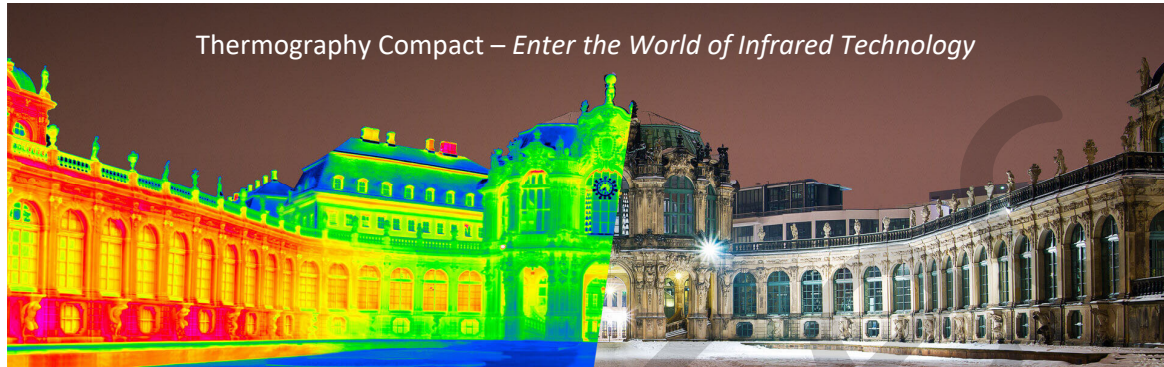


InfraTec, Thermography and You

Greetings from Dresden / Germany



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Thermography Compact – Enter The World of Infrared Technology

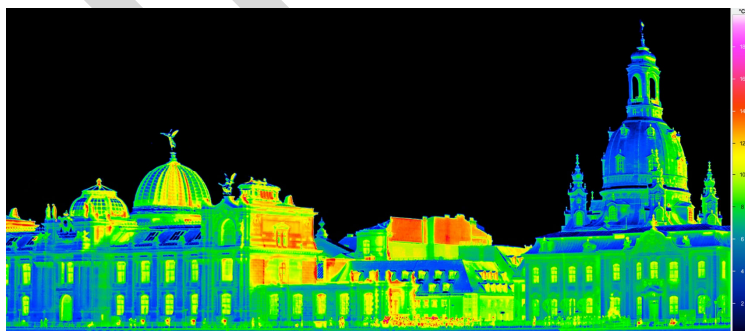
© Maik W / fotocommunity.de

1

InfraTec, Thermography and You

Overview

- ❑ Founded and based in Dresden in 1991
- ❑ Staff: 250
- ❑ Focus on Infrared Technologies
- ❑ Two business units: **Sensor Division** and **Infrared Measurement Division**



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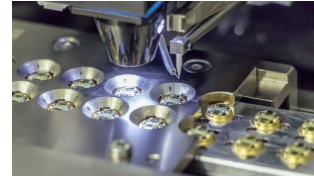
Thermography Compact – Enter The World of Infrared Technology

3

Sensor Division

Single and Multi Channel Pyroelectric Detectors

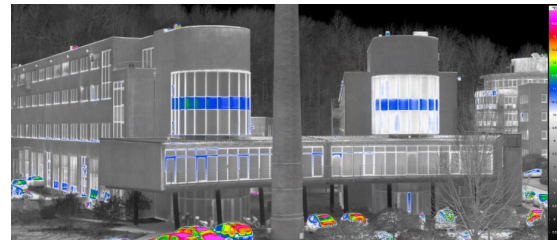
- ❑ Development, engineering and production of pyroelectric analogue and digital infrared detectors
- ❑ Production in 1,500 m² clean-room area in Dresden
- ❑ Modular concept with 50 standard detectors offers optimised solutions for nearly each application demands
- ❑ Development and production of customised single and multi channel IR detectors for:
 - ❑ Pyrometry
 - ❑ Gas and flame analysis
 - ❑ Heat and fire detection
 - ❑ Optical measurements



Infrared Measurement Division

Development, Design and Production of Thermographic Solutions

- ❑ **Thermographic systems** for:
 - ❑ Research and development
 - ❑ Non-destructive testing
 - ❑ Process and quality control



- ❑ **Turnkey solutions** for:
 - ❑ Process monitoring
 - ❑ Automatic fire detection
 - ❑ Surveillance

- ❑ Thermography **Training** courses
- ❑ Thermographic **Services**
- ❑ Thermographic **Software**
- ❑ Pre- & after-Sales **Support**



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In-time After-sales Customer Service for High System Availability



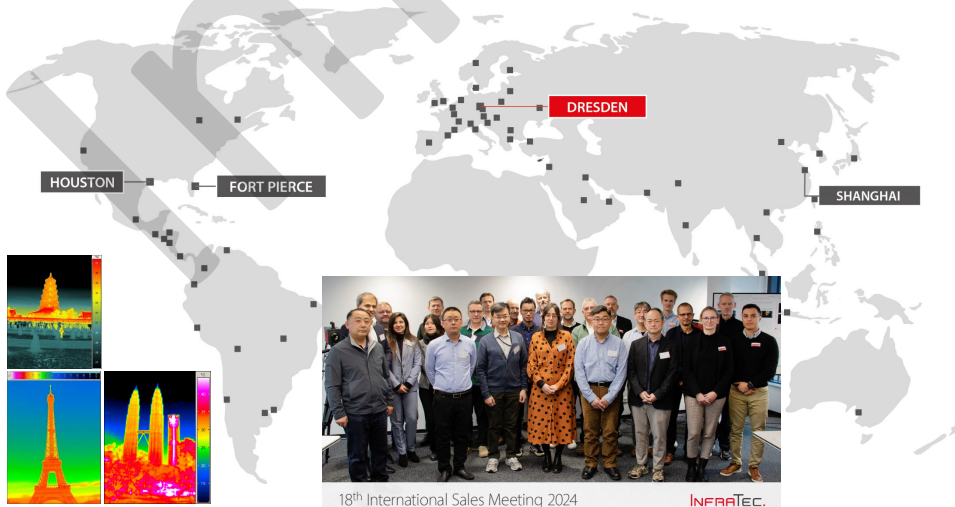
- ❑ > 30 years of thermography experience made available for our customers by:
 - ❑ Well designed products
 - ❑ Comprehensive application support
 - ❑ Feasibility studies
 - ❑ Qualified trainings at our headquarters and at customer sites
- ❑ Rental and lending service
- ❑ Up to 4 years guarantee (std. 2 years)
- ❑ Fast service response (24 h hotline)
- ❑ ISO 9001 certified



Management System
ISO 9001:2015
www.tuv.com
ID: 910500598

InfraTec, Thermography and You

Experts and Technology where They Are Needed



18th International Sales Meeting 2024

INFRAtec.

InfraTec, Thermography and You

Experts and Technology where They Are Needed

- More than 8,000 thermography solutions for customers all over the world



InfraTec, Thermography and You

Partner of Research and Science

- InfraTec regularly expands its know-how in the field of thermography by participating in cooperation of various research projects, like:



Crack Detection in Steel Production

The AMPLAST Research Project



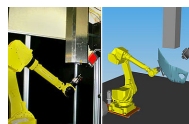
The ImageIR® 8300 hp in Use for Research Applications

The SPIRIT Research Project



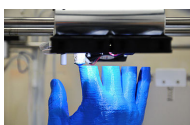
Inspection of CFRP Compounds and Components

The GEWOL Research Project



Automated Crack Detection on Forging Parts

The ThermoBot2 Research Project



More Efficiency in Laser Sintering with Plastics

The HiPer-LS Research Project



Thermographic Process and Quality Monitoring for Dissimilar Lightweight Designs

The LaserLeichter Research Project

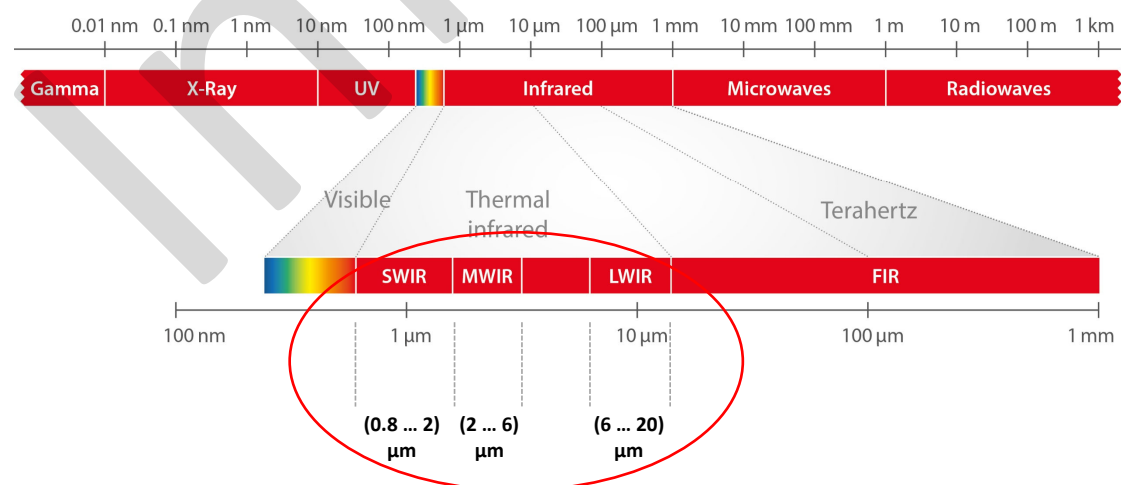
InfraTec, Thermography and You

Definition

- ❑ **Thermography** = Contactless (!) imaging & measuring (!) InfraRed radiation with FPA detectors
- ❑ **IR Radiation** = ?

InfraTec, Thermography and You

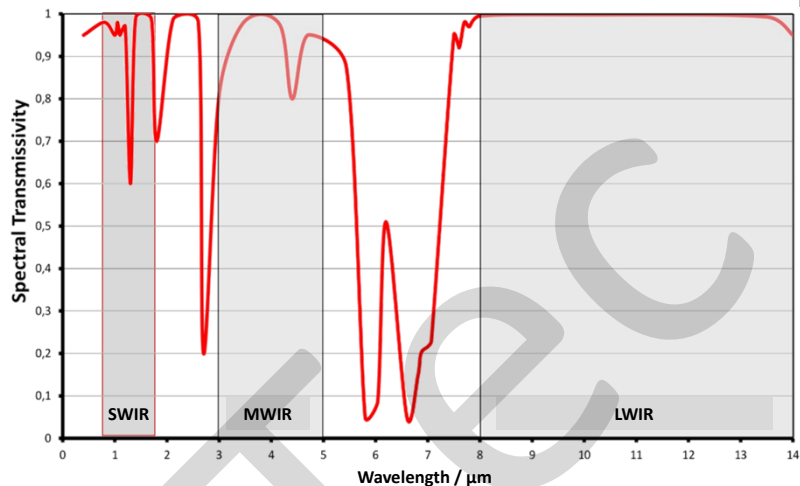
Electromagnetic Spectrums Detected by Thermographic Systems



InfraTec, Thermography and You

Transmission in Atmosphere Depends Greatly on the Wavelength

- ❑ First imaging applications of infrared was for long distances (Forward Looking InfraRed)
- ❑ **Atmosphere is absorbing** due to water, pollution, dust and gases
- ❑ So Mid Wave Infrared Range **MWIR** and Long Wave Infrared Range **LWIR** are best spectral ranges for **IR-detecting instruments**
- ❑ **Therefore, most IR cameras are working within MWIR od LWIR!**
- ❑ Short Wave Infrared Range **SWIR** is used as well for radiometric measurements in laboratory conditions and for high temperatures



InfraTec, Thermography and You

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- ❑ **MWIR & LWIR** = Most efficient and used IR ranges for (temperature) measurements

InfraTec, Thermography and You

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- ❑ **FPA Detector** = ?

