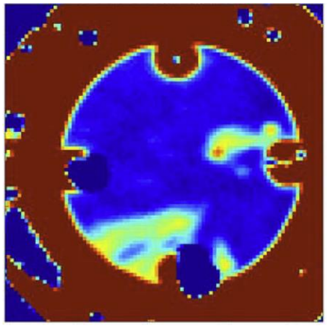
Foratherm Specimen 2 (scanned, measurement duration ca. 20min per image)


23 Hz


65 Hz


205 Hz


405 Hz


905 Hz

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# FORACAM SYSTEM COMPONENTS

Sensor head with dicroit and IR camera: Foracam


Synchronization: ESG

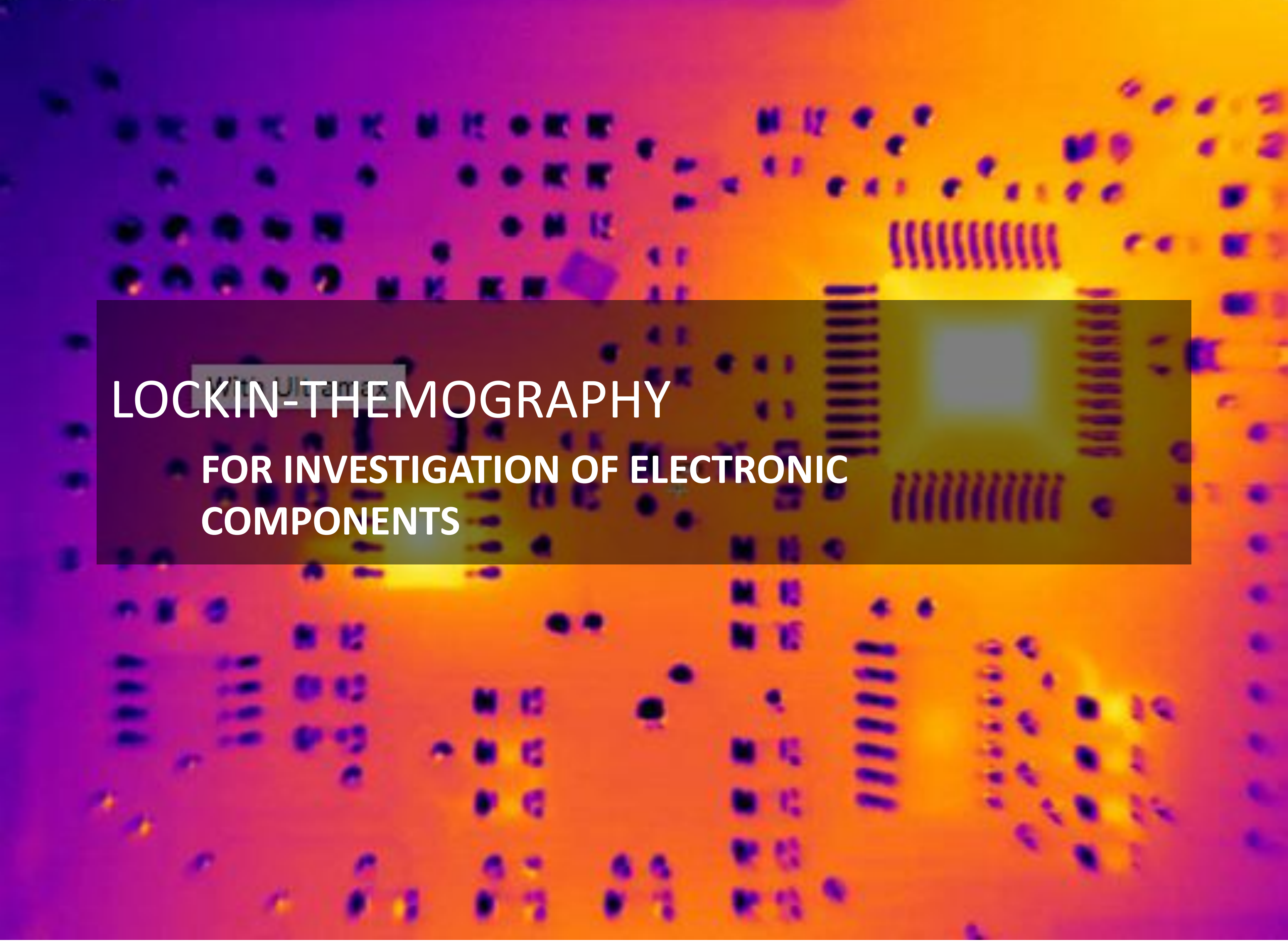
Software: DisplayImg

Laser: LTvis 250 NT

Optional: LTvis cabinet

# SUMMARY

- After a calibration, metallography can often be replaced
- For one spot measurements Foratherm is suited perfectly
- Imaging photothermal radiometry is now possible with highspeed IR cameras and edevis hard- and software
- Both methods reduce costs and increase reliability
