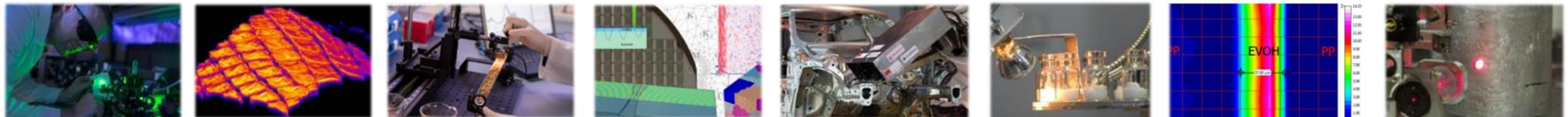
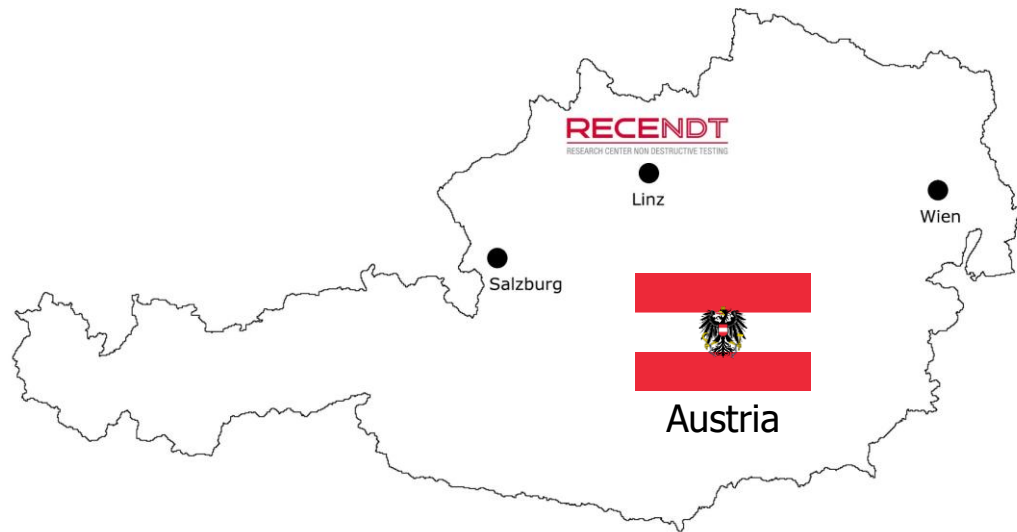