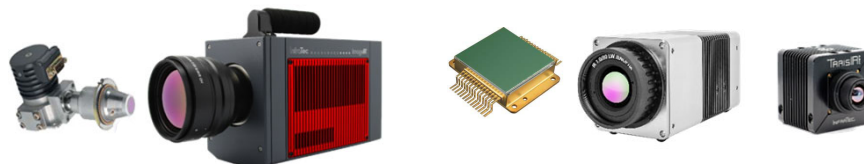
InfraTec, Thermography and You

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- ❑ **FPA Detector** = 2-dim array of sensors (= pixels) for IR radiation

InfraTec, Thermography and You

Typical Specifications of Infrared Detectors



Cooled Quantum Detectors

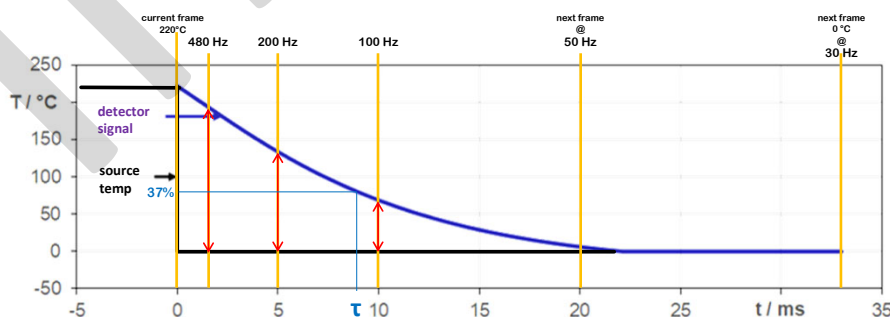
Uncooled Thermal Detectors (Microbolometers)

Materials	MCT, InSb, SLS, QWIP @ ~77 °K; InGaAs	a-Si, VOx
Spectral range	SWIR, MWIR, LWIR	LWIR
Thermal sensitivity	≤ 20 (10) mK	< 30 mK
FPA size	Up to (2,560 × 2,048) IR pixels / 5 µm PP	Up to (1,024 × 768) IR pixels / 17 µm PP
Stability / homogeneity	Very high	„Acceptable“ – (range of quality available)
Time resolution	IT: (< 1 ... > 20,000) µs – up to 105,000 fps	(Thermal) Delay: ~10 ms – around 30 / 50 fps
Acquisition mode	Snap shot	Line-by-line / Rolling shutter
Long-term operation	Mechanical (Stirling) cooler operation	Maintenance free
Investment	High	Low

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Time Delay of Thermal Detectors

- ❑ The time delay τ of microbolometers is caused by heating-up and cooling-down of the IR absorber.
- ❑ τ is the time of the signal change to 63 % of the final value; $\tau = (8 \dots 10)$ ms
- ❑ Final value reached after about $(2 \dots 3) \cdot \tau$ (about $(20 \dots 25)$ ms)

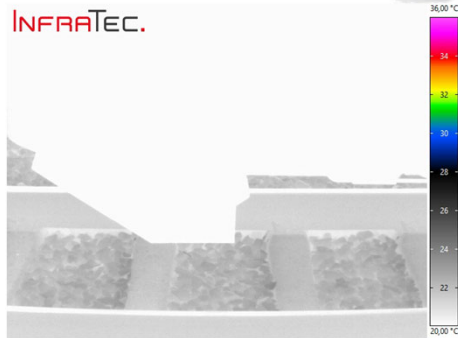


- ❑ Higher frame rates than about $(30 \dots 50)$ Hz of thermal detectors will decrease the measurement range dynamics.

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Snapshot vs. Rolling Shutter

(Cooled) Quantum Detectors



- ❑ Snapshot (all pixels acquired @ once) with short integration time

(Uncooled) Thermal Detectors (Microbolometers)

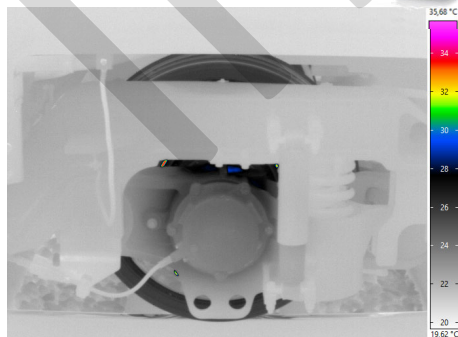


- ❑ Rolling shutter (line-by-line acquisition)

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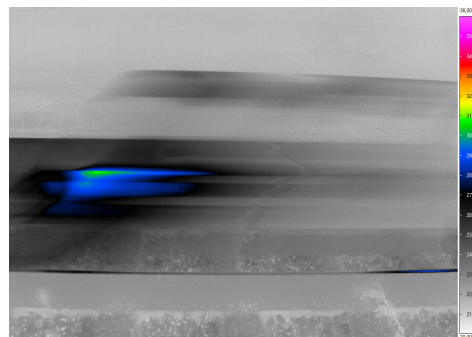
Snapshot vs. Rolling Shutter

(Cooled) Quantum Detectors



- ❑ With short integration time the scene in each image can be “frozen” perfectly

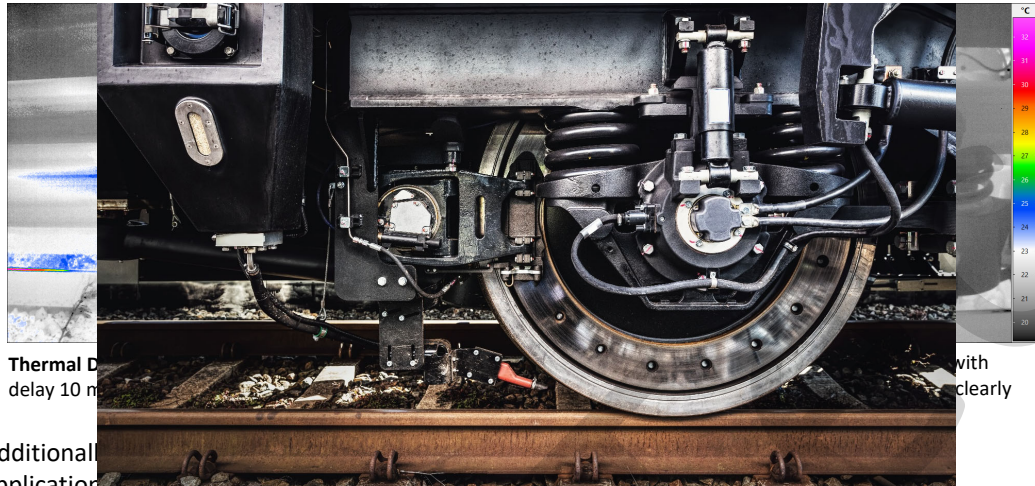
(Uncooled) Thermal Detectors (Microbolometers)



- ❑ Rolling shutter (line-by-line acquisition) “mixes up” the scene depending on speed and movement direction

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Comparison Detector Types – Passing Train Wheel



- Additional applications with fast movements

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Definition

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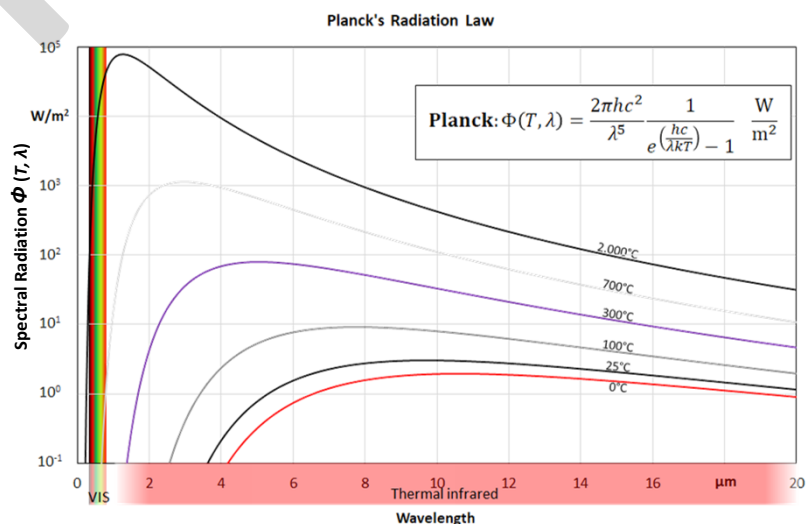
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- ❑ **Measurement** = **Calibration** of the detected IR radiation into absolute temperature values

InfraTec, Thermography and You

IR Radiation → Temperature

- ❑ Every material / object is radiating electromagnetic radiation @ $T > 0 \text{ K}$ (-273.15 °C)
- ❑ → (IR) Radiation is always and everywhere!!!
- ❑ **Planck's Law:**
Spectral radiation $\Phi_\lambda = f(T, \lambda)$



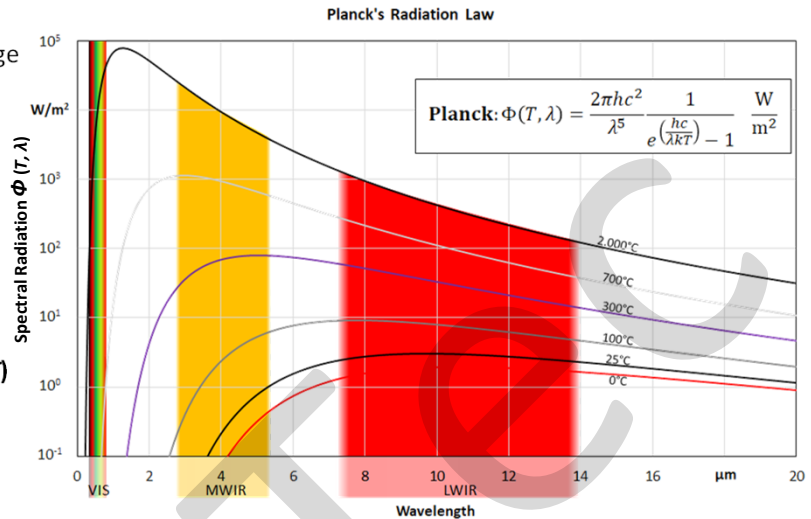
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IR Radiation → Temperature

- IR cameras are integrating over the MWIR or LWIR sensitive range
→ „Thermal wavebands“
→ „Thermal radiation“

- MWIR camera:
Sum ($\Phi_{\lambda(3 \dots 5) \mu\text{m}}$): $\Phi_{MW} = f_{MW}(T)$

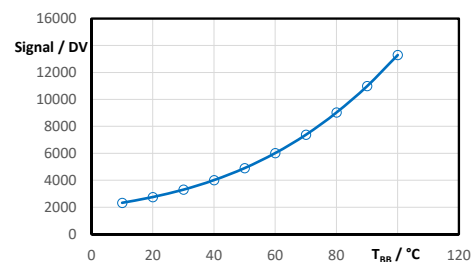
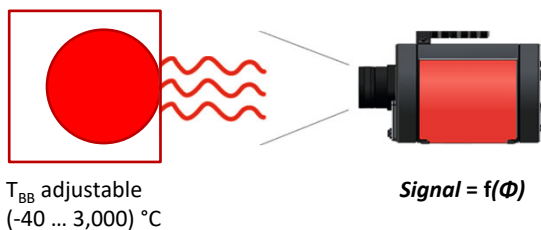
- LWIR camera:
Sum ($\Phi_{\lambda(7 \dots 14) \mu\text{m}}$): $\Phi_{LW} = f_{LW}(T)$



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IR Radiation → Temperature: Calibration

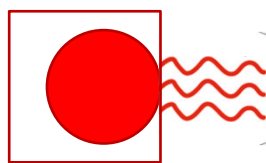
- A calibration is performed by using reference sources, called **Black Bodies**
- BBs are available for (-40 ... 3,000) °C equivalent radiation for MWIR and LWIR
- BBs are calibrated periodically
- Principle calibration process:
 - Camera temperature T_{cam} needs to be considered (rem.: IR radiation is always and everywhere!)



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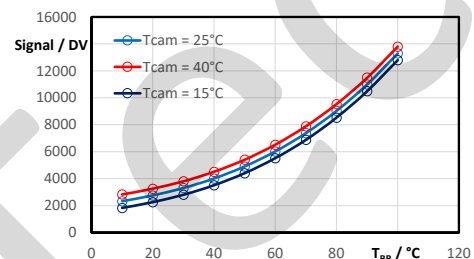
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- ❑ BBs are calibrated periodically
- ❑ Principle calibration process:
 - ❑ Camera temperature T_{cam} needs to be considered (rem.: IR radiation is always and everywhere!)



