

LUS4Metals, Hamilton

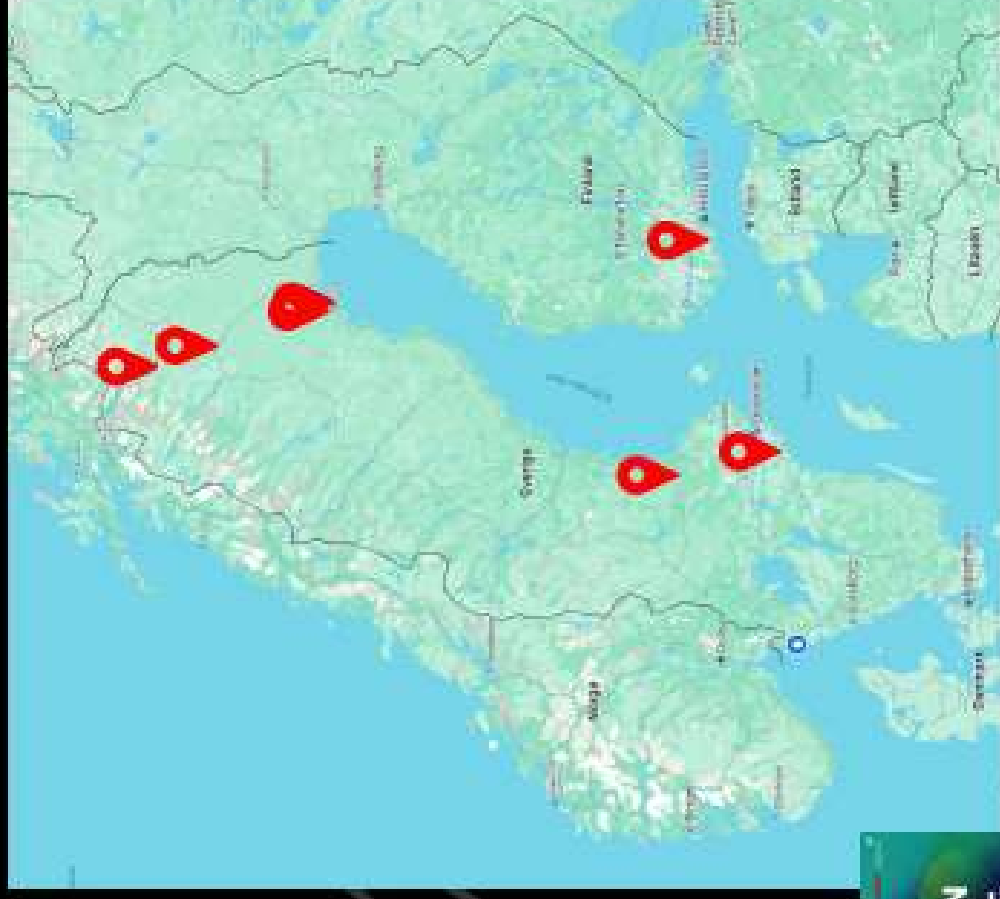
Laser-ultrasonics for material characterization of microstructures and defects in metals

Mikael Malmström

Planned fossil free steel production

- Stegra, Boden
 - 2025-2026: 2.5 M t/y
 - ~2030: 5 M t/y
- Blast Green Steel, Inkoo (Finland)
 - 2027-2030: 2.5 M t 2027: starting with sponge iron
- SSAB Luleå
 - 2025-2028: 2.5 M t/y
- SSAB Oxelösund
 - EAF and plate production
- LKAB, Vitåfors (HYBRIT Demo)
 - 2028: 1.2 M t, sponge iron
 - 2030 – 2040: increase
- LKAB Kiruna (HYBRIT full scale)
 - Start sponge iron production after 2040
- GreenIron H2, Sandviken
 - Now: Hydrogen reduced iron

• [THE GREEN STEEL CHALLENGE PODCAST](#)



SWERIM in short

- International research institute
- 17 member companies
- 13 research projects
- 2000 person-years of research effort
- 2000 person-years of research effort
- 2000 person-years of research effort
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- 2000 person-years of research effort

Laser ultrasonics – LUS

Diagram illustrating the LUS setup, showing a laser beam and a detector.

Photograph showing a laboratory setup for Laser Ultrasonics (LUS) with a person in a white lab coat.