Laser ultrasound for in line and in situ measurements during casting and rolling

Liquid Metal Processing & Casting Conference (LMPC) – 2024

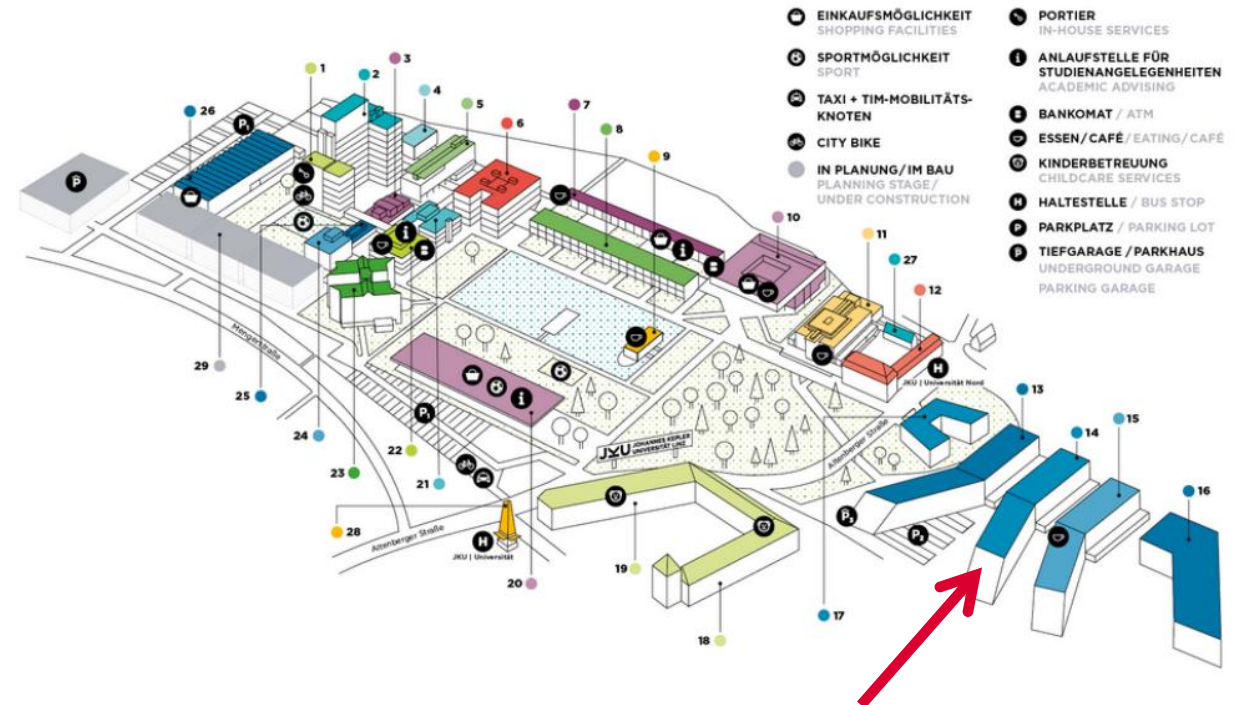


RECENDT = Research Center for Non-Destructive Testing

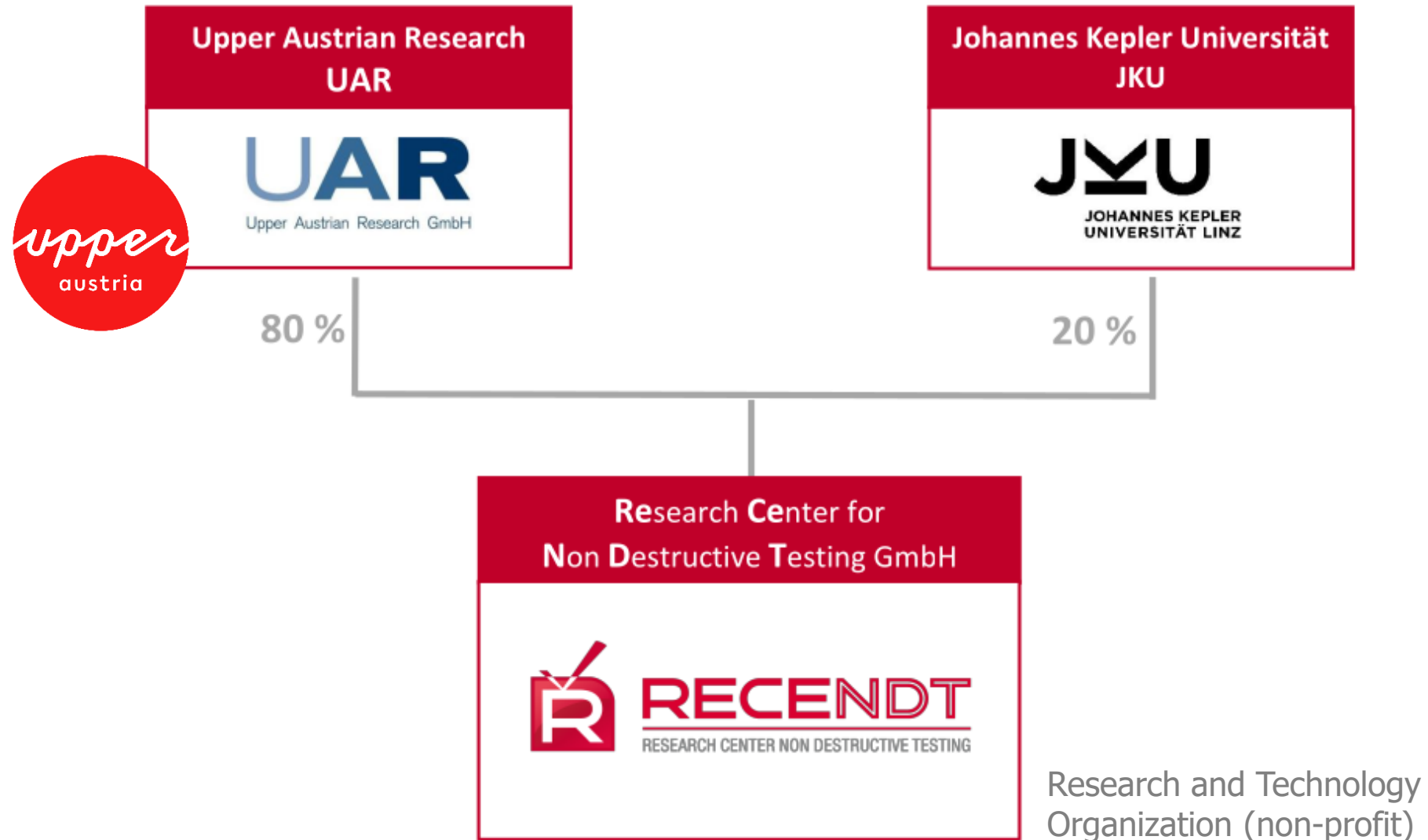


Altenberger Straße 69, 4040 Linz, Austria
Tel.: +43 732 2468 4600
E-Mail: office@recendt.at
Web: <https://www.recendt.at>

Campus of Johannes Kepler University Linz - JKU



Science Park 2, 2. OG



Member of
UAR INNOVATION
NETWORK



Members of UAR Innovation Network



Partners of UAR Innovation Network



Area Acoustics

- **Laser Ultrasonics (LUS)**

What: defect detection, material characterization

How: feasibility studies → method development → customized systems and services, consulting

- **Complementary methods**

Ultrasound: piezoelectric/electromagnetic/aircoupled; medical ultrasound, photoacoustics, acoustic emission

Emerging:

- **Quantum Sensing:** quantum optical interferometry for spectroscopy, imaging, and OCT

Area Optics

- **Infrared- and Raman Spectroscopy (IR)**

In-line process control and quality assurance, e.g. analysis of chemical compositions

- **Terahertz Technology (THz)**

Imaging and spectroscopy of non-conductive materials

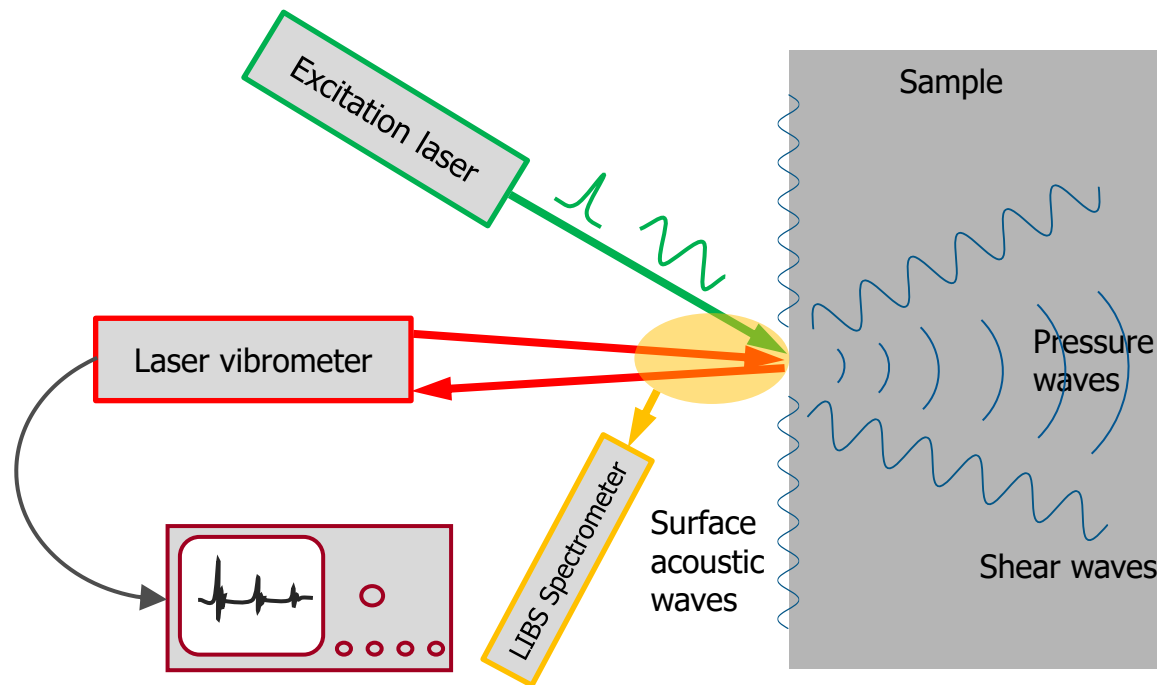
- **Optical Coherence Tomography (OCT)**

High-resolution imaging of non-conductive layer structures



Principle:

1. Excitation laser heats up surface shortly or periodically
2. Local expansion or even ablation excites ultrasonic waves
3. Laser vibrometer detects echos



Advantages:

- ✓ Non-contact
- ✓ Chemical analysis
- ✓ Remote operation
- ✓ Minimal influence on excited waves
- ✓ Applicable in harsh environment
- ✓ Wide bandwidth
- ✓ Off-line, At-line, In-line



Lab experiments



Professional equipment

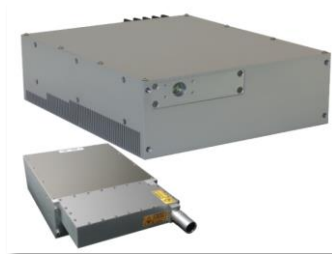


Monitor casting, rolling

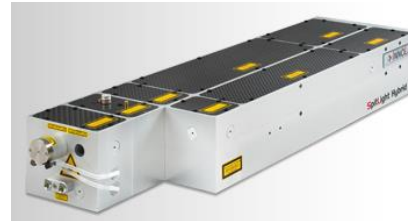
Source: <https://www.schmelzmetall.com/>

Typical: energy/pulse $1\mu\text{J} - 850\text{mJ}$ @1064/532nm; Rep rate 10 – 2000Hz