T_{BB} adjustable
(-40 ... 3,000) °C

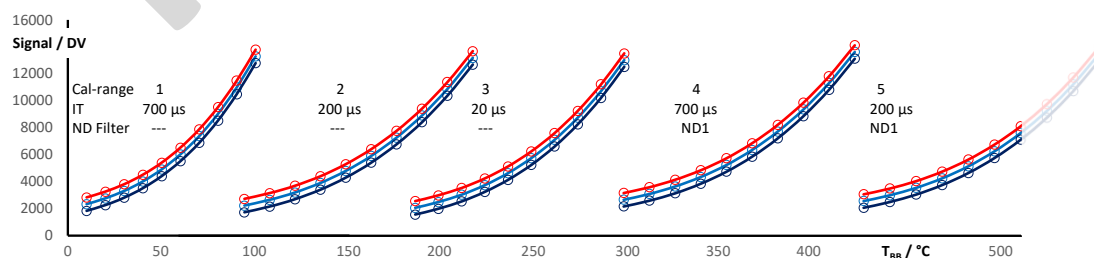
$Signal = f(\Phi)$



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IR Radiation → Temperature: Calibration

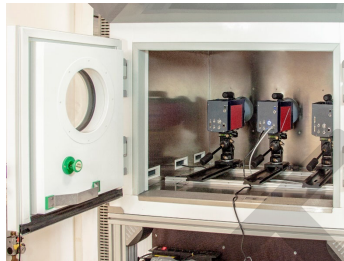
- ❑ Change of calibration ranges is performed by change of camera sensitivity by changing the **integration time IT** (equivalent to the exposure time)
- ❑ Depending on detector model a saturation will happen with high radiation/temperature
- ❑ Using optical **Neutral Density – ND – filters** to reduce the radiation allows calibrations up to 3,000°C (limited by the Black Body)



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Calibration – Automatized, Precise and Customized

- ❑ High-precision calibration incl. **calibration certificate** for measuring ranges of **(-40 ... 3,000) °C**
- ❑ **At least 3 response curves** incl. main response and at least two additional responses to compensate camera-body's temperature variations are assuring reliable and repeatable measurements even under changing ambient temperature conditions.
- ❑ Simultaneously, **automatized calibration** of multiple systems
- ❑ Generation of **customer-specific calibration ranges** (e. g. for / with spectral filters)



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Theory and Reality

- ❑ Black Body used as reference but **“real” objects / materials are different** due their optical properties:

- | | | |
|---|---------------------------------------|--------------------------|
| ❑ Emissivity / Emission coefficient ϵ: | Capability to emit (IR) radiation | $0 \leq \epsilon \leq 1$ |
| ❑ Transmissivity / Transmission coefficient τ: | Capability to transmit (IR) radiation | $0 \leq \tau \leq 1$ |
| ❑ Reflectivity / Reflection coefficient ρ: | Capability to reflect (IR) radiation | $0 \leq \rho \leq 1$ |

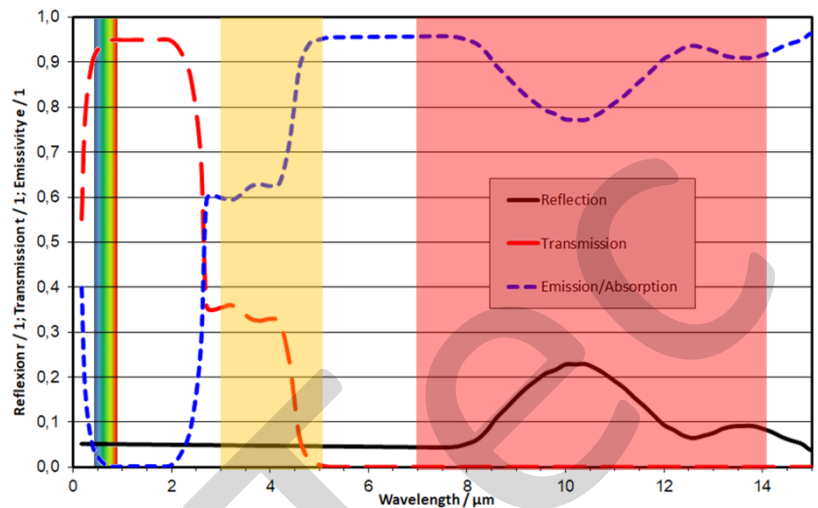
$$\epsilon_{\lambda} + \tau_{\lambda} + \rho_{\lambda} = 1$$

- ❑ **$(\epsilon, \tau, \rho = f(\lambda))$**

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Example: ϵ , τ , ρ of Glass

- ☐ IR spectral optical properties of glass
- ☐ For MWIR glass is partly transparent
- ☐ For LWIR glass is partly reflecting



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Special “Radiators”

- ☐ Special cases:

- ☐ $\epsilon = 1$ $\rightarrow \tau = \rho = 0 \rightarrow$ “Black Body”
- ☐ $\tau = 1$ $\rightarrow \epsilon = \rho = 0 \rightarrow$ “Perfect (IR) window”
- ☐ $\rho = 1$ $\rightarrow \tau = \epsilon = 0 \rightarrow$ “Perfect (IR) mirror”

- ☐ For most measurements we are assuming a “Grey Body”:

- ☐ No transparency ($\tau = 0$) $\rightarrow \epsilon + \rho = 1$ $\rightarrow \rho = 1 - \epsilon$
- ☐ Emissivity ϵ is constant within the detected IR band (MWIR / LWIR) $\rightarrow \epsilon \neq f(\lambda) = \text{const.}$

- ☐ With $\tau = 0$ we are consequently **measuring on the surface** of the objects
- ☐ Knowing the emissivity ϵ , also the reflectivity ρ is known

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Measurement Correction for Grey Bodies

- ❑ Finding T_{obj} by correction calculation when $\epsilon < 1$:
- ❑ You know ϵ and $\rho (= 1 - \epsilon)$ of the object and the reflected ambient temperature T_{amb}
 → Algorithms will calculate correct temperature of the object

$$(\Phi_{\text{obj}}(T_{\text{obj}}) = (\Phi_{\text{meas}} - \Phi_{\text{amb}}(T_{\text{amb}}) \cdot (1 - \varepsilon)) / \varepsilon \quad \rightarrow \text{Calibration function: } T_{\text{obj}} = f(\Phi_{\text{obj}}))$$

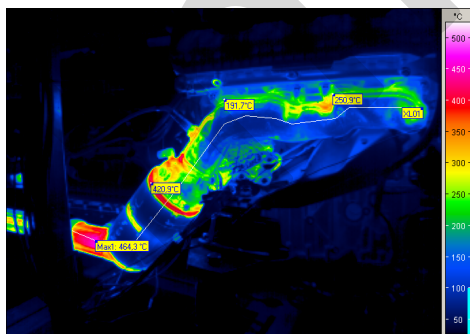
- You don't know ϵ and T_{amb} ?

→ Paint object surface with high-emissivity paint $\epsilon = 1 \rightarrow \rho = 0$ (= Black Body)

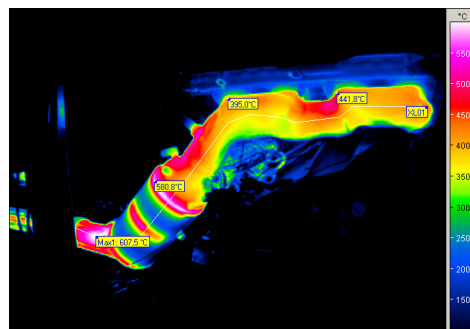
$((\Phi_{\text{obj}}(T_{\text{obj}}) = \Phi_{\text{meas}} \rightarrow \text{Calibration function: } T_{\text{obj}} = f(\Phi_{\text{meas}}))$

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Correct Measurement of an Exhauster by Taking Care of Its Emissivity



- ❑ Operating exhauster with reflecting surface
- ❑ Higher temperatures are only indicated where self-blackening effects occur
- ❑ Emissivity value needs to be adjusted regionally



- ❑ Operating exhauster with blackened surface
- ❑ No problem in determining the absolute temperature

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 - ❑ **Thermal Detectors (μ-Bolometers):** Rolling shutter, no cooler, cheap, LWIR
- ❑ **Measurement** = Calibration of the detected IR radiation into absolute temperature values
 - ❑ **Calibration** on accurate references allows absolute accuracy of $\pm 1\%$ of reading; possible range (-40 ... 3,000) °C
 - ❑ **Emissivity ϵ** (0 ... 1) is a material-dependent value which requires correction of T-measurement (by software)

→ Thermography is an imaging method of precise and contactless temperature measurement!

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Characteristics of IR Cameras

The measurement precision of a camera is based on three key characteristics & demands:

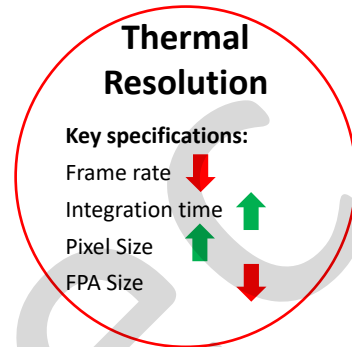
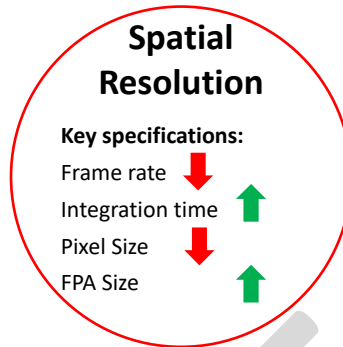
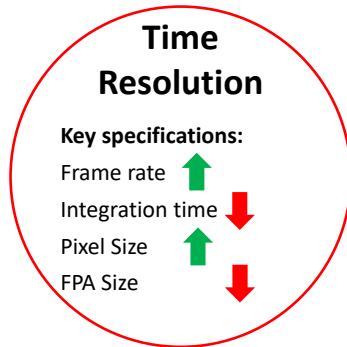
- ❑ **Thermal resolution**
 - ❑ Smallest temperature difference – commonly expressed by the **Noise Equivalent Temperature Difference**
- ❑ **Spatial resolution**
 - ❑ Number of pixels (**FPA size**)
 - ❑ Pixel size
 - ❑ Lenses → **Field of View** & instantaneous **Field of View (FOV & iFOV)**
- ❑ **Time resolution**
 - ❑ **Speed** (frame rate) → frames per second **fps or Hz**
 - ❑ **Integration time** (similar to „exposure time“) for photon detectors (**μs to ms**)
 - ❑ **Time delay** for thermal detectors (**ms range**)

These three parameters of a camera system are not independent from each other!

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Characteristics of IR Cameras

- Three essential (technical) characteristics for IR camera systems can be condensed:

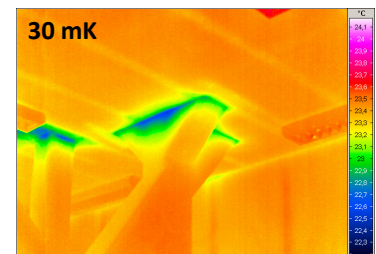
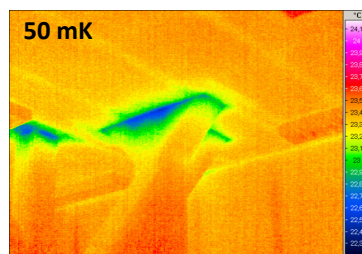
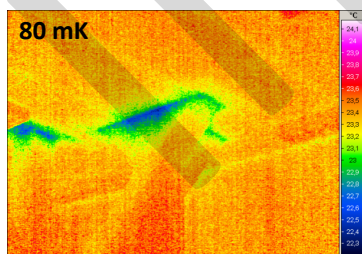


- It is not easy to have a camera or set-up with perfect resolutions all together.
(e.g. with "Binning" technology InfraTec did realise that → stay tuned!)