LUS grain size gauge

Diagram illustrating the LUS grain size gauge setup, showing a laser beam and a detector.

GLUS[®] and annealing

Photograph showing a GLUS[®] and annealing setup, featuring a laser beam and a detector.

GLUS[®] with stress-relaxation

Graph showing stress-relaxation curves for GLUS[®], with a QR code and a small inset image.

Laser ultrasonics for microstructure verification of heat treatments and thermal processes (LUPHEAT)

Photograph showing a LUPHEAT setup, featuring a laser beam and a detector.

SWERIM logo and text: The world has only one industry.

GLUS[®] with stress-relaxation graph and QR code.

Swerim in short

- Independent research institute
- ~190 employees
- Turnover SEK ~250 million
- Unique test and demonstration facilities
- Customers from all over the world
- Owners:
 - 80% Industry
 - 20% the Swedish state through RISE

SWERIM



Long tradition – the oldest part was established in 1921 (Metallografiska institutet) and MEFOS (1963)



DC furnace

Thermobalance

Induction heater

Roller leveller

Pit furnace

Fluidized bed

Bell-type furnace

Atomization

Universal converter

Computational cluster

Walking-beam furnace

Briquetting machine

Continuous casting simulator

Gleeble & GLUS

Vacuum induction furnace

Muffle furnace

Gas reformation

Chamber furnace

3D metal printing

Reversible rolling mill

Roller-hearth furnace

Drop test rig

40 ToD facilities

Grinding

Tamman furnace

Forging press

Machining

Continuous rolling mill

SEM/TEM

High-temperature lab

Joining laboratory

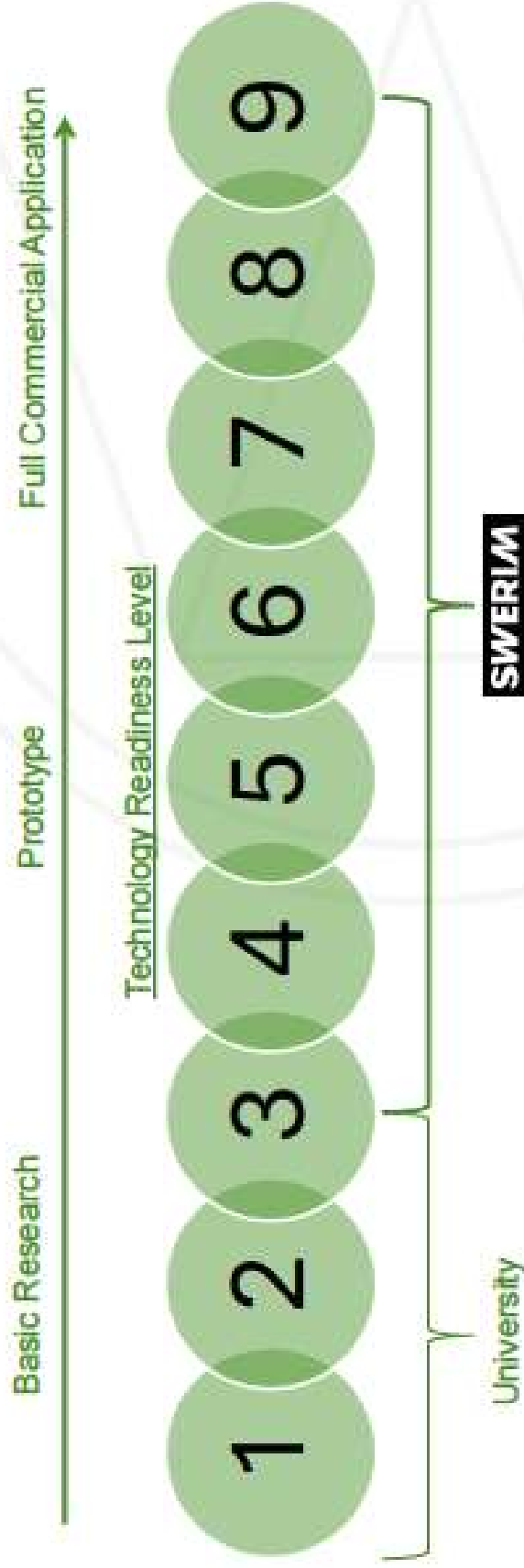
Pull test rig

Agglomeration lab

Mechanical testing

Analytical process monitoring

Research in high TRL-levels



Swerim

CEO Pontus Sjöberg

Operational development

HR/Marketing/Admin

Finance/IT

IT

Metallurgy

Material Development

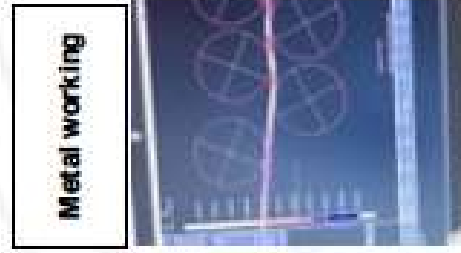
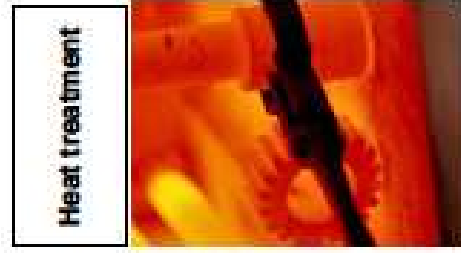
Production technologies

Pilot & Design



Production technology

Competence areas



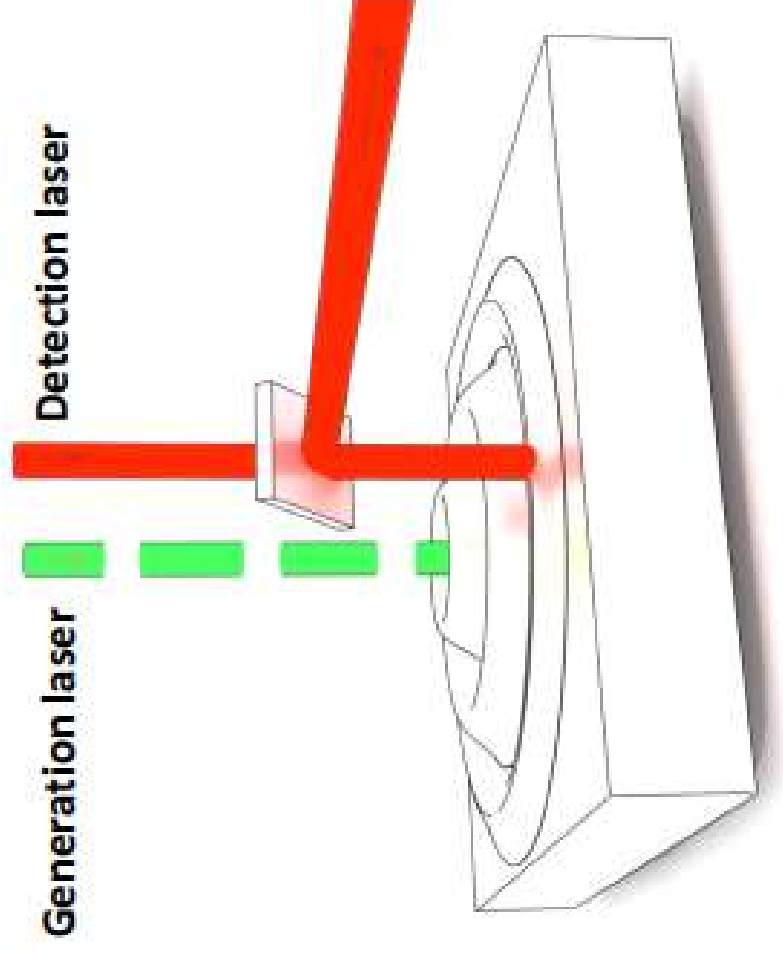
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Education: IWE – in collaboration with KTH and Swedish Welding Commission.