Excitation laser



Source: <https://brightsolutions.it>



Source: <https://innolas-laser.com>



Source: <https://www.quantel-laser.com>

Laser vibrometer

Commercially available



Source: <https://laser-ut.tecnar.com>

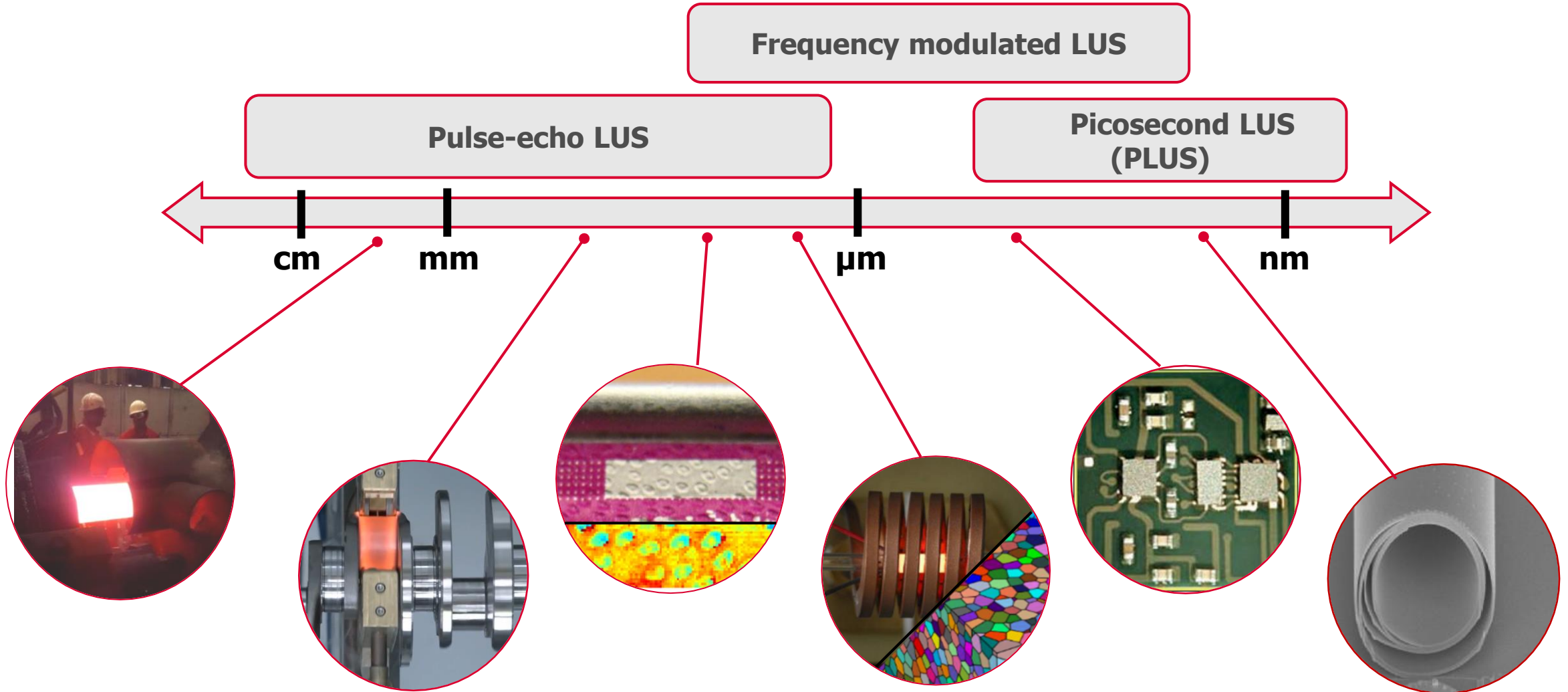
Customized



Source: <https://www.soundnbright.com>



Wide range of dimensions to investigate



Laser ultrasound during continuous casting

Thickness measurement of solidification zone



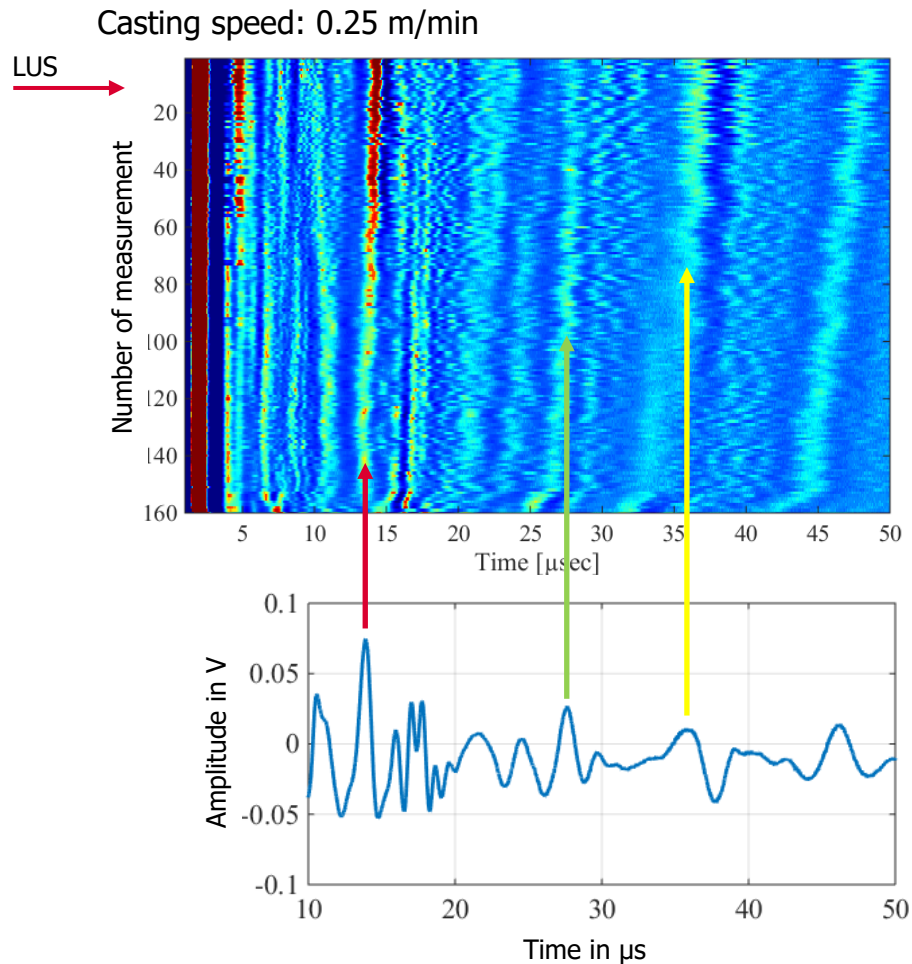
Technikum of voestalpine Stahl Donawitz

- Temperature at transition of aggregation state: $\sim 1370^{\circ}\text{C}$
- Casting speeds tested: 0.25, 0.30, 0.35 m/min