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Thermal Resolution – Small Numbers Big Effect

- The thermal sensitivity of a radiometric IR camera is defined by the Noise Equivalent Temperature Difference, NETD expressed in Millikelvin mK → **the lower the better**:

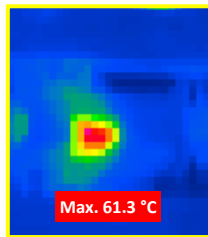
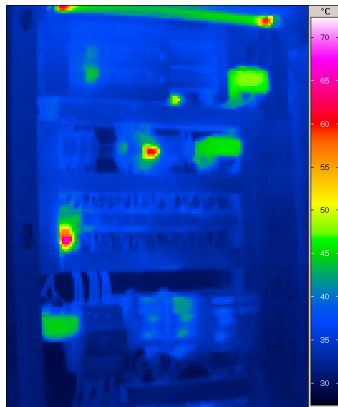


Measurement conditions

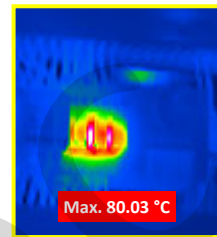
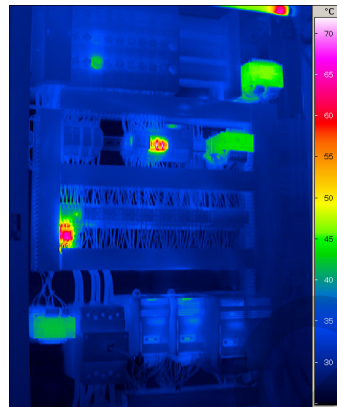
- Complex heat stream
- Very small temperature range displayed (only 2 K)
- Examples taken with uncooled μ -bolometer camera model

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Spatial Resolution is Essential for Correct Measurements



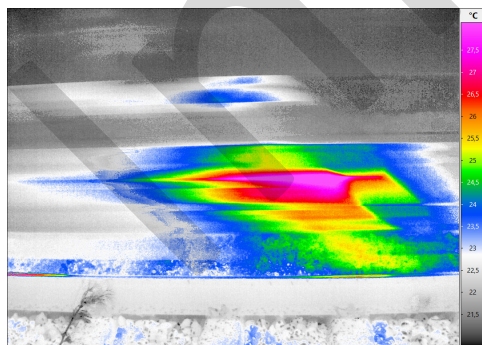
Incorrect measurement of absolute temperature as insufficient number of (120 × 160) IR pixels



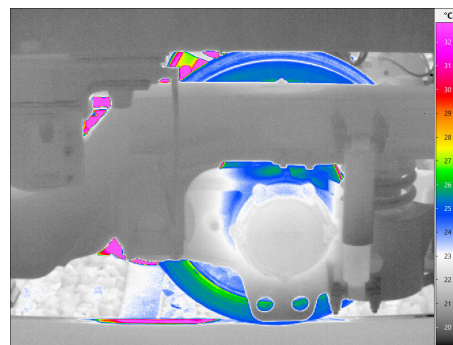
Correct measurement of absolute temperature as object details are sufficiently resolved by (1,280 × 960) IR pixels

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Time Resolution is Required for Fast Objects



Thermal Detector: Line-by-line acquisition plus time-delay 10 ms results in smearing & morphing



Quantum Detector: Snapshot acquisition with low Integration Time resolves movements clearly without smearing

- Additionally adjustable integration times of cooled cameras supporting measurements of applications with fast movements

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Rough Guideline along the Camera Characteristics

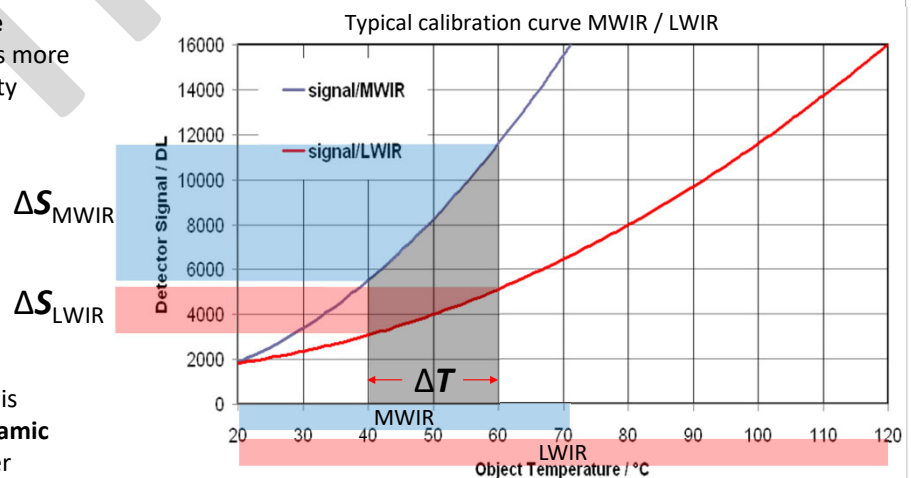
- ☐ You need **high frame rate** (= best time resolution) → **Quantum detector** camera!
- ☐ You need to monitor (single) **short lasting events** → **Quantum detector** (short IT, sync, trigger)
- ☐ You need **highest thermal resolution** → **Quantum detector** (MWIR preferred)
- ☐ You need **big FOV** → **μ-B & QD** with selected lenses
- ☐ You need **big FOV & small iFOV** → **μ-B (1,024 × 768)** with selected lenses
QD (2,560 × 2,048) with selected lenses
- ☐ You need **microscopic iFOV** → With microscopic lenses
iFOV (μ-B) ~ 17 μm
iFOV (QD) ~ 1.3 μm
- ☐ You need **active thermography** → **QD** preferred (sync, trigger, fast, sensible)
μ-B possible for non-metallic materials
- ☐ You need **more?** → Just ask **the specialists @ InfraTec!**



InfraTec, Thermography and You

MWIR or LWIR?

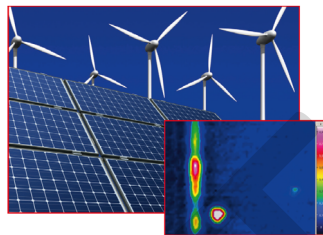
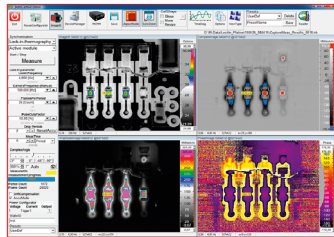
- ☐ For **precise T-difference measurements** **MWIR** is more useful – higher sensitivity
- ☐ On the other side **LWIR** is more useful **higher dynamic range / cal range** – wider measurement range



InfraTec, Thermography and You

InfraTec's IR Solutions

- ☐ Cameras
- ☐ Software
- ☐ Turnkey solutions



InfraTec, Thermography and You

Camera Product Categories – Website: <https://www.infratec.eu/thermography/infrared-camera/>



High-End Solutions

- ☐ Meet the highest demands



Compact Cameras

- ☐ Small, lightweight and robust



OEM Camera Modules

- ☐ System Integration



System Cameras

- ☐ Industrial and laboratory use



Infrared Radiometric Zoom Cameras

- ☐ Precision at long distance ranges

InfraTec, Thermography and You

InfraTec Is Supplier of Jenoptik® LWIR μ -Bolometer Cameras: **VarioCAM® HD(x)**



1,024 768 Detector	1,200 °C 2,000	PoE
2,048 1,536 MicroScan	±1 %	Trigger
GigE 240 Hz	≥ 20 mK	IP67

VarioCAM® HD head

- ❑ (1,024 × 768) IR pixels native
- ❑ (2,048 × 1,536) IR pixels MicroScan
- ❑ 30 Hz FF / 60 Hz HF / 120 Hz QF / 240 Hz Line
- ❑ 15 / 30 / 60 / 120 mm lenses
- ❑ M=1× lens (iFOV 17 μ m)

VarioCAM® HDx head

- ❑ (640 × 480) IR pixels native (HDx)
- ❑ 30 Hz FF
- ❑ 10 / 20 / 30 / 40 / 60 mm lenses

InfraTec, Thermography and You

InfraTec Special Zoom Lens for μ -Bolometer Camera: **VarioCAM® HD Z**

- ❑ Modified **VarioCAM® HD Z** with (1,024 × 768) IR pixels
- ❑ Spectral range **LWIR** (7.5 ... 14) μ m
- ❑ Frame rate: **30 Hz**
- ❑ Focal length: (25 ... 150) mm
- ❑ WFOV: (1,024 × 768): 41.5°
- ❑ NFOV: (1,024 × 768): 6.6°
- ❑ **6× infrared zoom lens**



InfraTec, Thermography and You

Fixed-mount μ -Bolometer LWIR: **TarisIR® mini** – when **SIZE** matters...



Highlights:

- Dimensions/weight (50 × 55 × 55) mm; 220 g
- Pixel Pitch 12 μ m
- Measurement range (-40 ... 600) °C, full **radiometric**
- Lenses 6.2 mm / 13.6 mm / 25 mm
- Interfaces **Gig-E**, 2 × digital I/O
- "M" Version (50 × 30 × 30) mm ; 66 g



Compact Class Camera **TarisIR® mini**

When **SIZE** matters



**640
x
480**
Detektor

Detector: (640 × 480) IR-Pixel

**640
x
480**
50 Hz

Full frame rate: 50 fps

**±2
%**

Accuracy: ± 2 %

**≥ 20
mK**

Thermal resolution
@30°C: **0.02 K**

GigE

High-speed data transfer & **PoE!**

Case

Rugged light **metal housing**

Software

IRBIS® 3 Software & SDK

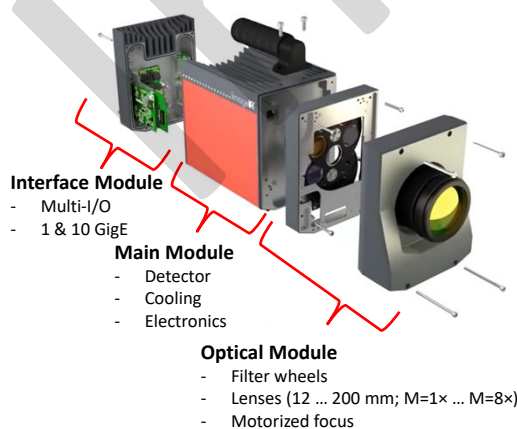
InfraTec, Thermography and You
Cooled High-end Camera Series **ImageIR®**



- ❑ Quantum Detector based
- ❑ MWIR and LWIR ranges
- ❑ More than 10 models for all demands

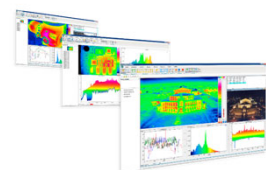


InfraTec, Thermography and You
Modular Concept of ImageIR® Series



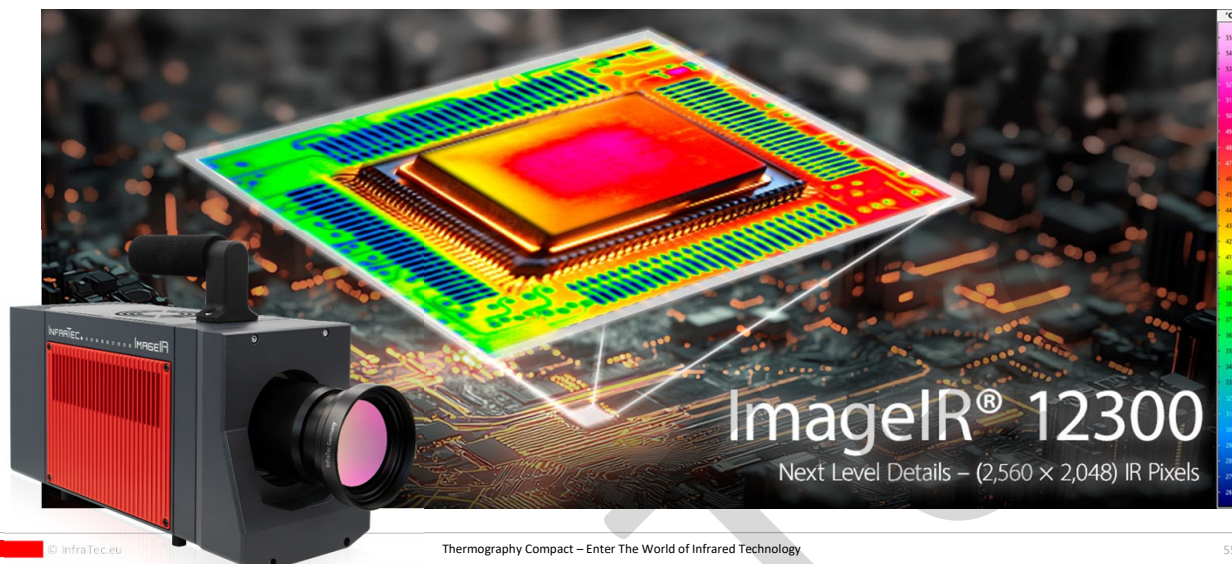
- ❑ **IIR 5300** – *The Fast* (up to 105,000 fps)
- ❑ **IIR 8300** – *The Standard* (640 × 512) – 355 fps / 1,105 fps
- ❑ **IIR 9400** – *The Flexible* (1,280 × 1,024) – **Binning 622 fps**
- NEW** ❑ **IIR 12300** – *The Big* (2,560 × 2,048) – Binning 1,600 fps
- ❑ **IIR 8800** – *The LWIR* (640 × 512) – 232 fps
- ❑ **Big variety of lenses**
12 / 25 / 50 / 100 / **200 mm**
M=1× / M=2.5× / M=3× / **M=8×**

- ❑ **Comprehensive software family IRBIS®**



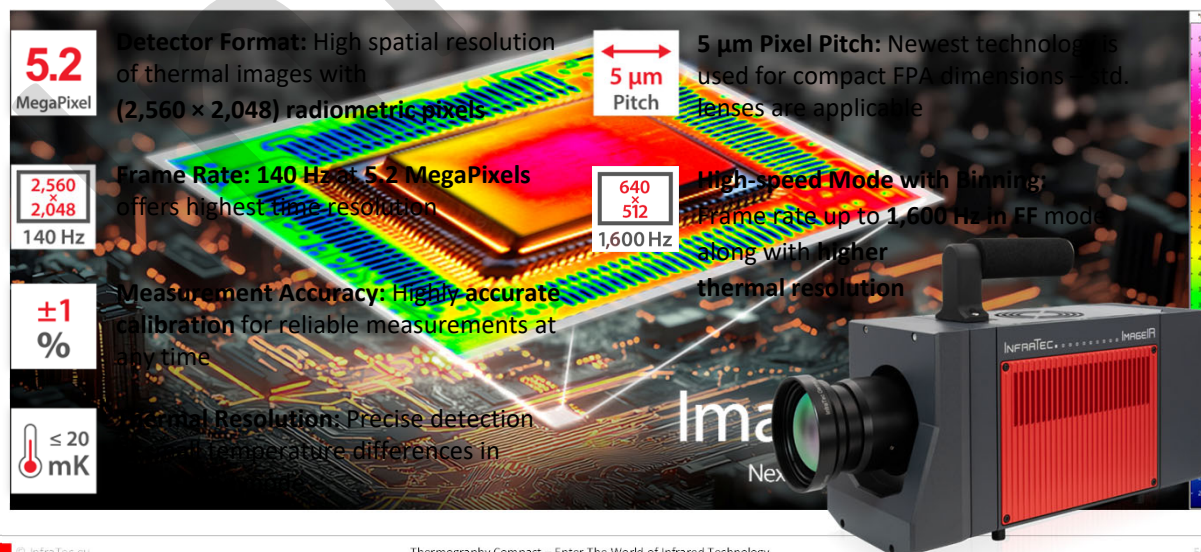
InfraTec, Thermography and You

ImageIR® 12300: Next Level Details!