- Lab systems and industrial test stands availably

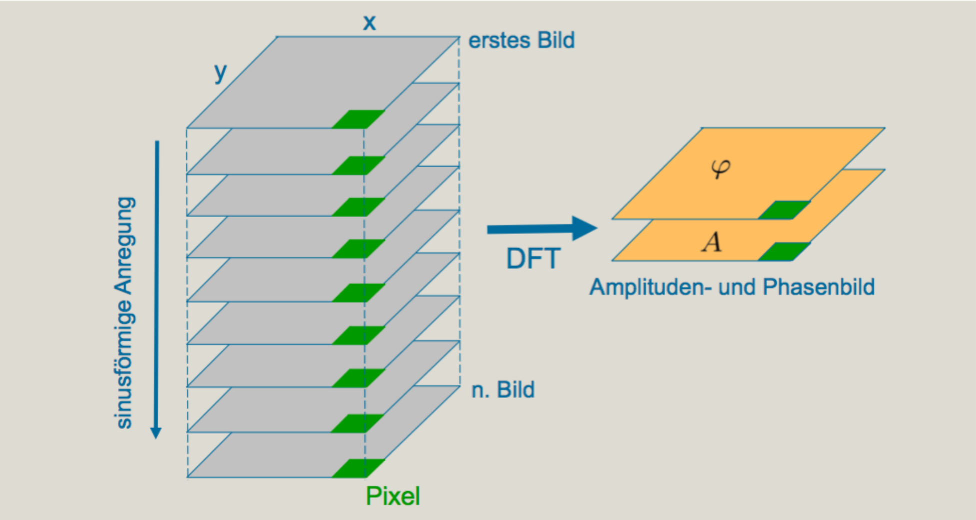


# LOCKIN-THEMOGRAPHY

## FOR INVESTIGATION OF ELECTRONIC COMPONENTS

# WHY LOCK-IN?

- **Lock-In Thermography** is well known and widely used in active thermography. Typical applications are non-destructive material testing and material characterization
- This powerful technique can help to see **smallest temperature differences** in electronic components with **increased contrast** and **improved spatial resolution** avoiding thermal undesired dissipation effects
- The technique can be combined with current FLIR cameras such as FLIR A655sc, FLIR A6750sc, or T1030sc