Research program and network: Heat treatment centre, Process monitoring Centre for Joining and Structures, Research program within Heating and metalworking, Forging Committee

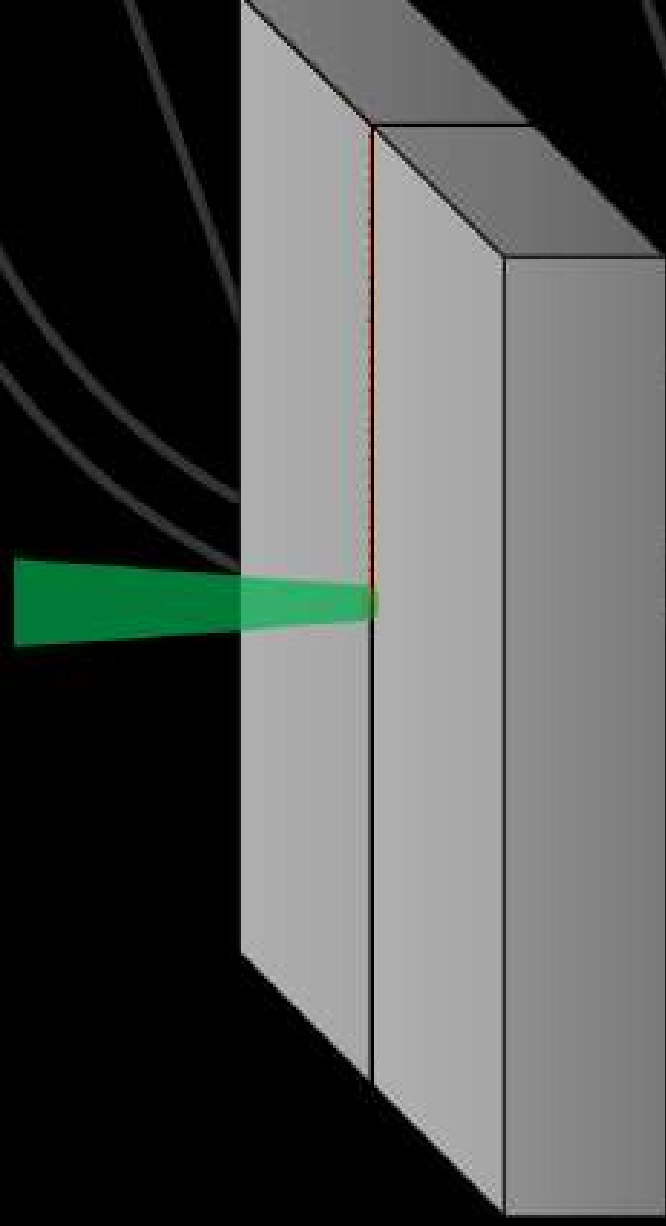


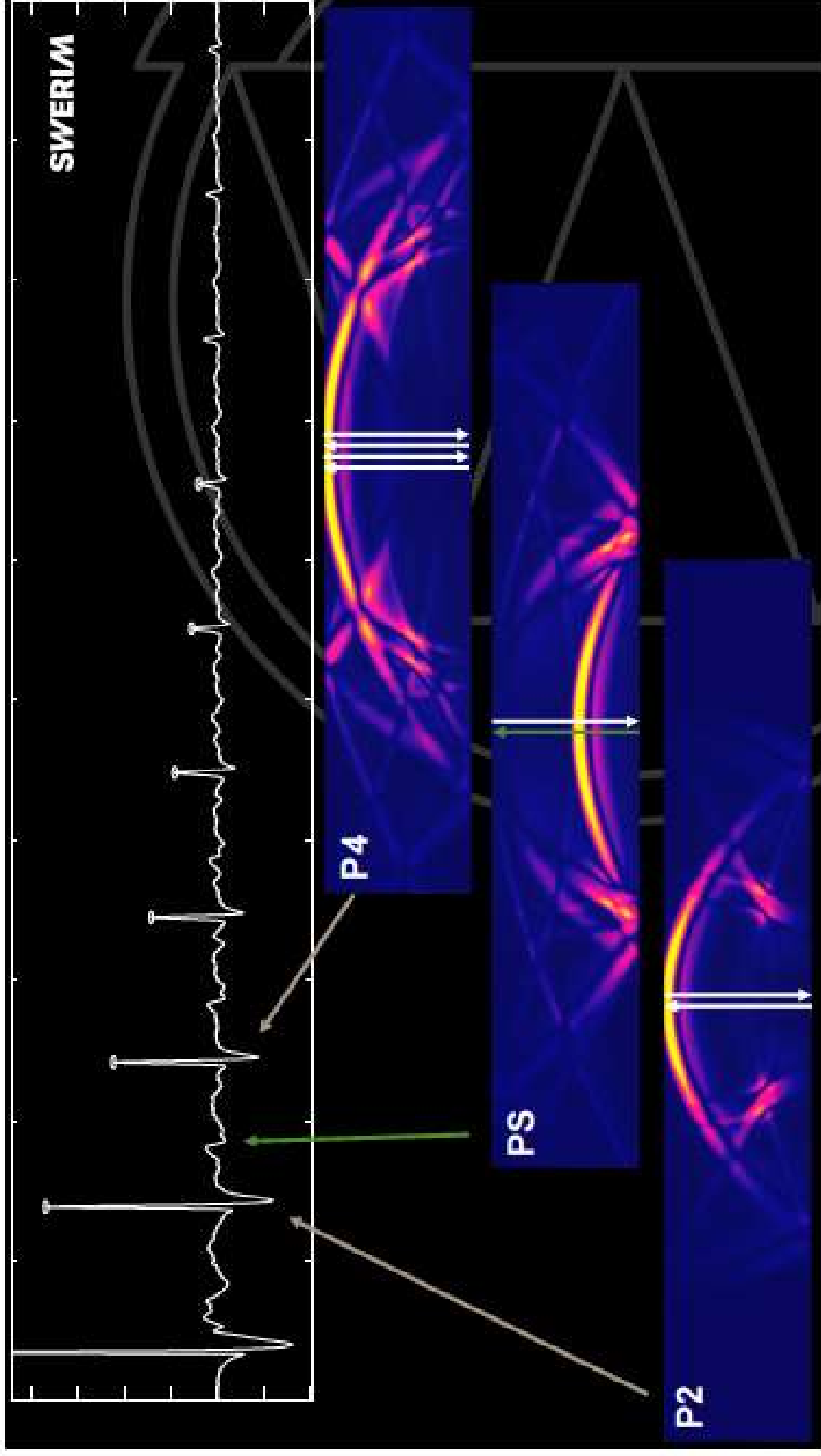