InfraTec, Thermography and You

ImageIR® 12300: Next Level Details!



InfraTec, Thermography and You

Radiometric SWIR – ImageIR® 8100 / 9100

- ❑ Detectors: **(640 × 512) / (1,280 × 1,024)** IR pixels; InGaAs; TEC-stabilized
- ❑ Pixel pitch **5 µm**
- ❑ Spectral range: **(0.9 ... 1.7) µm**
- ❑ Frame rates:
 - ❑ 8 bit: Up to 237 Hz (VGA), up to 83 Hz (SXGA)
 - ❑ 12 bit: Up to 137 Hz (VGA), up to 56 Hz (SXGA)
- ❑ Temperature measurement range: **(300 ... 1,700)°C**
- ❑ HighSense calibration; measurement accuracy $\pm 1 \%$
- ❑ Integration time (20 ... 20,000) µs
- ❑ **Trigger (IN / OUT), Synchronization**
- ❑ Lens range: 8, 12, 16, 25, 35, 50, 100 mm



InfraTec, Thermography and You

ImageIR® Series – Quantum Detectors

Application related features of the ImageIR® series

- ❑ **Multiple filter wheels**
- ❑ MicroScan
- ❑ Binning
- ❑ High dynamic resolution
- ❑ HighSense
- ❑ Special zoom edition – ImageIR® Z

InfraTec, Thermography and You

Wheel Solutions for Spectral, High Dynamic Range and MicroScan Measurements

Depending on camera model most different filter wheel combinations are possible:

❑ Filter Wheel

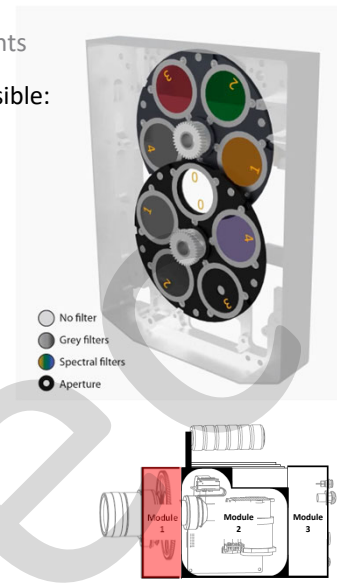
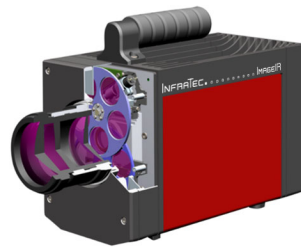
- ❑ Up to 5 (4) filters 1" diameter
- ❑ Max. 1 (2) mm filter thickness
- ❑ Can be combined with aperture wheel

❑ Aperture Wheel

- ❑ Up to 5 (4) filters 1" diameter
- ❑ Max. 1 (2) mm filter thickness
- ❑ Can be combined with filter wheel

❑ Fast Filter Wheel

- ❑ 4, 6 or 7 filters 1" diameter
- ❑ Max. 1 mm filter thickness
- ❑ 5,400 rpm – suitable for detector frame rate up to 360 Hz
- ❑ Can be combined with aperture wheel



→ Unique 35 filter combinations conveniently software controlled

InfraTec, Thermography and You

ImageIR® Series – Quantum Detectors

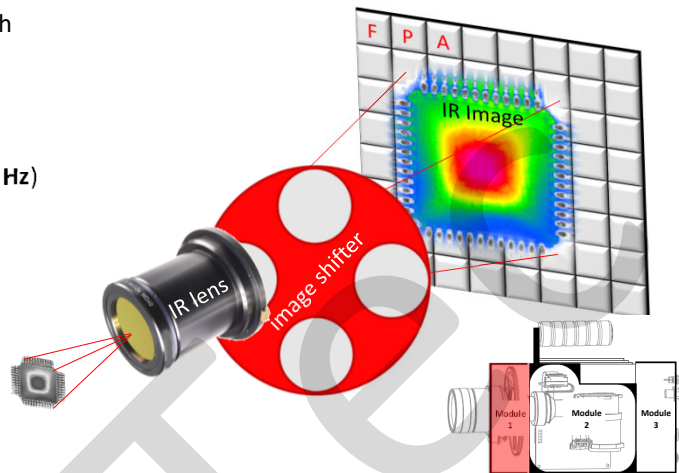
Application related features of the ImageIR® series

- ❑ Multiple filter wheels
- ❑ **MicroScan**
- ❑ Binning
- ❑ High dynamic resolution
- ❑ HighSense
- ❑ Special zoom edition – ImageIR® Z

InfraTec, Thermography and You

ImageIR® Series – MicroScan – 4 Times More Pixels on ImageIR® Series

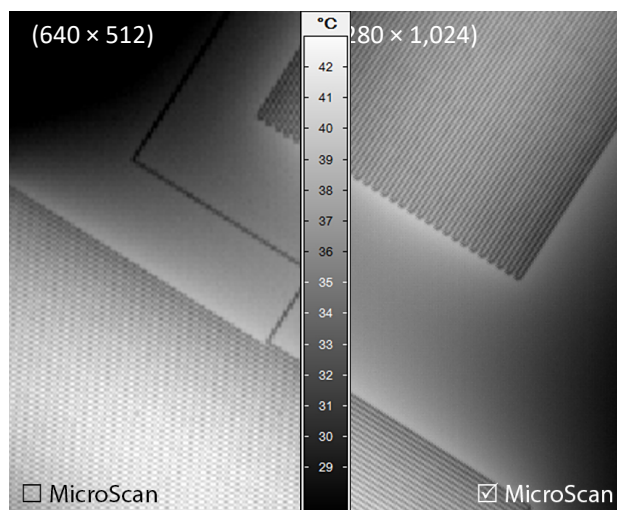
- ❑ Enhancement of spatial resolution by **opto-mechanical shifting** of the optical path
- ❑ **High-speed** rotating **wheel** equipped with optical image-shifters in 4 directions
- ❑ Speed of optical wheel up to **5,400 rpm** (suitable for **detector frame** rate up to **360 Hz**)
- ❑ Up to **(2,560 × 2,048)** IR pixels are possible
- ❑ Can be **combined** with 5-pos **spectral filter** wheel
- ❑ Affordable alternative for high spatial resolution enhancement!



InfraTec, Thermography and You

ImageIR® Series – MicroScan – 4 Times More Pixels on ImageIR® Series

- ❑ Comparison with 75 µm test structure
- ❑ ImageIR® 8300
 - ❑ (640 × 512) → (1,280 × 1,024) IR pixels



InfraTec, Thermography and You

ImageIR® Series – Quantum Detectors

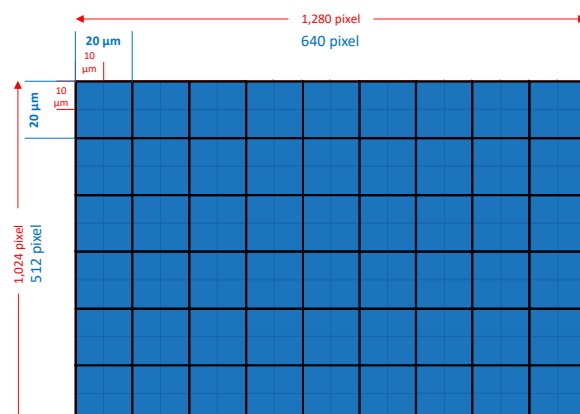
Application-related features of the ImageIR® series

- ☐ Multiple filter wheels
- ☐ MicroScan
- ☐ **Binning**
- ☐ High dynamic resolution
- ☐ HighSense
- ☐ Special zoom edition – ImageIR® Z

InfraTec, Thermography and You

ImageIR® Series – **Binning** – Enhancement of Speed & Sensitivity for ImageIR® Series (Model-dependent)

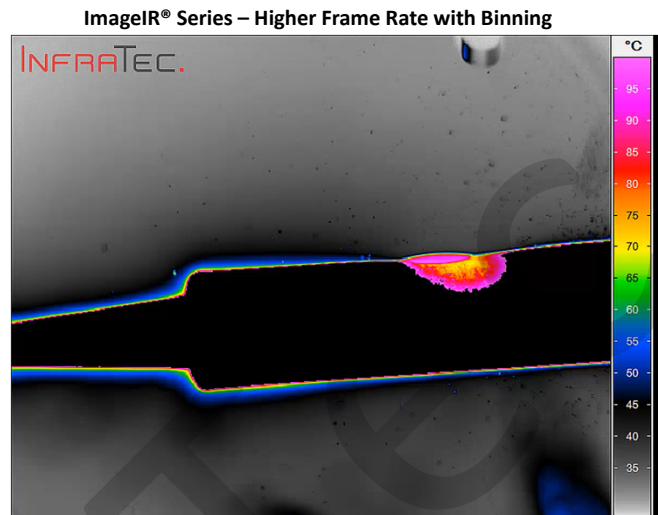
- ☐ Binning: Hardware (!) combination of pixels of an (IR) FPA
- ☐ Resulting in an effective larger new pixel
e. g. : 10 μm $\rightarrow$ 20 μm
- ☐ Advantages of binning:
 - ☐ Larger pixel: Better SNR! $\rightarrow$ **Low NETD**
 - ☐ Less number of pixels: **Higher frame rate!**
 - ☐ **Same FOV** in standard mode (high number of pixels) and binning mode (high speed, low NETD)
 - ☐ You always can switch between both modes just with a click



InfraTec, Thermography and You

- Less number of pixels:
Higher frame rate!
(even higher than just sub-windowing)

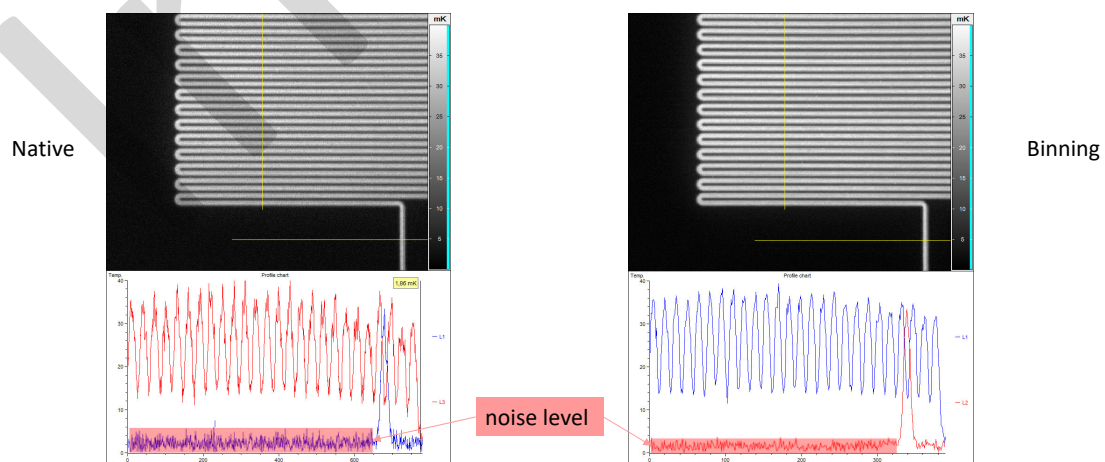
- ImageIR® 9400 @
 - (640 × 512) IR pixels
 - 20 µm pp
 - 630 Hz



