Investigation on the suitability of laser-excited thermography to detect porosities in metallic components

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NDTiC 2019, June 18-20, Edmonton, Alberta, Canada

CINDE
CANADIAN INSTITUTE FOR NON-DESTRUCTIVE EVALUATION

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June 18 - 20
River Cree Resort & Casino
Edmonton, Alberta

Technische Universität Braunschweig

Institute of Joining and Welding

Technische Universität Braunschweig
- Founded 1745

Institute of Joining and Welding
- Prof. Dr.-Ing. Klaus Dilger
- app. 60 research assistants

Research interests in NDT

Thermography
- Adhesive Bonds
- Composites
- Welds
- Riveting
- …

Computer tomography
- Void analysis in welded joints
- Stress distribution in adhesive bonds
- …

Agenda

- Motivation
- Experiments
- Simulations
- Conclusions & Outlook

Classification of geometric imperfections

- ISO 6520-1 → Fusion welding
- ISO 6520-2 → Welding with pressure

Quality levels for imperfections

- ISO 5817 → Steel, nickel, titanium and their alloys
- ISO 10042 → Aluminium and its alloys

ISO 17635: Connection of NDT and imperfections

- Surface inhomogeneities
- Internal irregularity

Inner defects

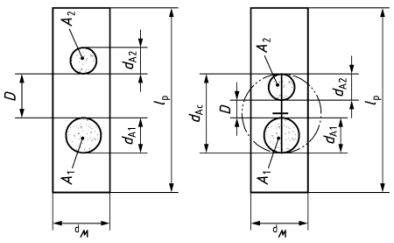
- Depends on the materials and thickness
- RT, UT

Typical inner defects

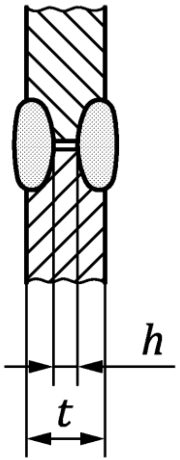
- Cavities
- Solid inclusions
- Lack of penetration

Quality levels for imperfections

- ISO 5817 → Steel, nickel, titanium and their alloys
- ISO 10042 → Aluminium and its alloys