Laser ultrasonics – LUS

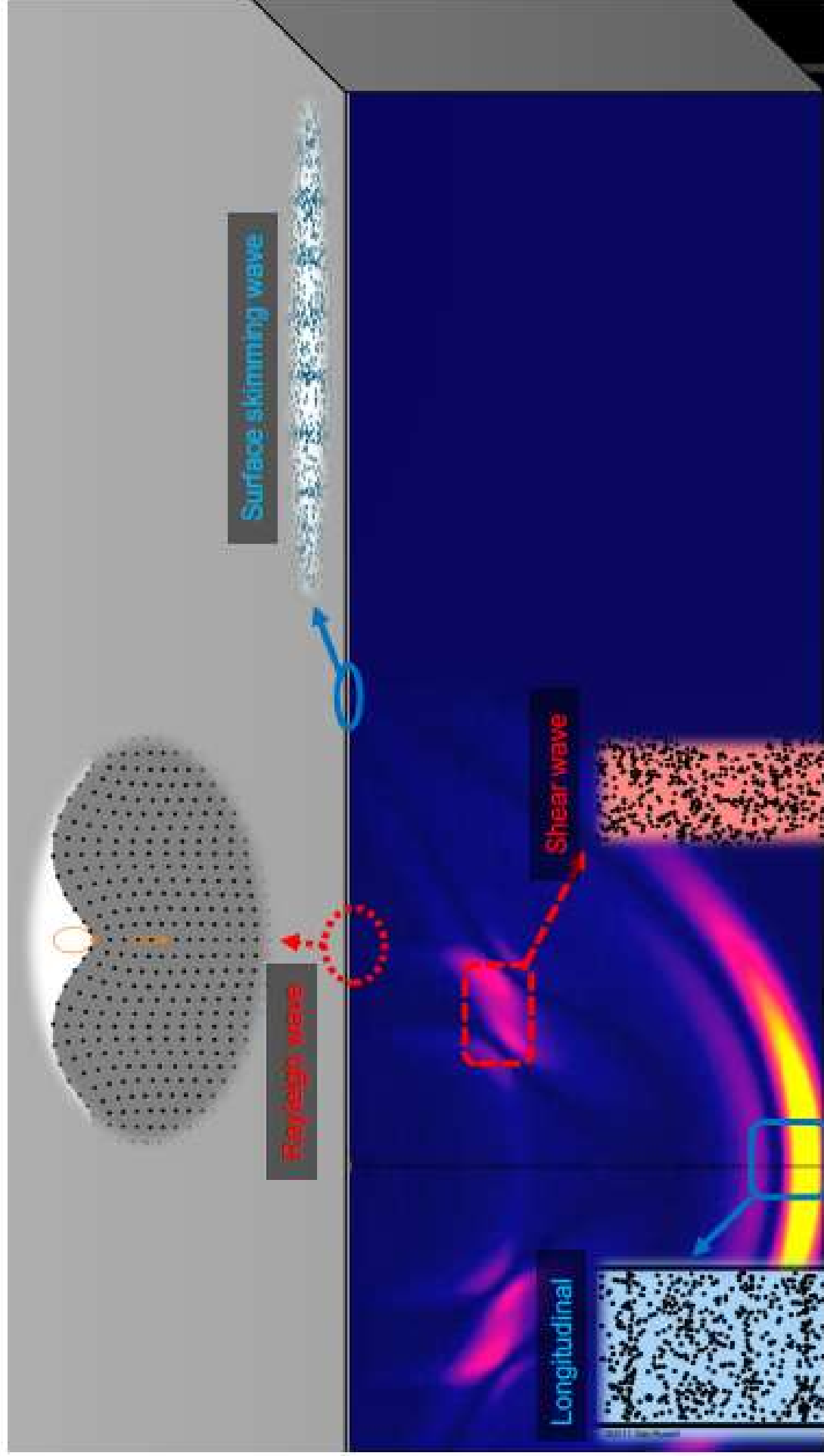


Laser ultrasonics – LUS

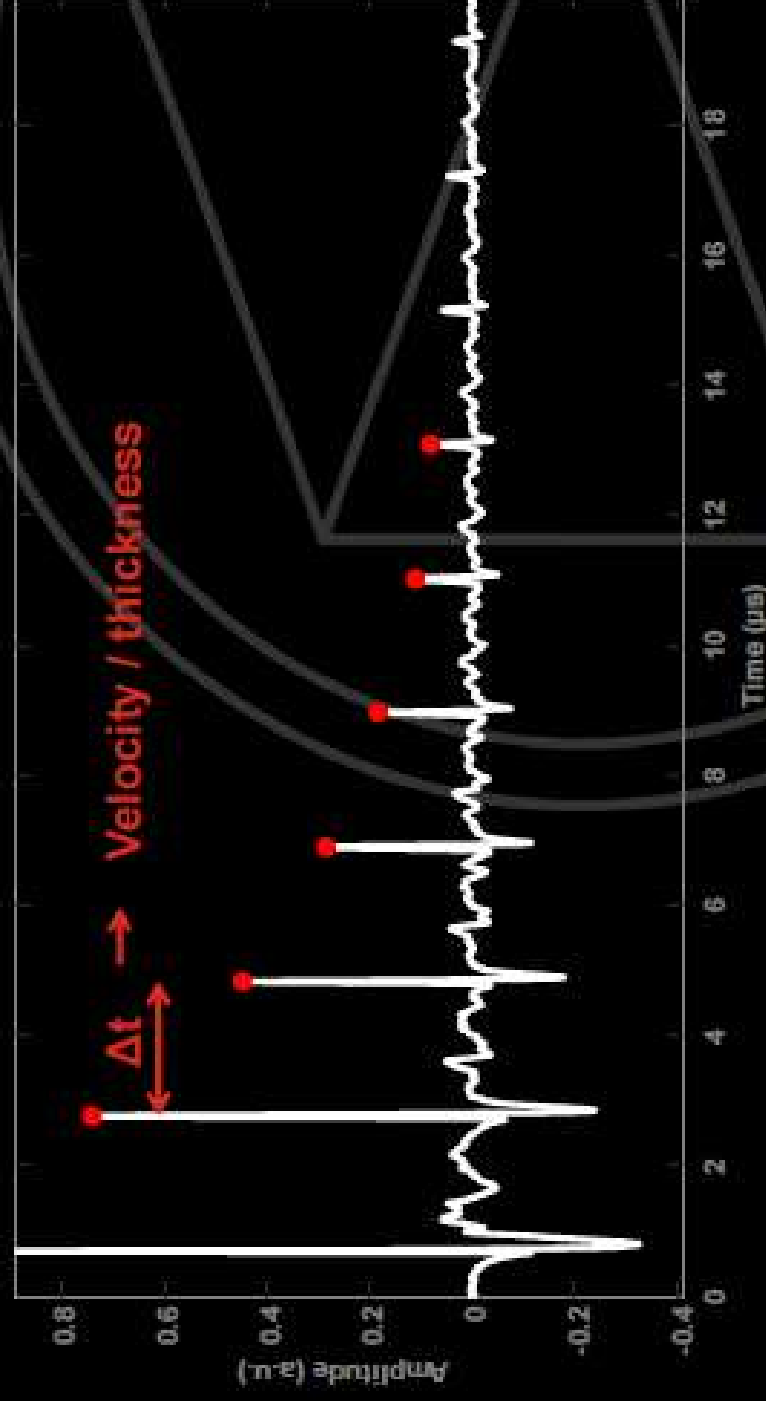