InfraTec, Thermography and You

ImageIR® Series – Binning – Higher Sensitivity with Binning

- Larger pixel: Better SNR! → Low NETD → Shorter integration times → Higher frame rate



InfraTec, Thermography and You

Binning Enables 2 Cameras in 1

□ This option will be available for following InfraTec MWIR cooled cameras:

□ **ImageIR® 9400** series with

- "Camera 1": Native (1,280 × 1,024) IR pixels – 10 µm pp @ 180 Hz – NETD < 30 mK
- "Camera 2": Binning (640 × 512) IR pixels – 20 µm pp @ 622 Hz – NETD < 20 mK

□ **ImageIR® 10300** series with

- "Camera 1": Native (1,920 × 1,536) IR pixels – 10 µm pp @ 100 Hz – NETD < 30 mK
- "Camera 2": Binning (960 × 768) IR pixels – 20 µm pp @ 400 Hz – NETD < 20 mK

InfraTec, Thermography and You

Binning Enables 2 Cameras in 1

□ This option will be available for following InfraTec MWIR cooled cameras:

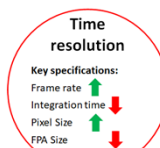
□ **ImageIR® 9400** series with

- "Camera 1": Native (1,280 × 1,024) IR pixels – 10 µm pp @ 180 Hz – NETD < 30 mK
- "Camera 2": Binning (640 × 512) IR pixels – 20 µm pp @ 622 Hz – NETD < 20 mK

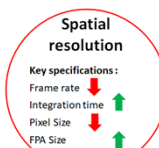
□ **ImageIR® 10300** series with

- "Camera 1": Native (1,920 × 1,536) IR pixels – 10 µm pp @ 100 Hz – NETD < 30 mK
- "Camera 2": Binning (960 × 768) IR pixels – 20 µm pp @ 400 Hz – NETD < 20 mK

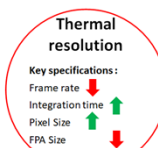
□ 1 purchase → "2 cameras" → 3 advantages:



"Binning"



"Native"



"Binning"

InfraTec, Thermography and You

ImageIR® Series – Quantum Detectors

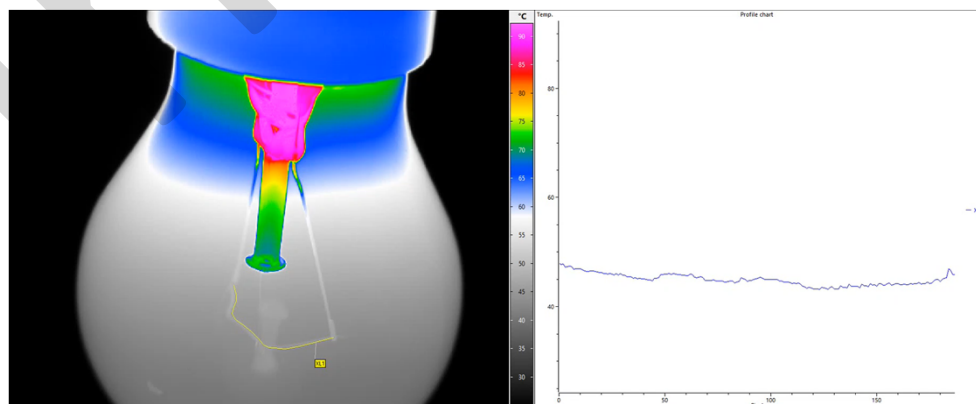
Application related features of the ImageIR® series

- ☐ Multiple filter wheels
- ☐ MicroScan
- ☐ Binning
- ☐ **High dynamic resolution**
- ☐ HighSense
- ☐ Special zoom edition – ImageIR® Z

InfraTec, Thermography and You

ImageIR® Series – High Dynamic Resolution Mode

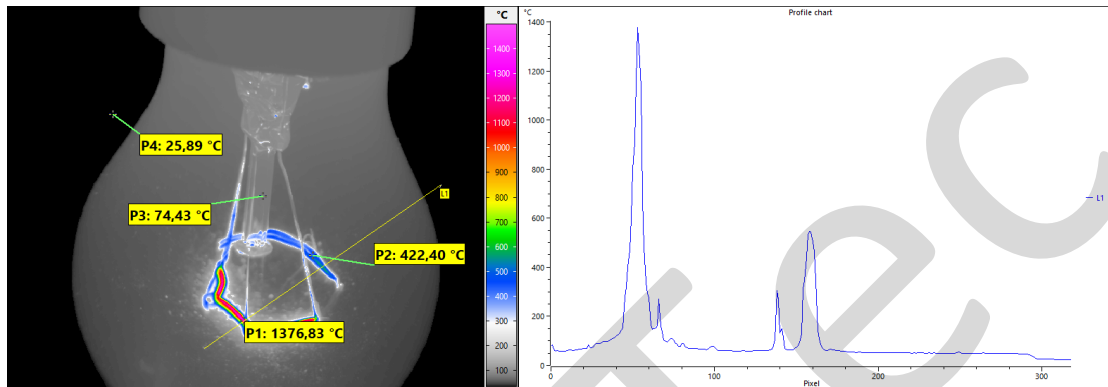
- ☐ HDR Mode for extended calibration range with high-speed filter wheel (ND filters)
- ☐ E.g., ImageIR® 8300 with (10 ... 1,500) °C range at once while keeping full frame rate of 350 Hz!



InfraTec, Thermography and You

ImageIR® Series – High Dynamic Resolution Mode

- ❑ HDR Mode for extended calibration range with high-speed filter wheel (ND filters)
- ❑ E.g., ImageIR® 8300 with (10 ... 1,500) °C range at once while keeping full frame rate of 350 Hz!



InfraTec, Thermography and You

ImageIR® Series – High Dynamic Resolution Mode

- ❑ Perfect for scenarios with extreme temperature gradients
- ❑ No need for manual filter change due to high-speed filter wheel
- ❑ Possible to cover about 1,500 K span within one image / measurement
- ❑ Frame rates up to 350 fps



InfraTec, Thermography and You

ImageIR® Series – Quantum Detectors

Application related features of the ImageIR® series

- ☐ Multiple filter wheels
- ☐ MicroScan
- ☐ Binning
- ☐ High dynamic resolution
- ☐ **HighSense**
- ☐ Special zoom edition – ImageIR® Z

InfraTec, Thermography and You

ImageIR® Series – HighSense Mode

- ☐ Standard factory calibration for e.g. (-10 ... 300) °C range consists of typically 3 calibration ranges related to the integration time:
 - ☐ (-10 ... 30) °C @ 2,500 µs – factory
 - ☐ (10 ... 50) °C @ 1,000 µs – custom
 - ☐ (20 ... 125) °C @ 300 µs – factory
 - ☐ (80 ... 150) °C @ 100 µs – custom
 - ☐ (100 ... 300) °C @ 25 µs – factory
- ☐ You need a different / additional integration time IT for some reason?
 - ☐ Example: You select IT = 1,000 µs → (10 ... 50) °C cal. range with HighSense
- ☐ You need a calibration range different from the factory ones?
 - ☐ Example: You select (80 ... 150) °C cal. range → IT = 100 µs with HighSense



InfraTec, Thermography and You

ImageIR® Series – Quantum Detectors

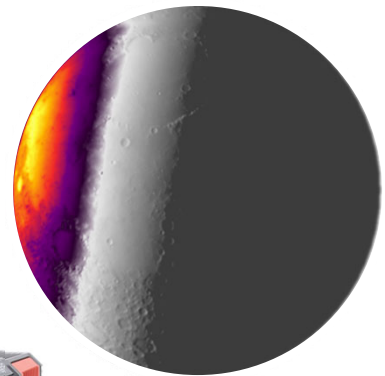
Application related features of the ImageIR® series

- ☐ Multiple filter wheels
- ☐ MicroScan
- ☐ Binning
- ☐ High dynamic resolution
- ☐ HighSense
- ☐ **Special zoom edition – ImageIR® Z**

InfraTec, Thermography and You

InfraTec Special Zoom Cameras

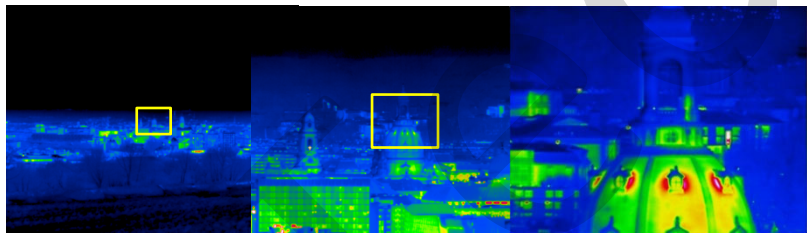
- ☐ Zoom cameras are useful for **outdoor** but as well as for **laboratory** use!
- ☐ Zoom cameras from InfraTec are ALL **radiometric calibrated!**

**ImageIR® 8300 Z / 9300 Z****ImageIR® 6300 Z**

InfraTec, Thermography and You

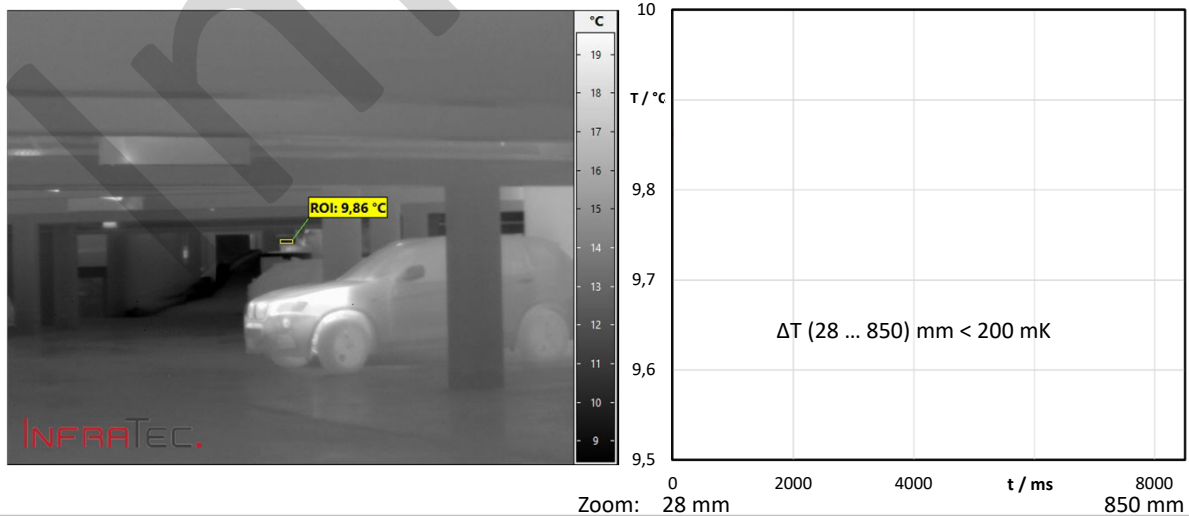
ImageIR® 8300 Z / 9300 Z

- ❑ Spectral range: (3.7 ... 4.8) μm
- ❑ Calibration: (-10 ... 300) $^{\circ}\text{C}$
- ❑ Frame rate: 100 Hz
- ❑ Focal length: (28 ... 850) mm or (50 ... 1,350) mm
- ❑ 30 $\times$ infrared zoom lens
 - ❑ (640 $\times$ 512): (0.65 ... 19.8) $^{\circ}$ or (0.41 ... 11) $^{\circ}$
 - ❑ (1,280 $\times$ 1,024): (1.29 ... 26) $^{\circ}$ or (0.81 ... 14.4) $^{\circ}$
- ❑ Zooming:
 - ❑ NFOV $\rightarrow$ WFOV: ≤ 8 s
 - ❑ 100 mm $\rightarrow$ 850 mm ≤ 2 s
- ❑ Focussing:
 - ❑ Close $\rightarrow$ Infinity: ≤ 8 s
 - ❑ 300 mm $\rightarrow$ Infinity: ≤ 0.5 s
- ❑ Detection range:
 - ❑ 15 km for persons
 - ❑ 18 km for vehicles