# SYSTEM CONFIGURATION

FLIR R&D Camera

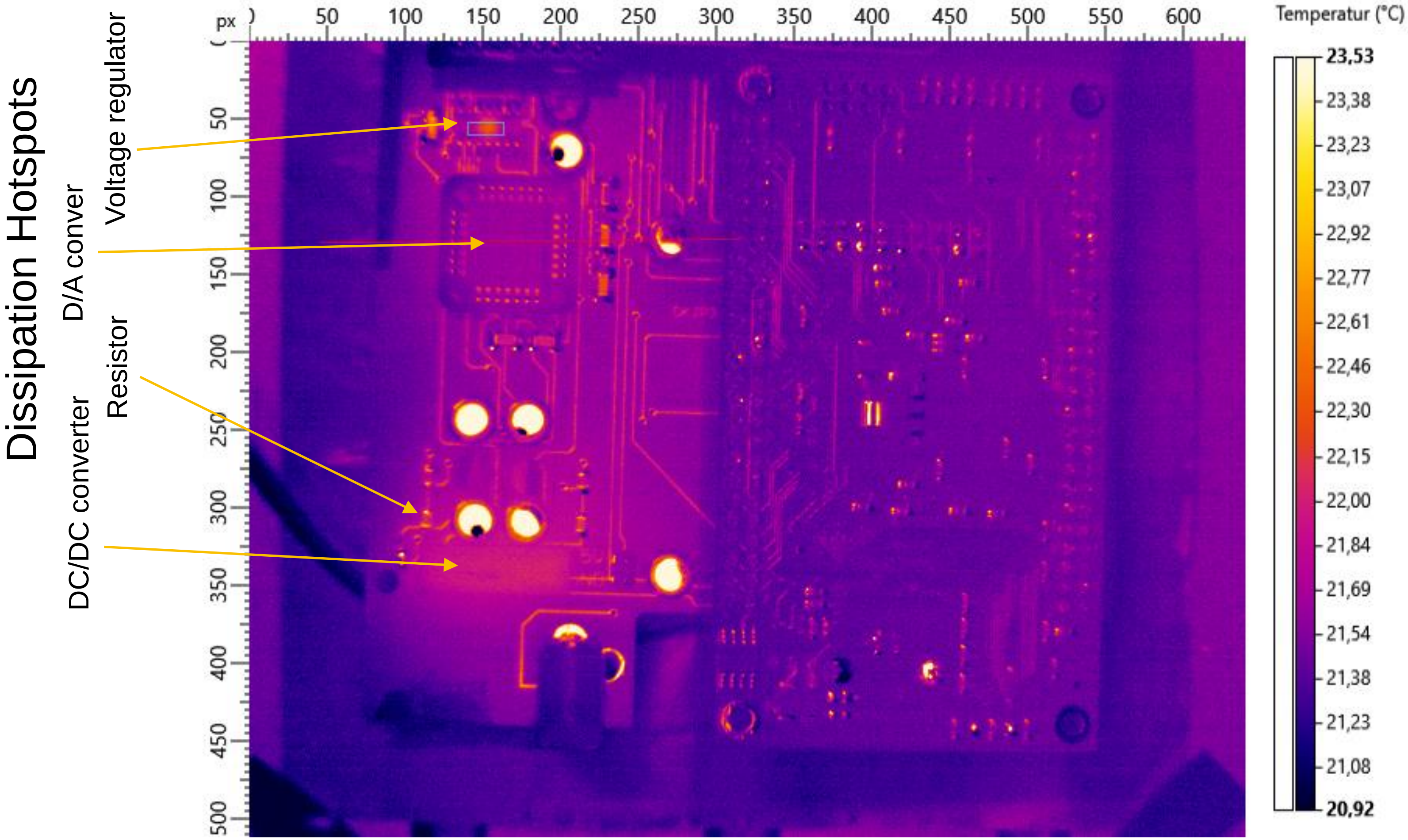



Standard Core i7 computer

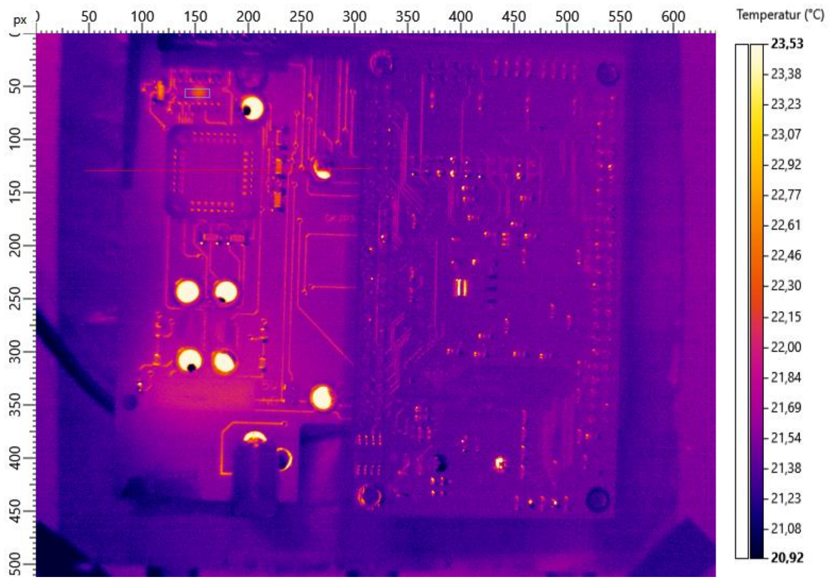

Edevis signal generator
and power switch


Standard power supply