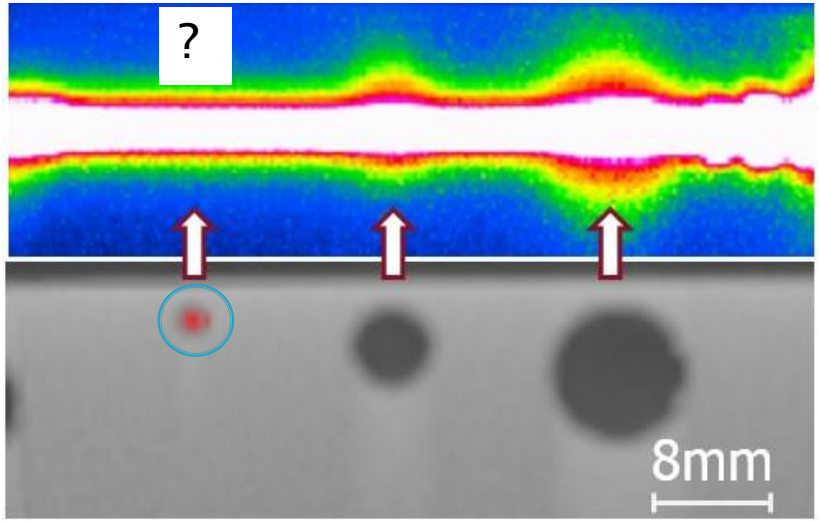


Source: ISO 5817



Source: ISO 5817

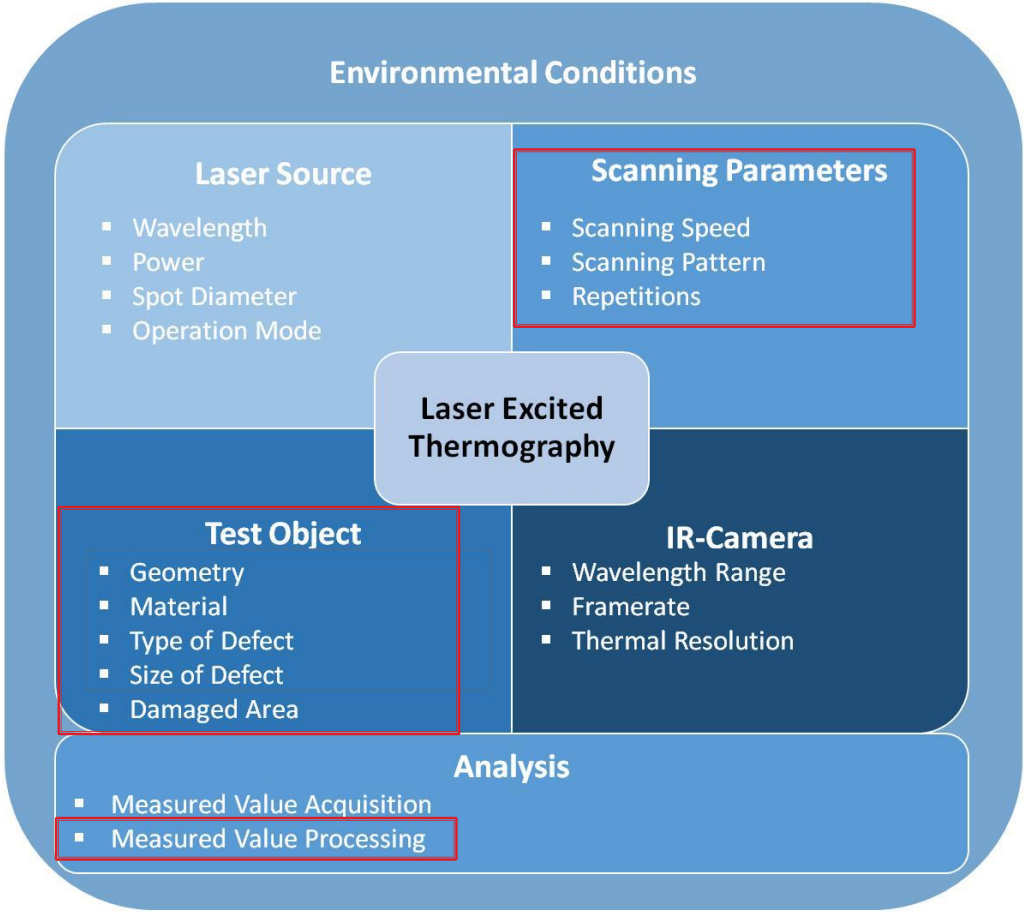
Is flying laser spot thermography suited to detect cavities?



Parameters	
Working distance [mm]	– 25
Average output power [mm]	14
Scanning speed [mm/s]	10 – 100

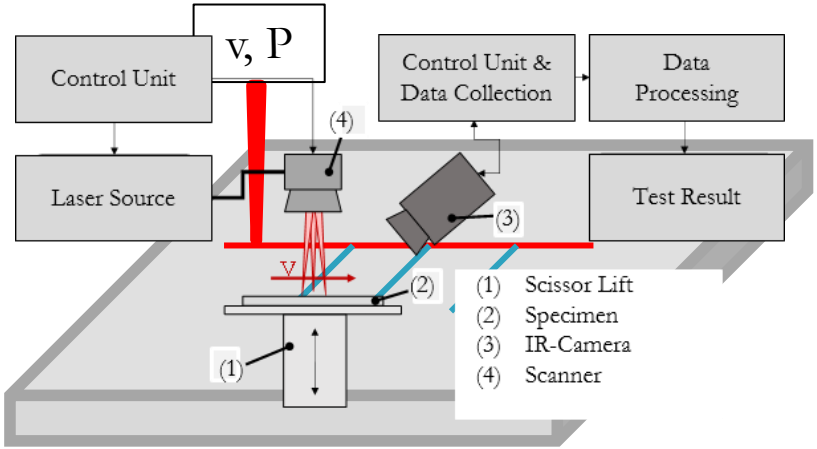
- Large voids are easy to detect
- Smaller voids can not be visualized

→ What are the limits?