InfraTec, Thermography and You

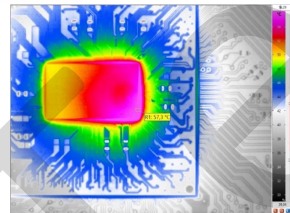
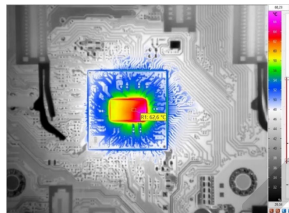
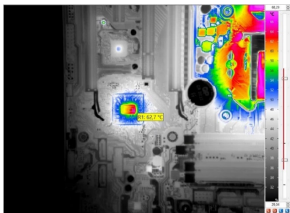
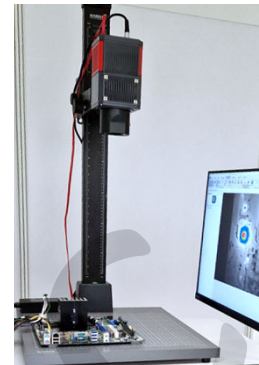
Full Radiometric Temperature Measurement While Zooming



InfraTec, Thermography and You

ImageIR® 6300 Z

- ❑ **SWaP** technology based on **xBn-HOT** detector
- ❑ Spectral range: (3.6 ... 4.15) μm
- ❑ Calibration: (-10 ... 600) $^{\circ}\text{C}$ (no filter change)
- ❑ Frame rate: 180 fps / **600 fps binning mode**
- ❑ Focal length: 7.5 $\times$ infrared zoom
(15 ... 115) mm or (25 ... 170) mm
- ❑ Fixed mount lens
- ❑ Small size (226 $\times$ 100 $\times$ 100) mm^3
- ❑ Low weight 2.0 kg incl. lens



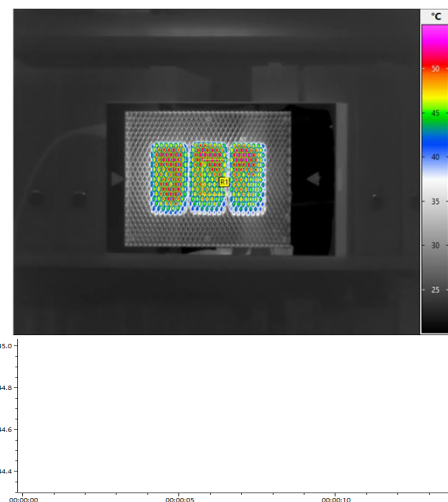
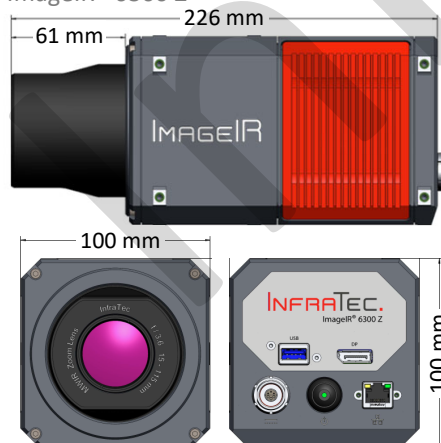
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Thermography Compact – Enter The World of Infrared Technology

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InfraTec, Thermography and You

ImageIR® 6300 Z



- ❑ Compact design allows **mobile** but also **laboratory applications**
- ❑ Radiometric zoom offers **precise & reliable measurements** w/o time-consuming adjustment / lens exchanges

© InfraTec.eu

Thermography Compact – Enter The World of Infrared Technology

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InfraTec, Thermography and You

Efficient and Convenient **Software Solutions** by InfraTec

- Control
- Acquisition
- Analysis
- Exporting
- Reporting
- Presentation

- Special active thermography software
- Customized solutions



InfraTec, Thermography and You

Data Acquisition, Remote Control and Analysis



InfraTec, Thermography and You

Software IRBIS® 3 – Some Highlights

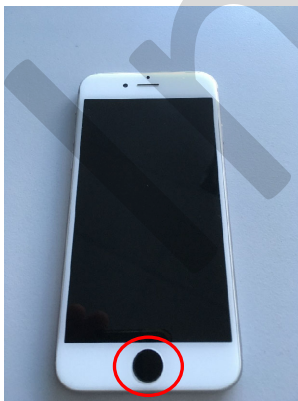
- ❑ **One Software** for all InfraTec cameras
- ❑ **Fast acquisition** even with 10 Gig-E **directly to PC / laptop** (recording time limited only by SSD size)
- ❑ Radiometric **correction algorithms** for emissivity, transmission, reflection
- ❑ Spatial pixel-wise **emissivity mapping**
- ❑ Various **analysis functions**
- ❑ **Multiple export** possibilities (cvs, ascii, avi, 3D avi, bmp, jpg, txt, ...)
- ❑ Online analysis with possibility for **IN / OUT of external signals** (support of various I/O interfaces)

- ❑ **Active thermography software** for lock-in & pulse-phase thermography

- ❑ **Software Development Kit** incl. **LabView** and **MatLab** support

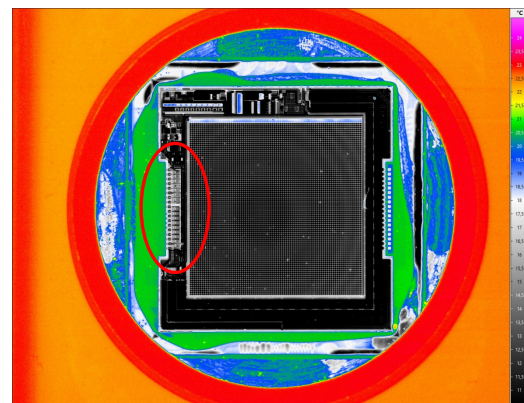
InfraTec, Thermography and You

Microscopic Thermography: iPhone Fingerprint Sensor



iPhone 6 with Touch ID

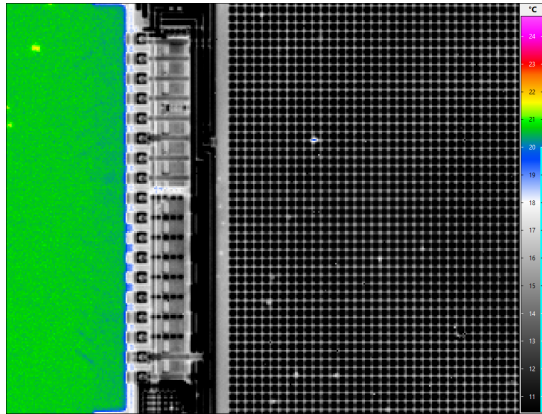
- ❑ Touch ID sensor is covered with an IR-semi-transparent plastic cap
- ❑ IR image has been realized „through“ this cap
- ❑ Sensor dimension approx. (6 × 6.2) mm



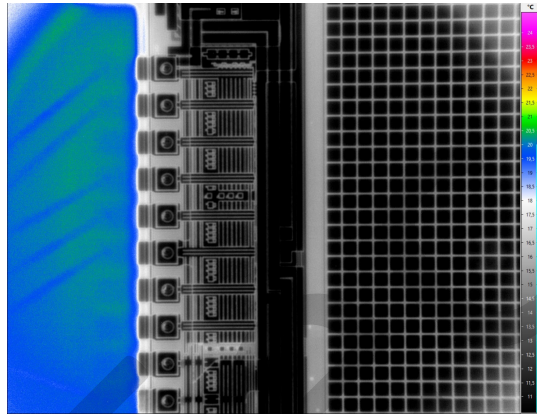
Touch ID with M=1× lens → IFOV 10 µm/pixel

InfraTec, Thermography and You

Microscopic Thermography: iPhone Fingerprint Sensor



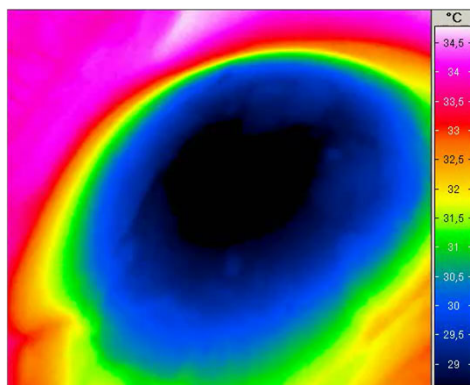
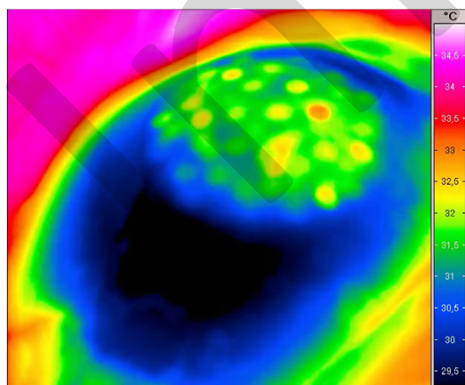
Detail zoom, M=1x lens



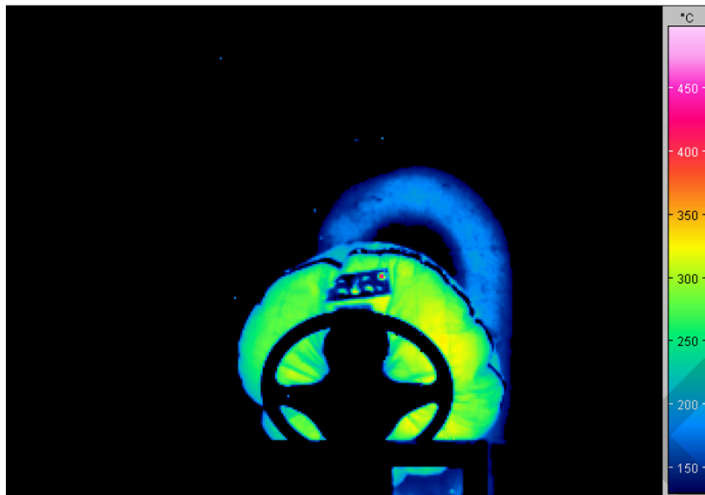
M=8x lens → iFOV 1.25 $\mu\text{m}/\text{pixel}$

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High-speed Thermography: Laser Treatment on Eye Lens



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High-speed Thermography: Airbag Test

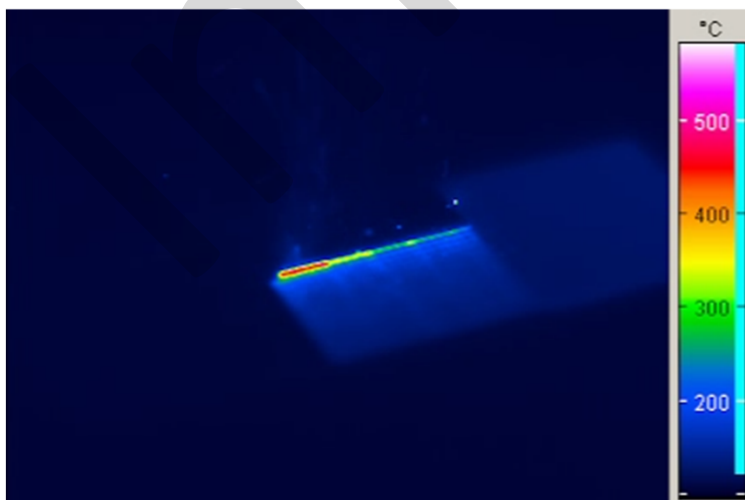


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High-speed Thermography: Laser Sintering on Metal Powder – Additive Manufacturing