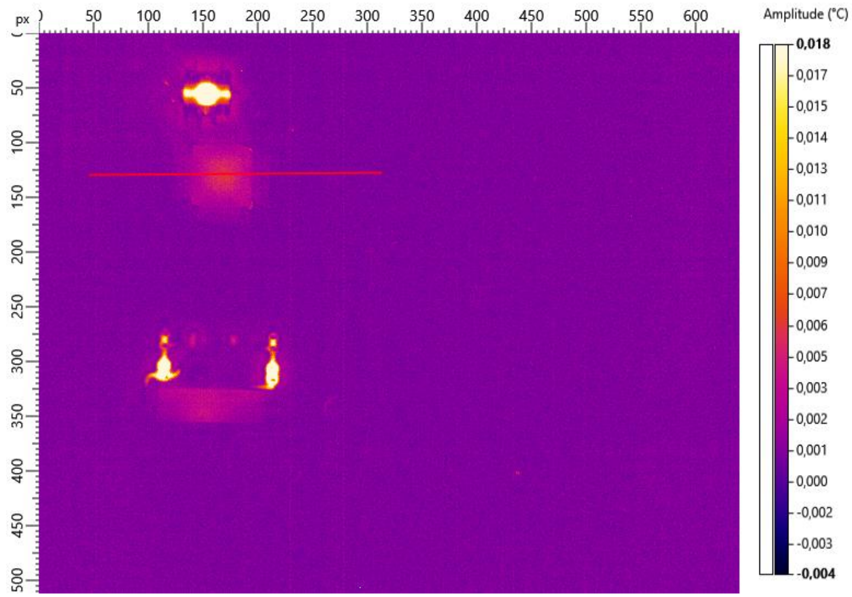
# TEMPERATURE IMAGE



# TEMPERATURE VS. LOCK-IN

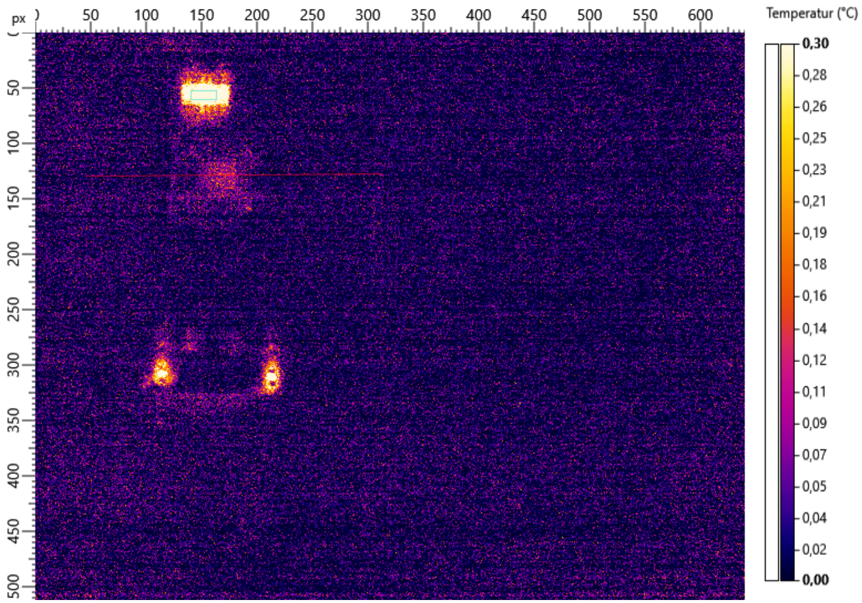



Temperature image.
Overall temperature distribution is visible.