Environmental Conditions
Laser Source
Wavelength
Power
Spot Diameter
Operation Mode
Scanning Parameters
Scanning Speed
Scanning Pattern
Repetitions
Laser Excited Thermography
Test Object
Geometry
Material
Type of Defect
Size of Defect
Damaged Area
IR-Camera
Wavelength Range
Framerate
Thermal Resolution
Analysis
Measured Value Acquisition
Measured Value Processing

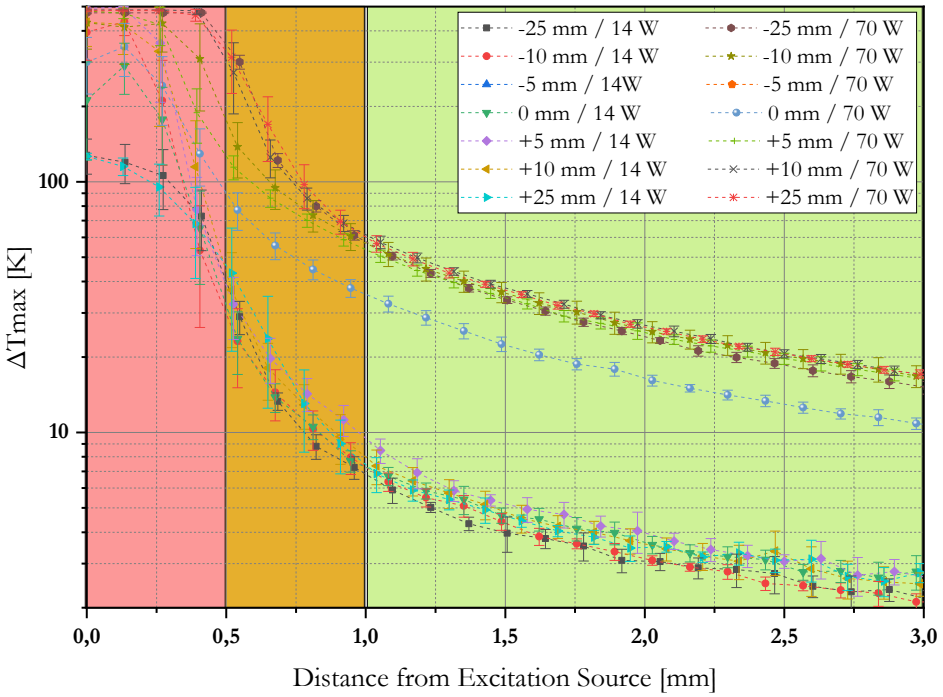
Laser	redEnergy G4 (SPI Lasers UK Ltd)
Scanner	Axialscan-20/-30 (Raylase AG)
Avg. Output Power [Watt]	20 – 70
Wavelength [nm]	1062

Varied Parameters	
Working distance [mm]	± 25
Average Output Power [W]	20 – 70
Scanning Speed [mm/s]	10 – 100



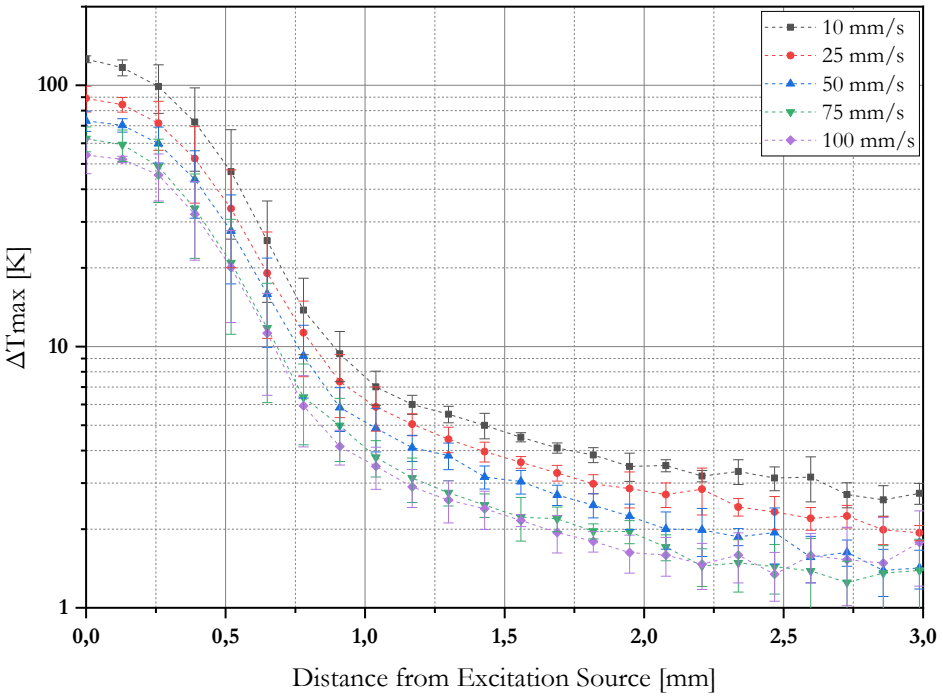
IR-Camera:

- Variocam HD (Infratec GmbH)
- Resolution 320x240 Pixel
- Framerate 240 Hz



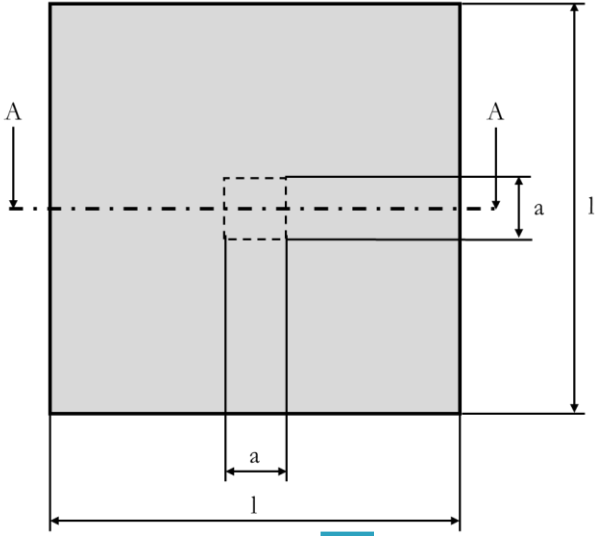
Parameters	
Working distance [mm]	– 25
Average output power [mm]	14 –70
Scanning speed [mm/s]	10

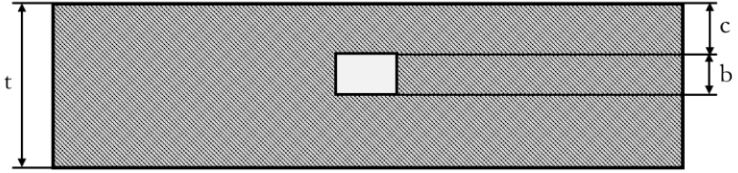
- Temperature increase for higher input power
- Ablation may occur if local energy input is too high
- Influence of spot diameter is negligible



Parameters	
Working distance [mm]	– 25
Average output power [mm]	14
Scanning speed [mm/s]	10 – 100

- Temperature increase for lower scanning speeds
- Lower influence than applied power
- “Blind Areas” if scanning speed is to high and framerate to low





Schnitt A-A

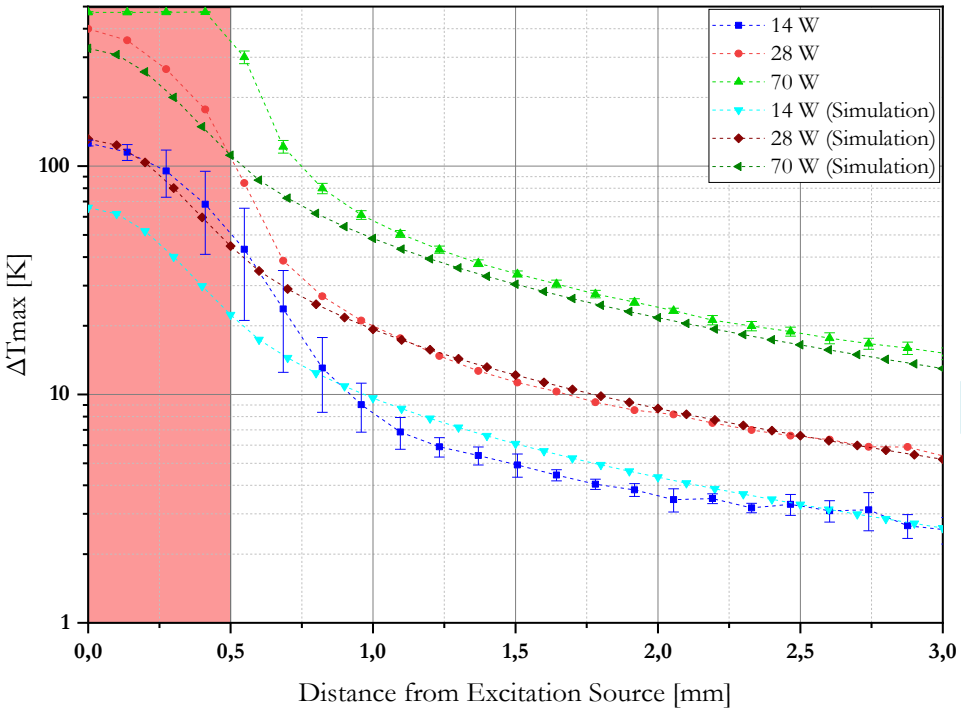
Parameter	Benennung
Length	l = 50 mm
Thickness	t = 8 mm
Kantenlänge der Pore	a
Höhe der Pore	b
Tiefe der Pore	c