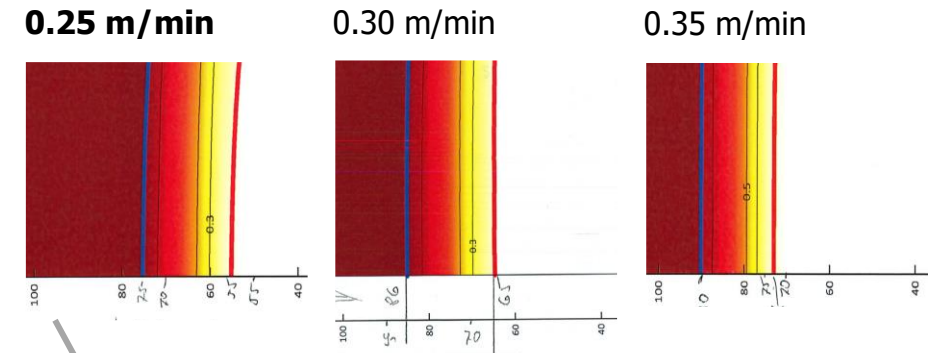


LUS-measurement head
with water cooling

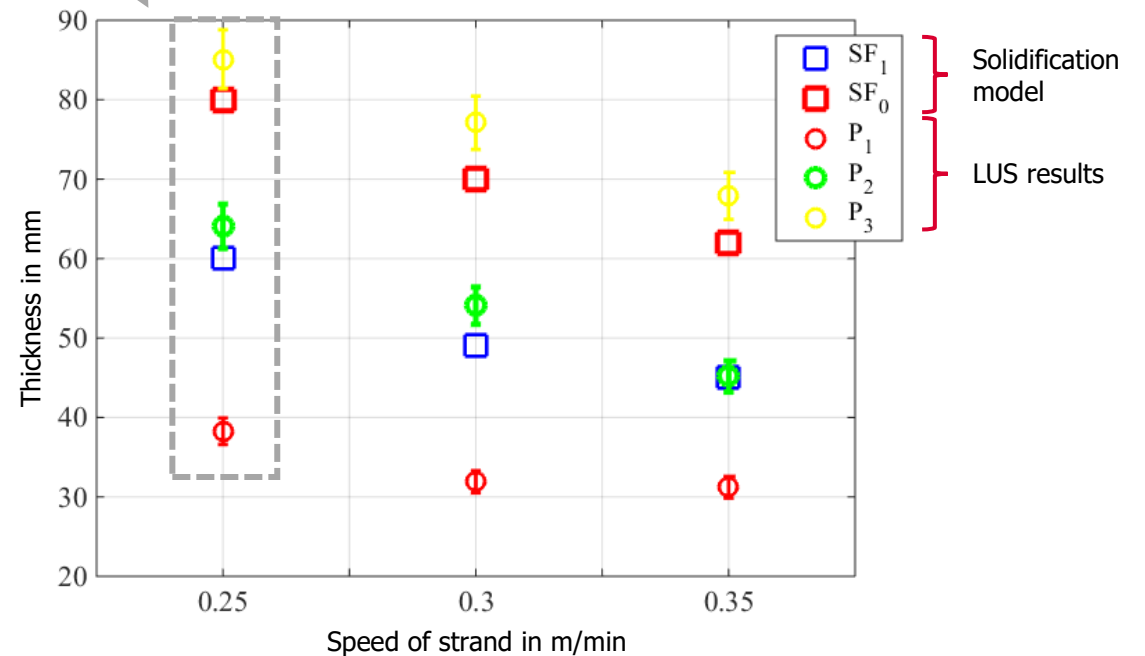
Ultrasonic signals of strand passing by



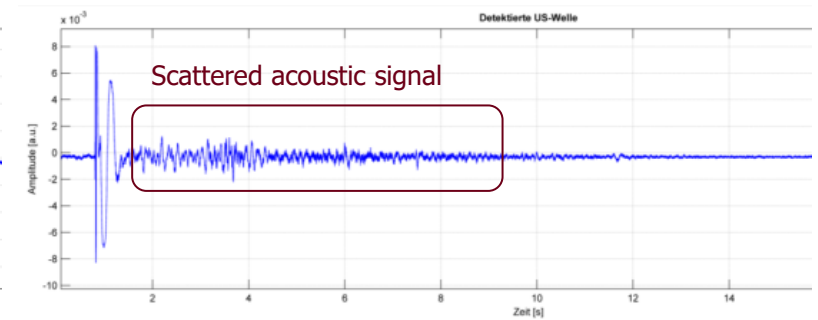
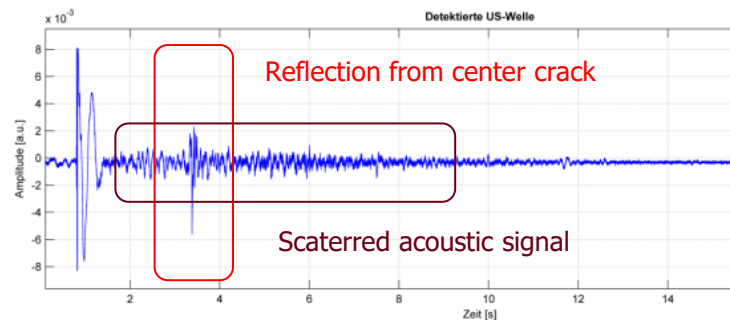
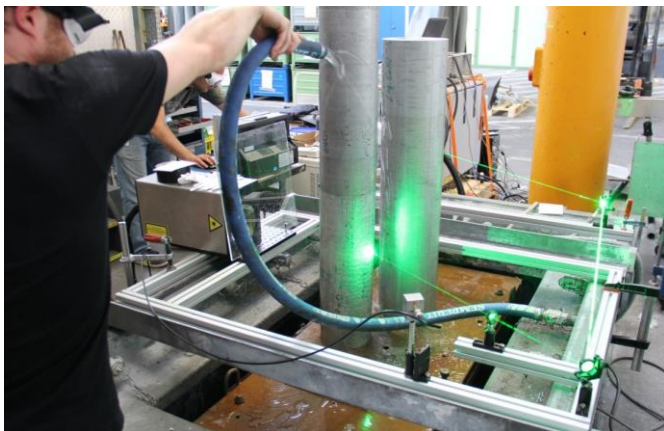
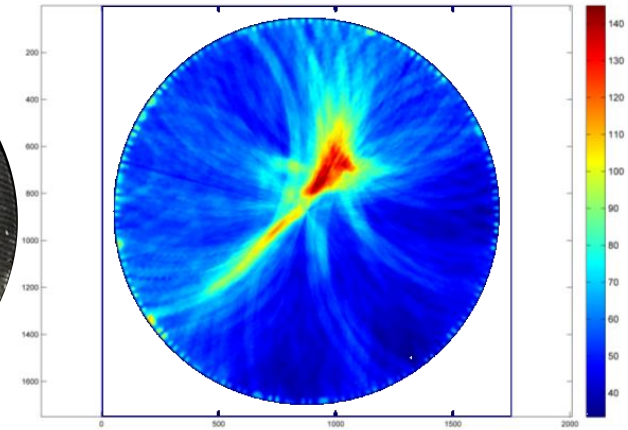
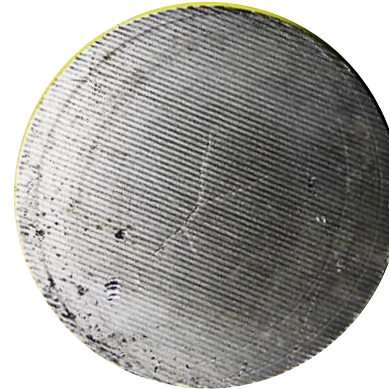
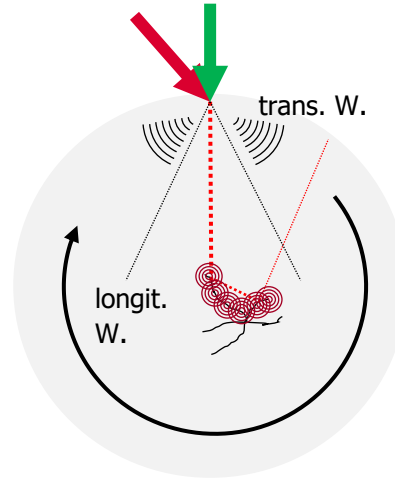
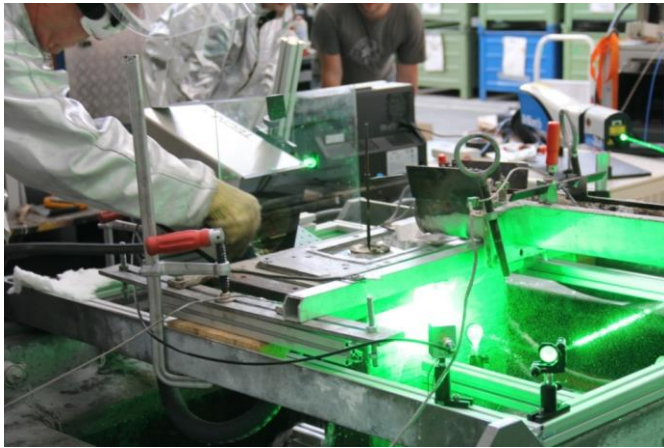
Comparison to solidification model:



Thickness: Solidification model vs. LUS



Center crack detection during aluminium continuous casting

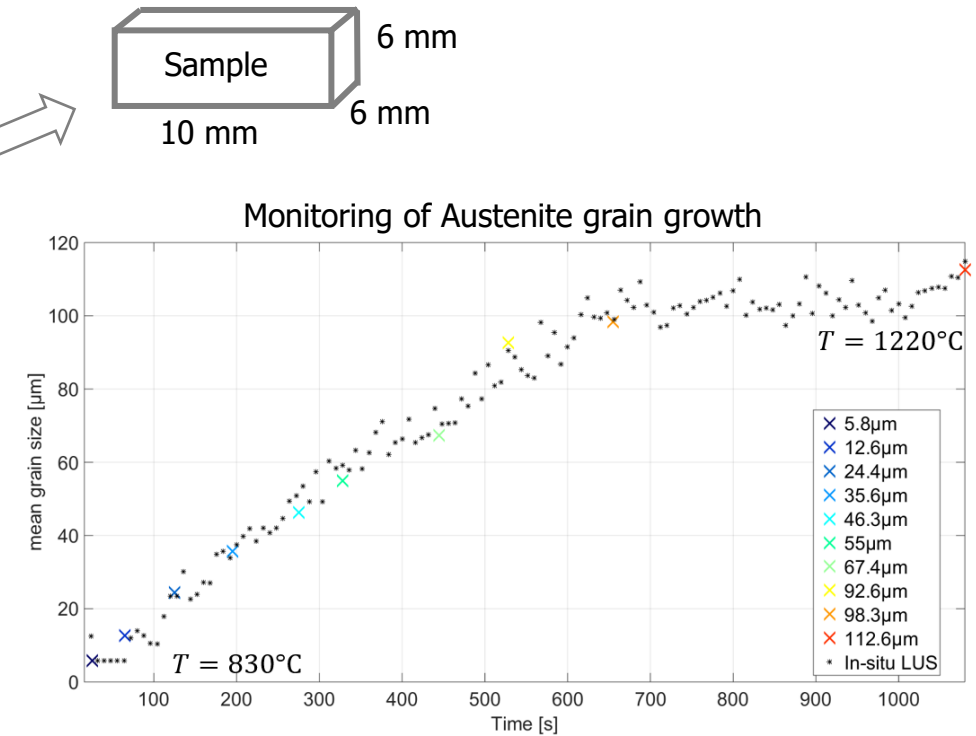
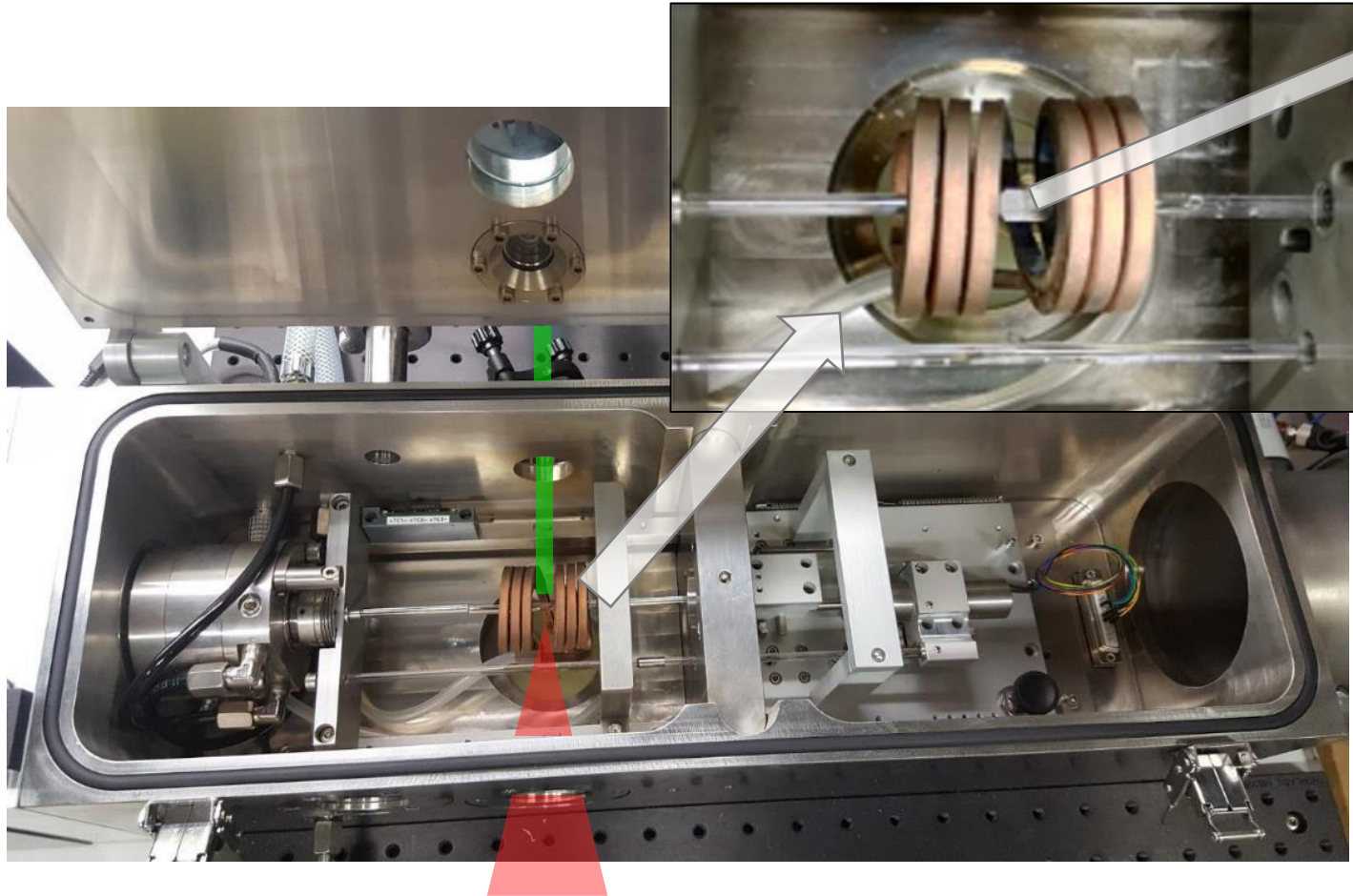