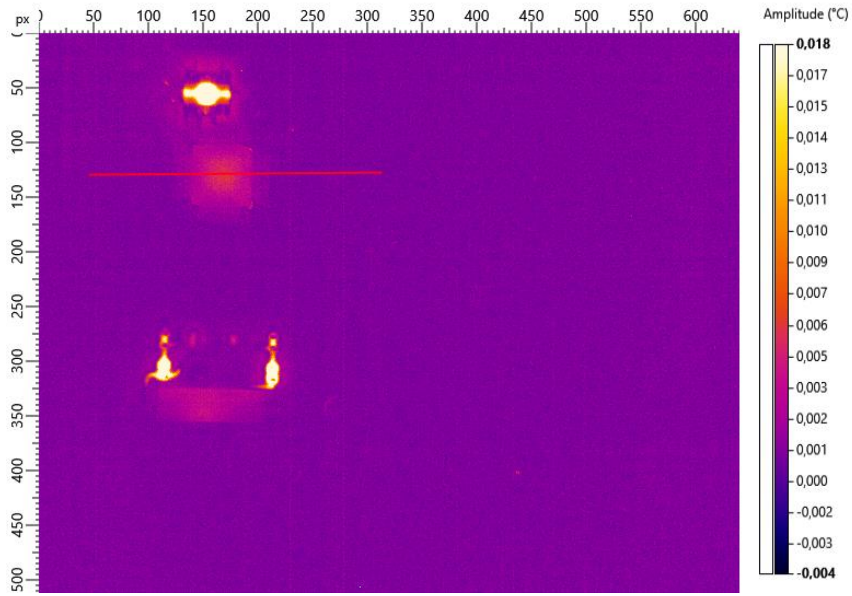



Lock-In Amplitude at 0,5 Hz.
Areas of local dissipation are highlighted selectively.

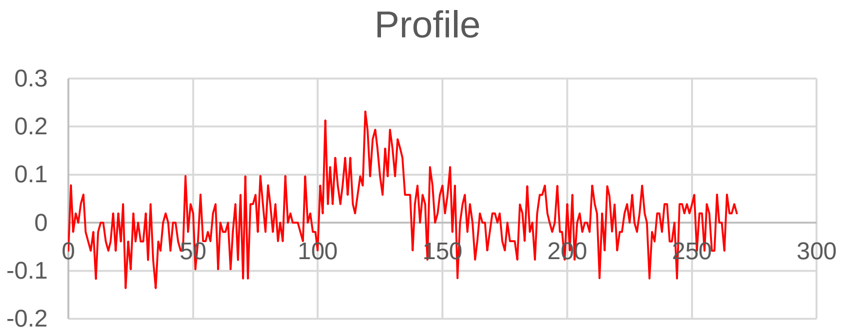
# TEMPERATURE VS. LOCK-IN

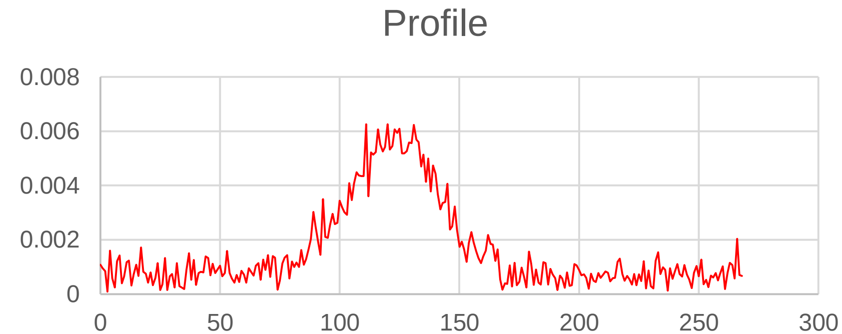



Temperature increase 4s after start of heating




Lock-In Amplitude at 0,5 Hz.
Measured difference: 6mK



# CONCLUSIONS

- Lockin technique can significantly increase system sensitivity
- Spatial resolution is increased as well due to reduction of thermal diffusion length
- Emissivity effects are suppressed
- Compatible to many existing cameras