Exitation

- Scanning speed
- Power
- Spot diameter

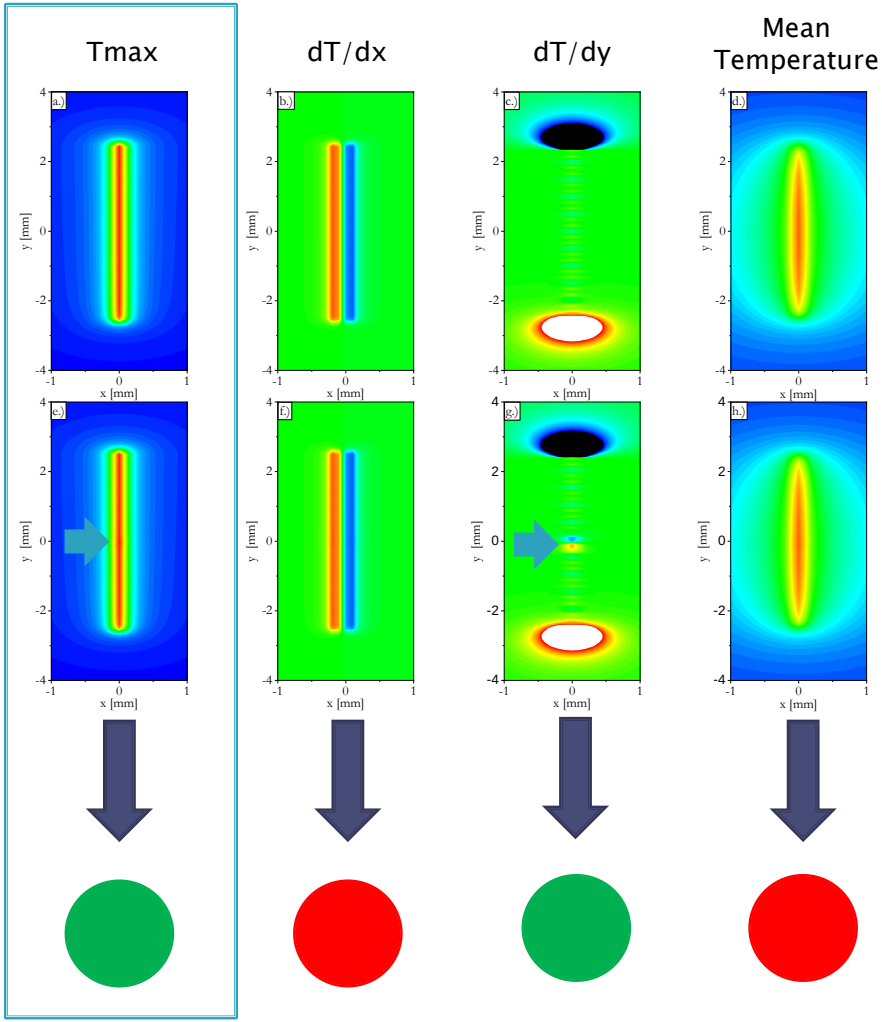
Geometrical parameters

- Depth
- Shape
- Size



Parameters	
Working distance [mm] Spot diameter [mm]	-25 1
Average output power [mm]	14/28/70
Scanning speed [mm/s]	10

- Temperature increase for higher input power
- Ablation may occur local energy input is too high