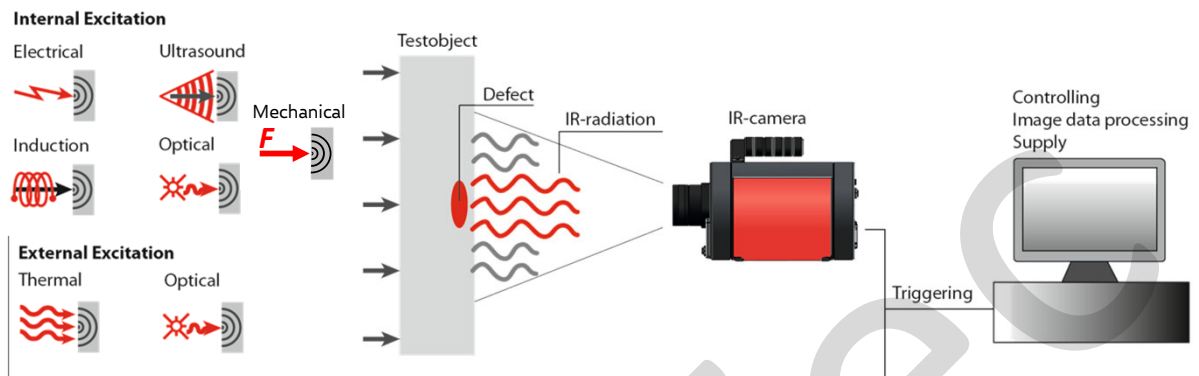
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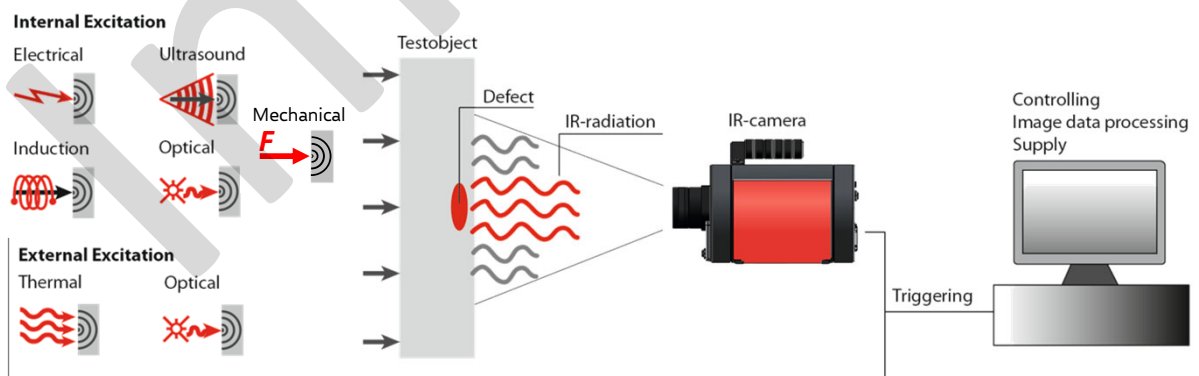
Active Thermography – Principle



- Most common active thermography methods:
 - **Lock-in thermography** (periodically excitation within the non-destructive range of the sample)
 - **Pulse-phase thermography** (one-shot excitation and analysing the delayed thermal response of the sample)

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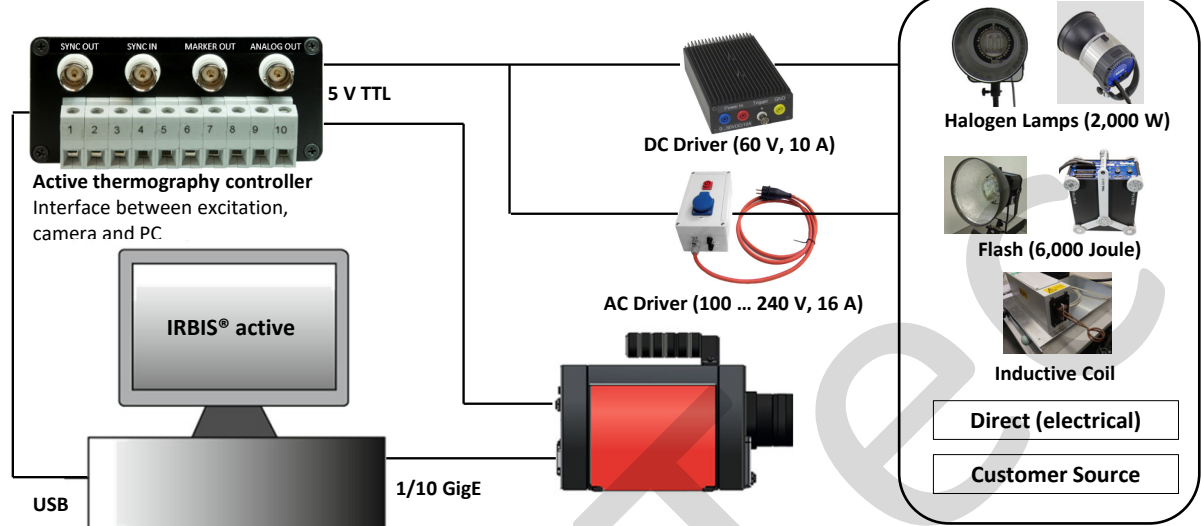
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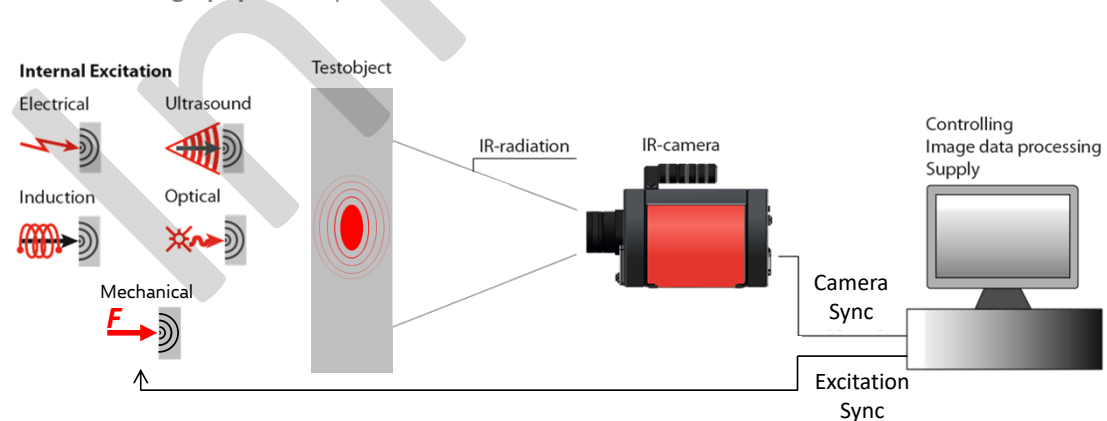
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InfraTec Offers All Hardware and Software for Active Thermography



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Active Thermography – Principle – Internal Heat Generation

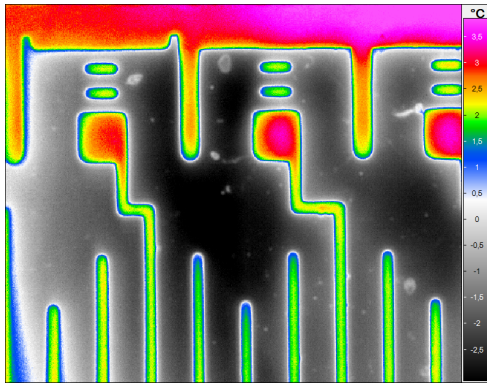


- ☐ Correlated heat generation within the material by energy application to the object
- ☐ Lock-in principle is used mostly: Periodically induced energy with synchronized IR image acquisition

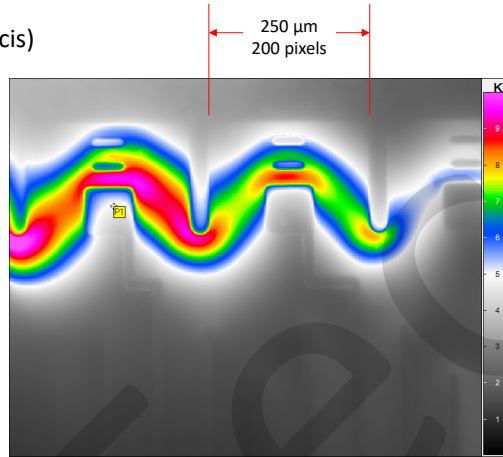
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Electronic Microscopy with Lock-in Thermography

- High-precision SMD resistor (metal film on ceramics)



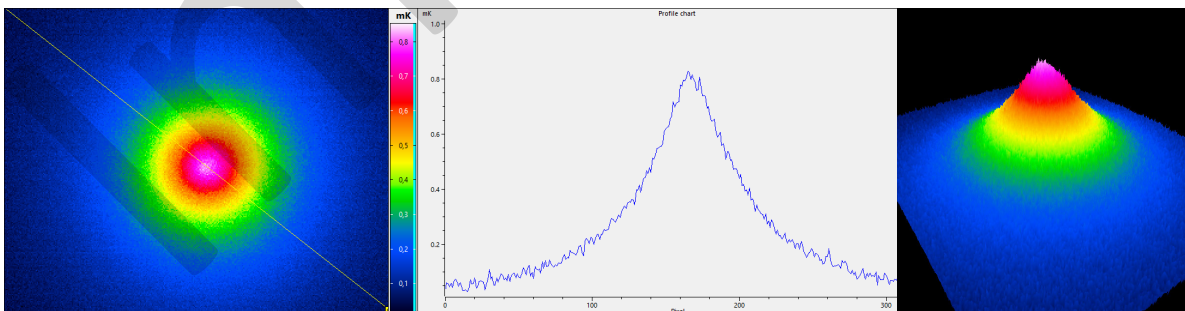
Passive thermography image – background is heated up and metall structure seems cool because of low heat capacity and low emissivity.



Lock-in amplitude result image – heated background is suppressed by frequency-based amplification. Heat generated by current can be seen in the metal structure.

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Lock-in Thermography: Hotspot Detection on an IC with Rather Low Energy

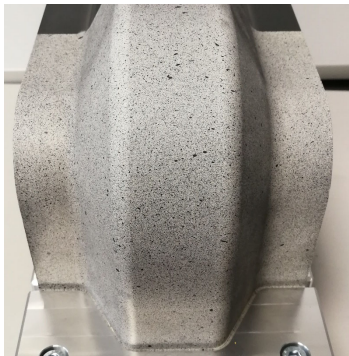


Applied energy: 70 μ W
Peak value of this „hotspot“ is just **0.8 mK = 0.0008 K**
 The **thermal measurement resolution** is about **8 μ K!**
 (FOV: (4.8×3.8) mm²; iFOV: 15 μ m)

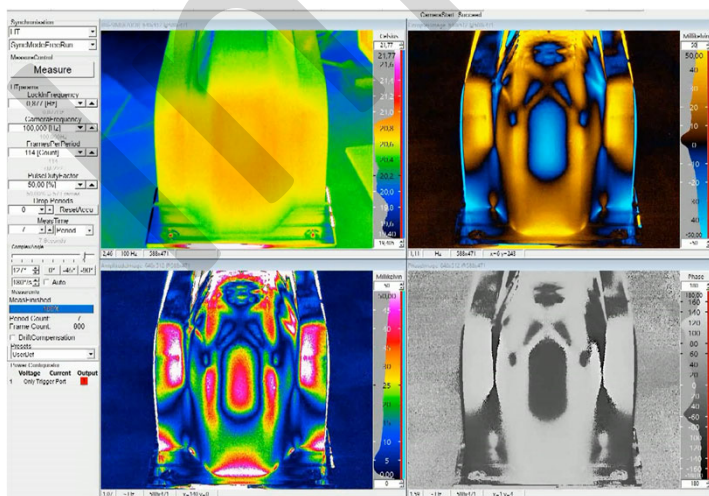
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Thermal Stress Analysis with Lock-in Thermography

- ❑ Mechanical stress onto a plastic car bumper (f_{exc} : 0.8 Hz)
- ❑ This sample is also used for DIC (Digital Image Correlation) and therefore painted with a speckle pattern

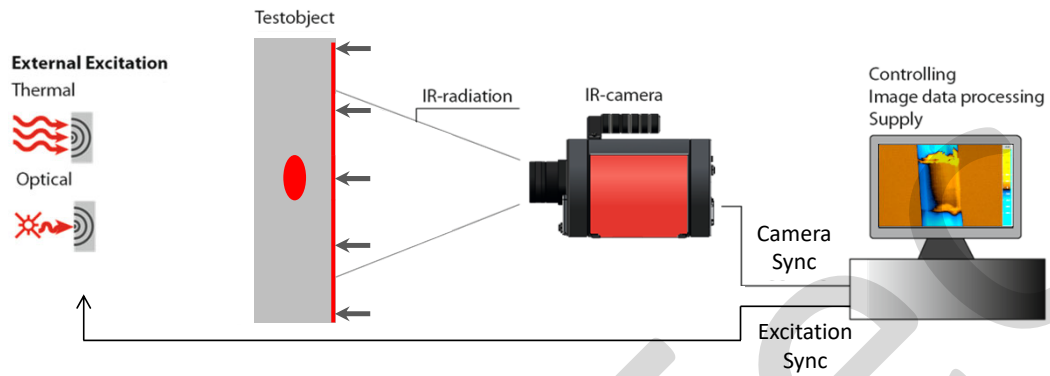


Lock-in Analysis with IRBIS® active online



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Active Thermography – Principle – External Heat Generation (on Front Surface)



- Heat generation on the (front) surface of the material – „reflection“ mode

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Lock-in Thermography: Materials Testing

- Carbon bicycle frame – Internal structures and damages