Laser ultrasound during thermal treatment

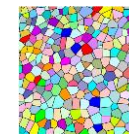
Dilatometer as thermal simulator combined with laser ultrasonic equipment used at RECENDT



Monitoring of grain size evolution during thermal treatment

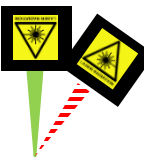


Black dots: LUS-model on one sample.
Colored x: metallographic results on 10 quenched samples.

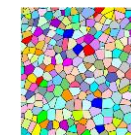
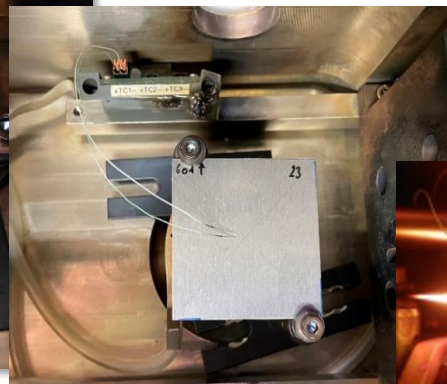
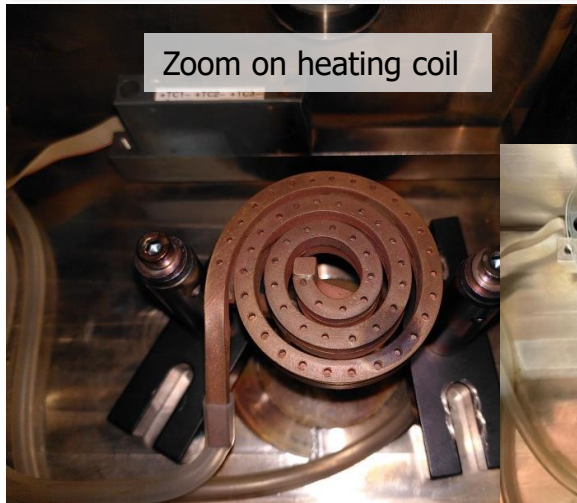
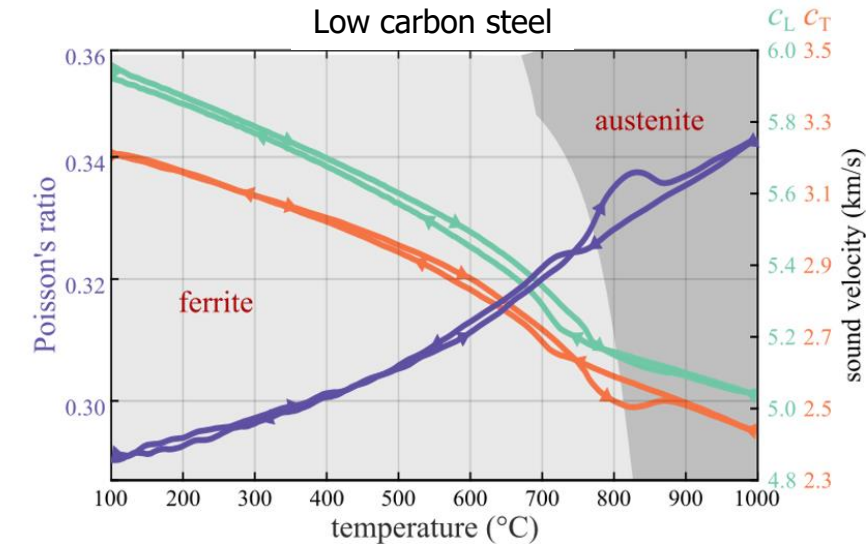
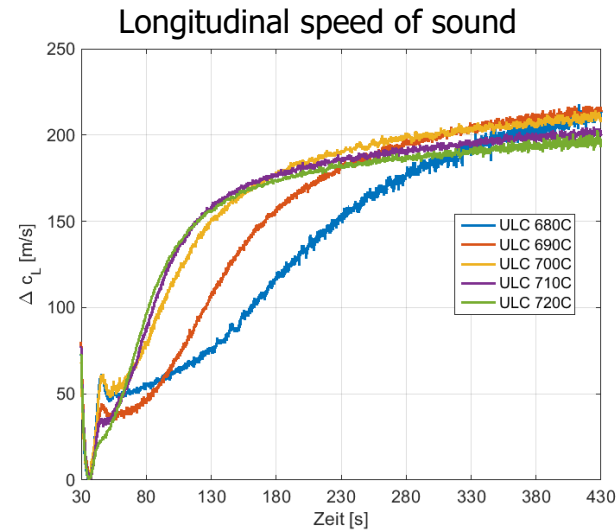
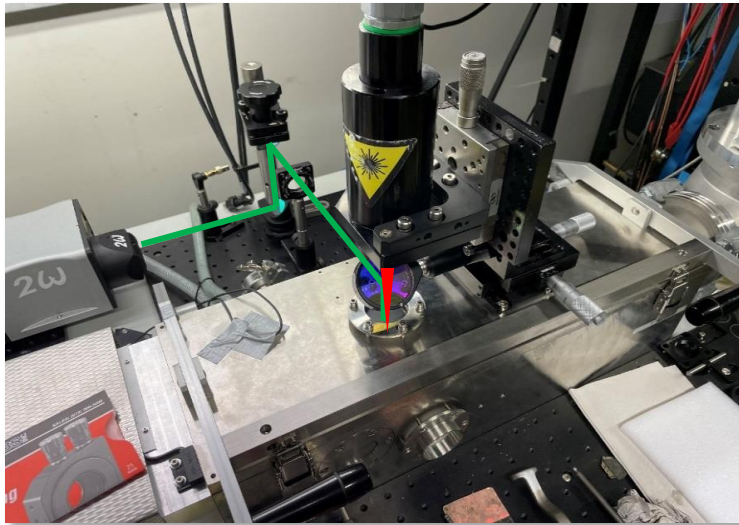