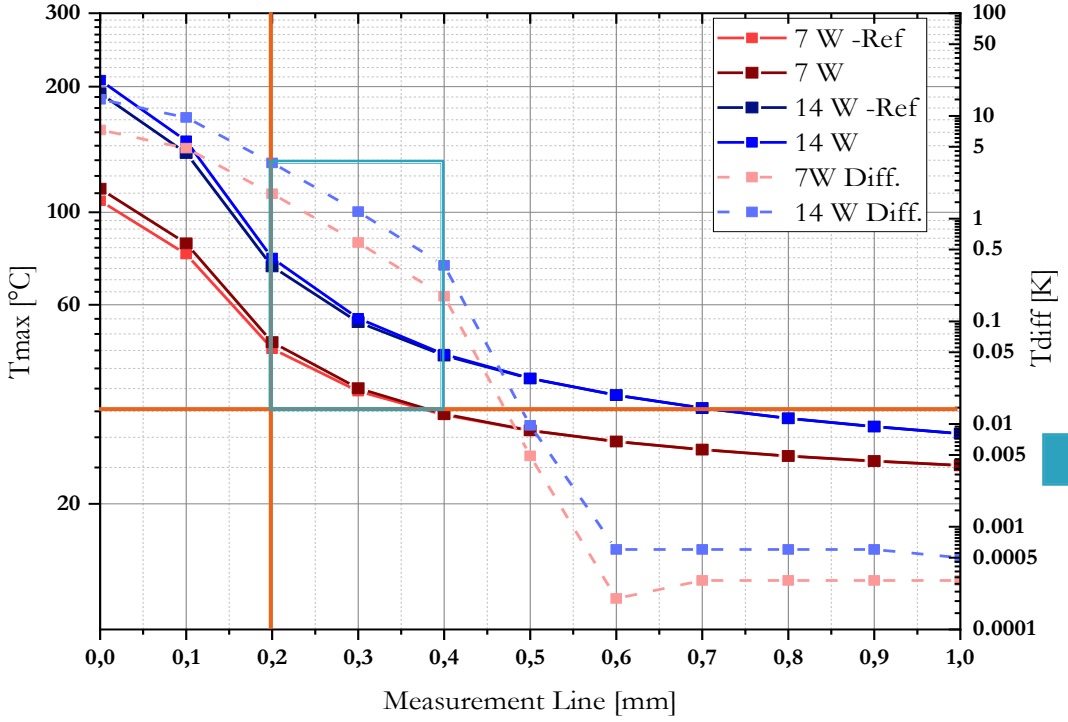


Reference sample

Sample with void

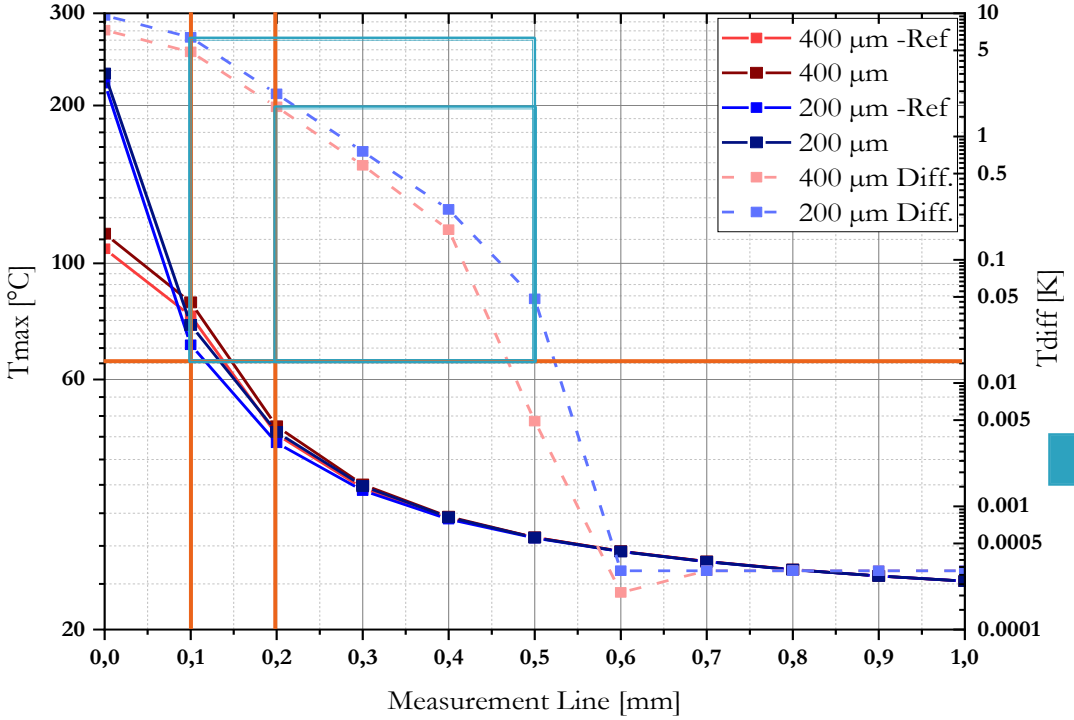
- First derivation as well as peak temperatures for each measurement point illustrate the porosities

→ Use peak temperatures



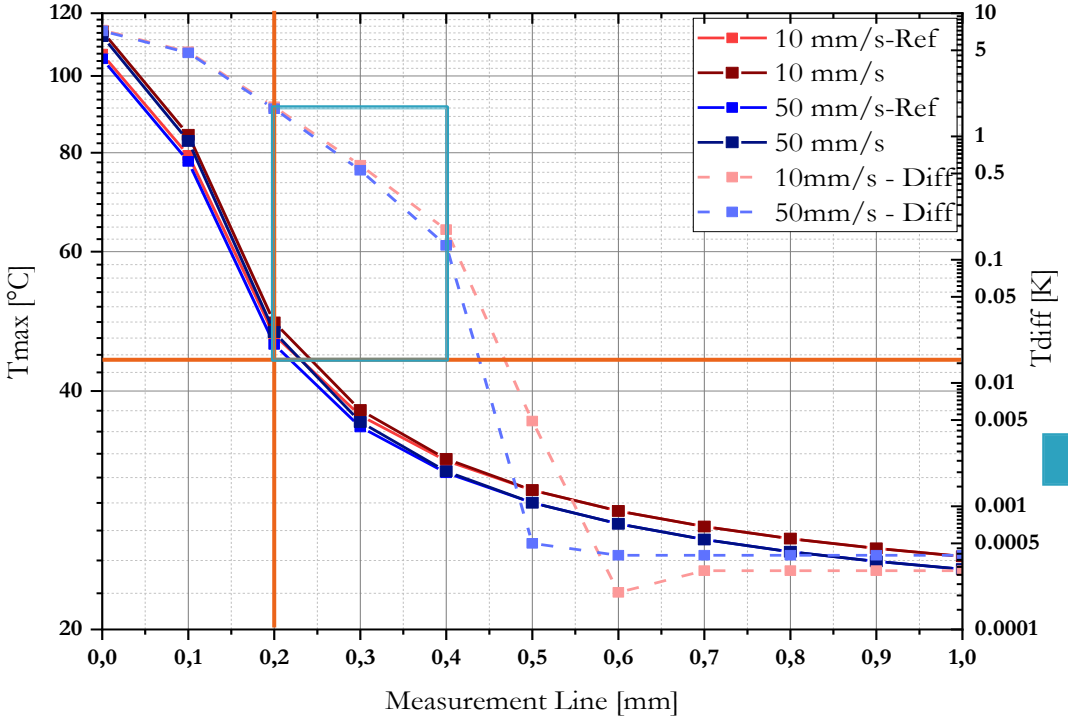
Parameters	
Spot diameter [mm]	0.4
Average output power [mm]	7/14
Scanning speed [mm/s]	10

- Temperature increase for higher input power
- Ablation may occur local energy input is too high



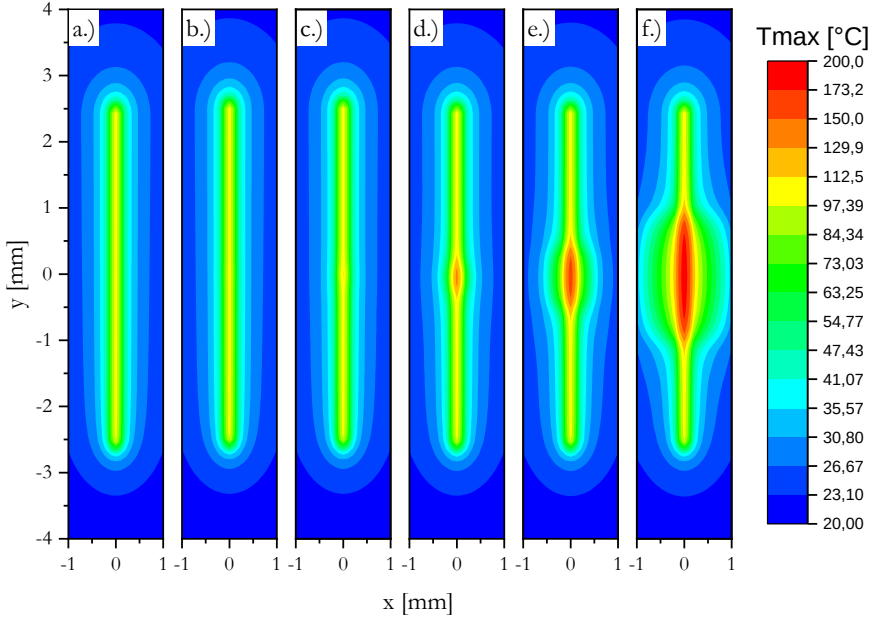
Parameters	
Spot diameter [mm]	0.1/0.2
Average output power [mm]	7
Scanning speed [mm/s]	10