- texture changes
- grain size
- shape, elongation
- single crystal

- Velocity
- Attenuation
- Resonances

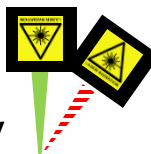


Sheet steel samples observed in-situ by LUS for studies of recrystallization and phase changes



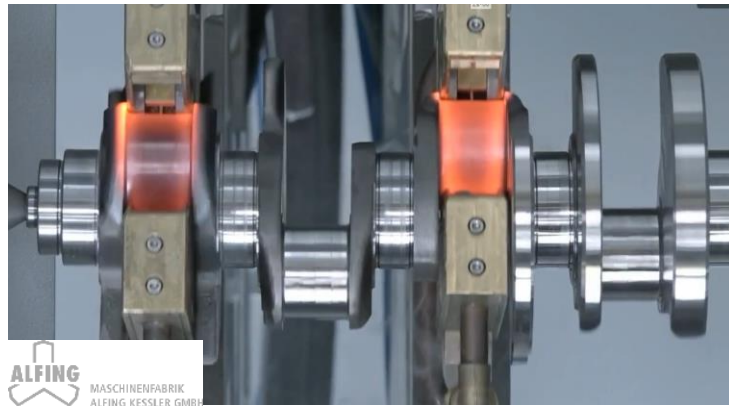
- texture changes
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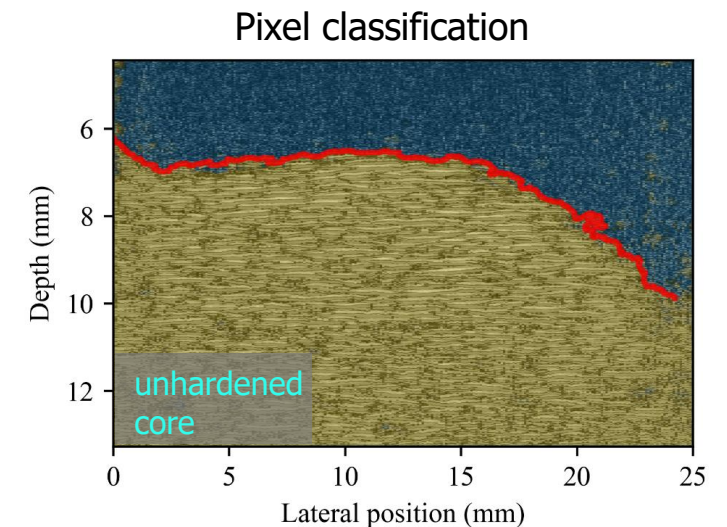
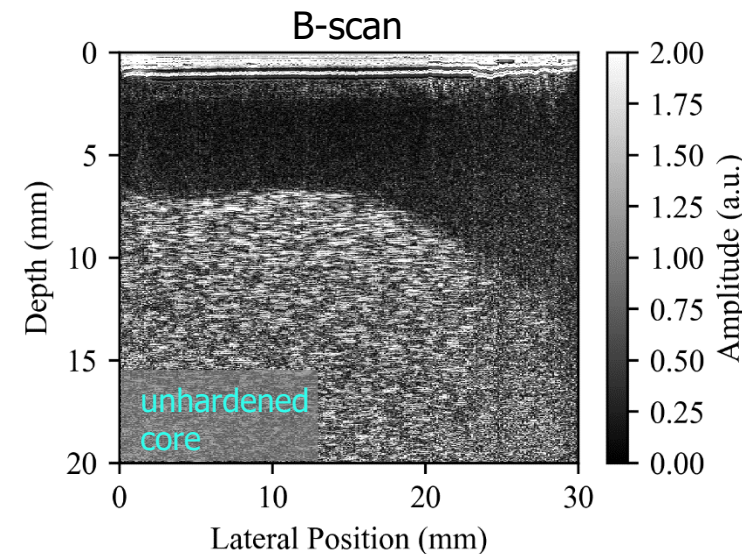
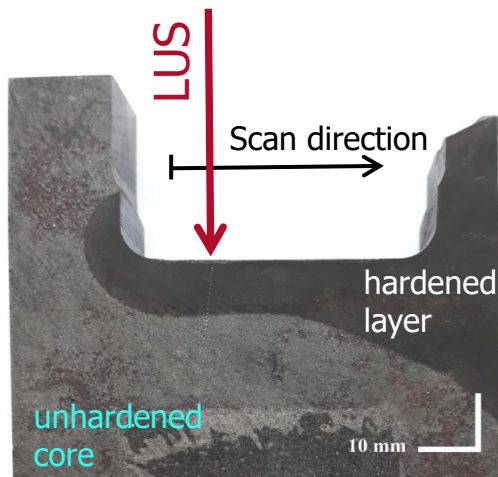
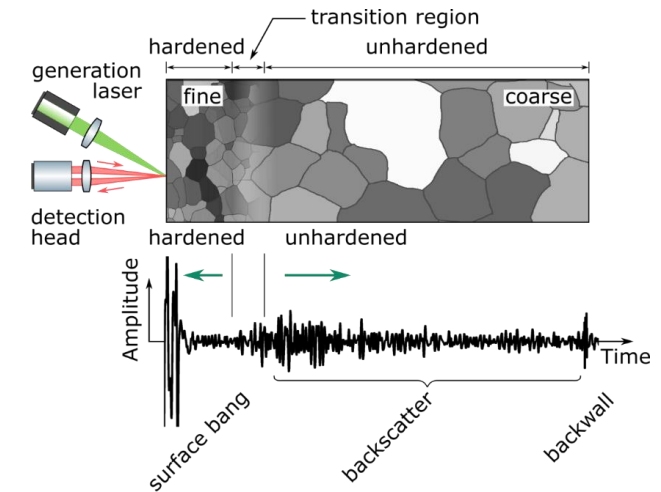