- Spot diameter increase field of detection
- Ablation may occur local energy input is too high



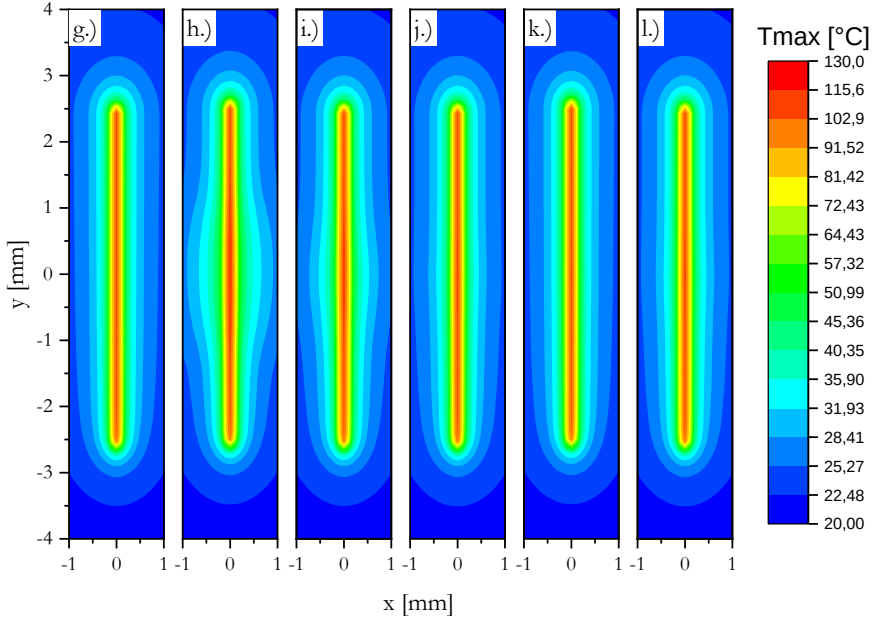
Parameters	
Spot diameter [mm]	0.2
Average output power [mm]	7
Scanning speed [mm/s]	10/50

- Nearly no effect on heating of scanning speed
- Ablation may occur local energy input (low scanning speeds)



	Sample	a [mm]	b [mm]	c [mm]
a.)	Reference	–	–	–
b.)	Size1	0.1	0.1	0.1
c)	Size2	0.2	0.2	0.2
d.)	Size 3	0.5	0.5	0.5
e.)	Size 4	1	1	1
f.)	Size 5	2	2	2
Depth	0.1 mm			

- Size of porosity influence temperature distribution significantly
- Large voids →higher temperatures



	Sample	a [mm]	b [mm]	c [mm]
g.)	Reference	–	–	–
h.)	Volume 1	0.1	3.2	3.2
i.)	Volume 2	0.2	2.4	2.4
j.)	Volume 3	0.5	1.4	1.4
k.)	Volume 4	2	0.7	0.7
l.)	Volume 5	3	0.6	0.6
Depth	0.5 mm			

- Size of porosity influence temperature distribution significantly

Experiments

- Power and scanning speed determine energy input
- Spot diameter (and scanning line length) can be neglected
- Upper boundaries for excitation → Ablation
- Voids cannot be detected within the area the excitation

Simulations

- Simulations cover basic properties of the laser based excitation process
- Idealised voids can be detected
- Projected surface has the largest impact
- Laser parameters do not have a significant influence on detectability (except spot diameter)

Next steps

- Comparison of results to requirements of testing standards
- Experimental evaluation on real welds
- DoE for evaluation of experimental results

Thank you for your attention!

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