Laser ultrasound after thermal treatment

Non-destructive determination of surface hardening depth

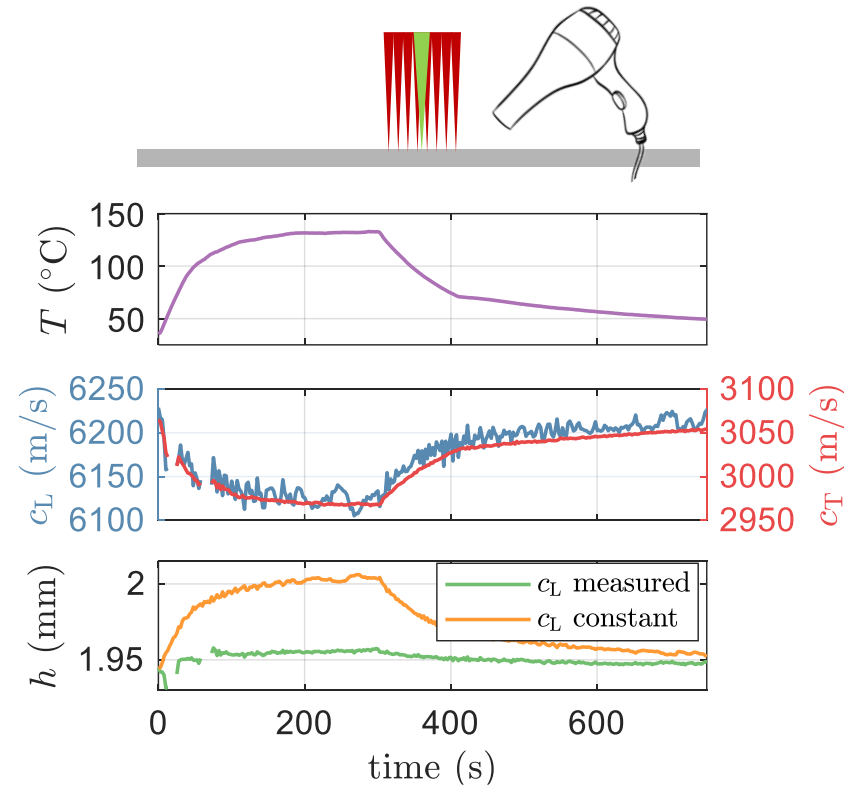
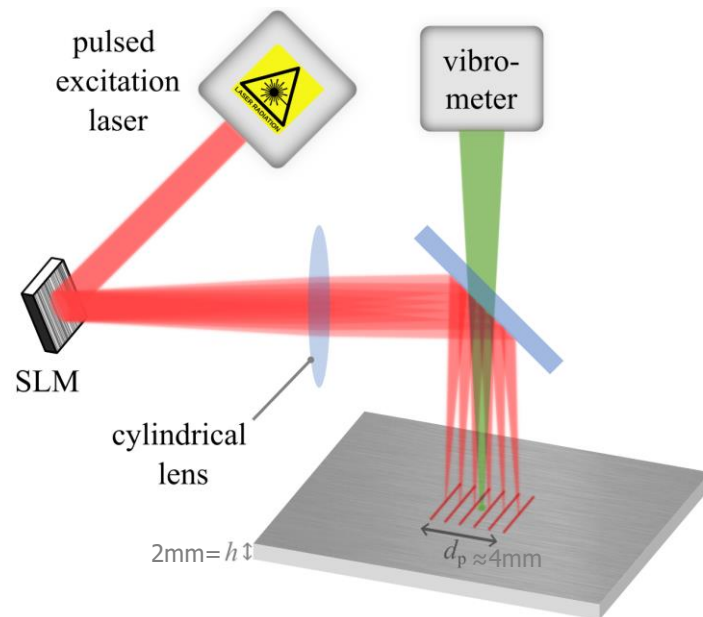


- For inductively hardened steel parts
- Grain structure changes during hardening
- Can substitute standard, destructive testing



New methods by modelling and simulation

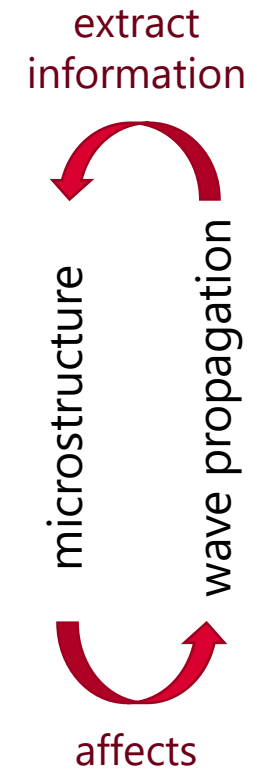
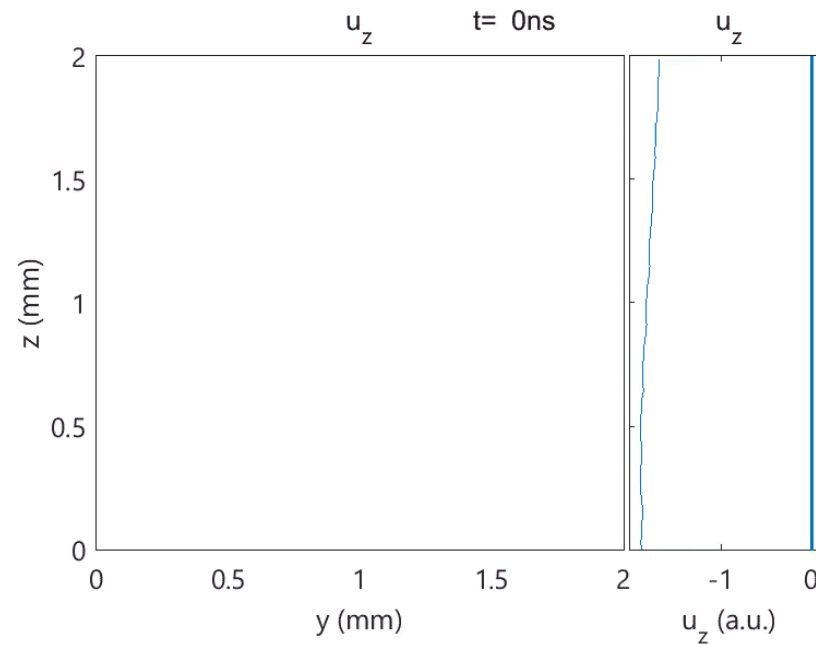
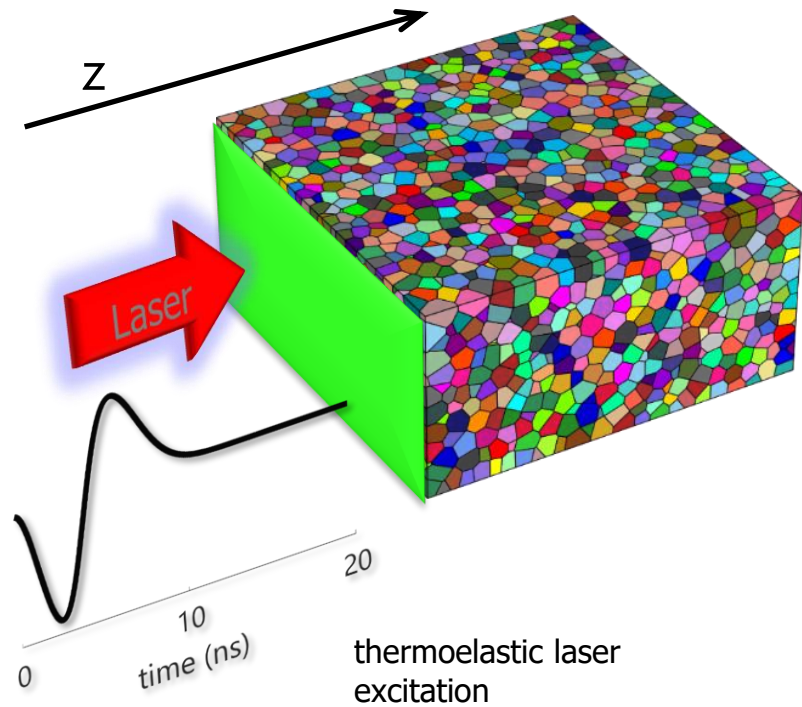
Simultaneous measurement of isotropic elastic plate properties and thickness:



PATENTED

- Robust thickness measurements
- Robust elastic properties measurements

Investigation of influence of microstructure on elastic wave propagation





We're looking into it!



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We receive public funding from:



Finanziert von der
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