Generation and pulse propagation



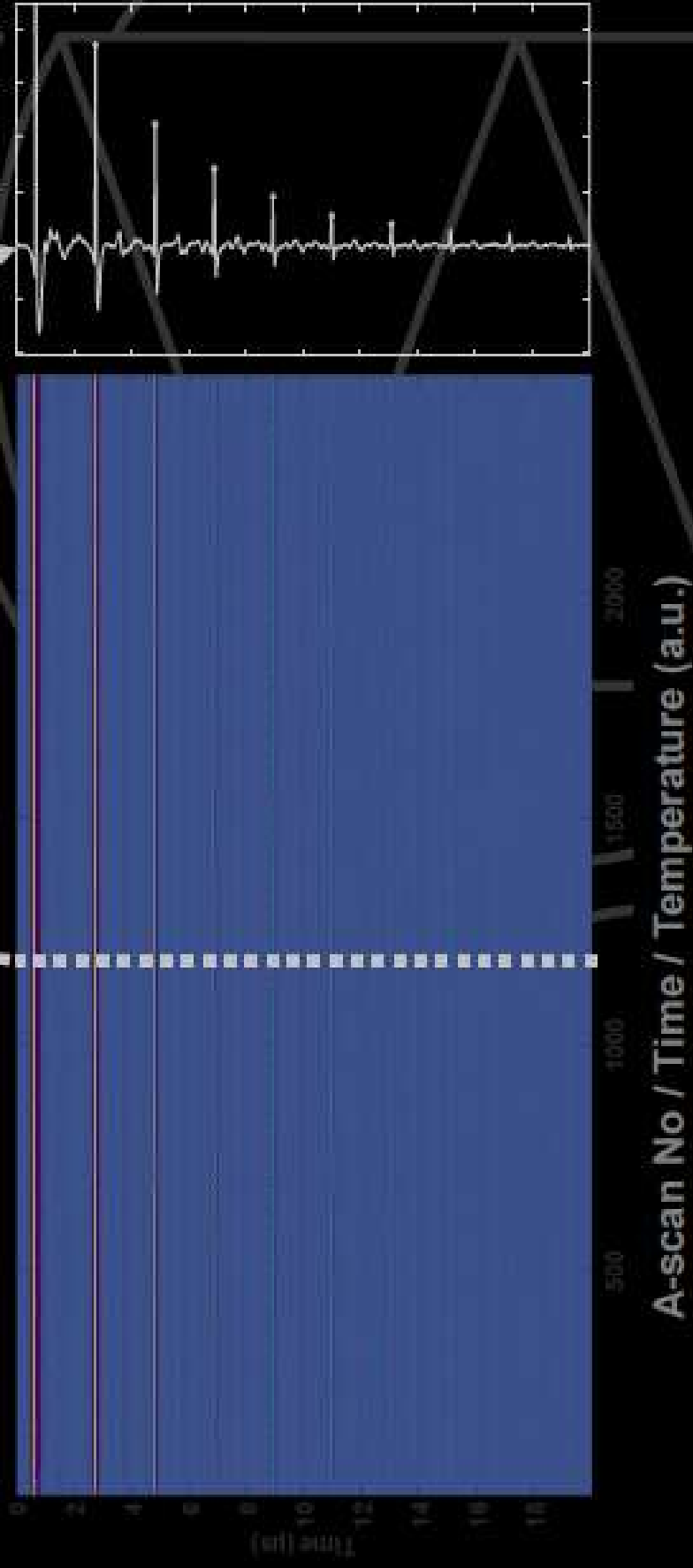




LUS principle A-scan



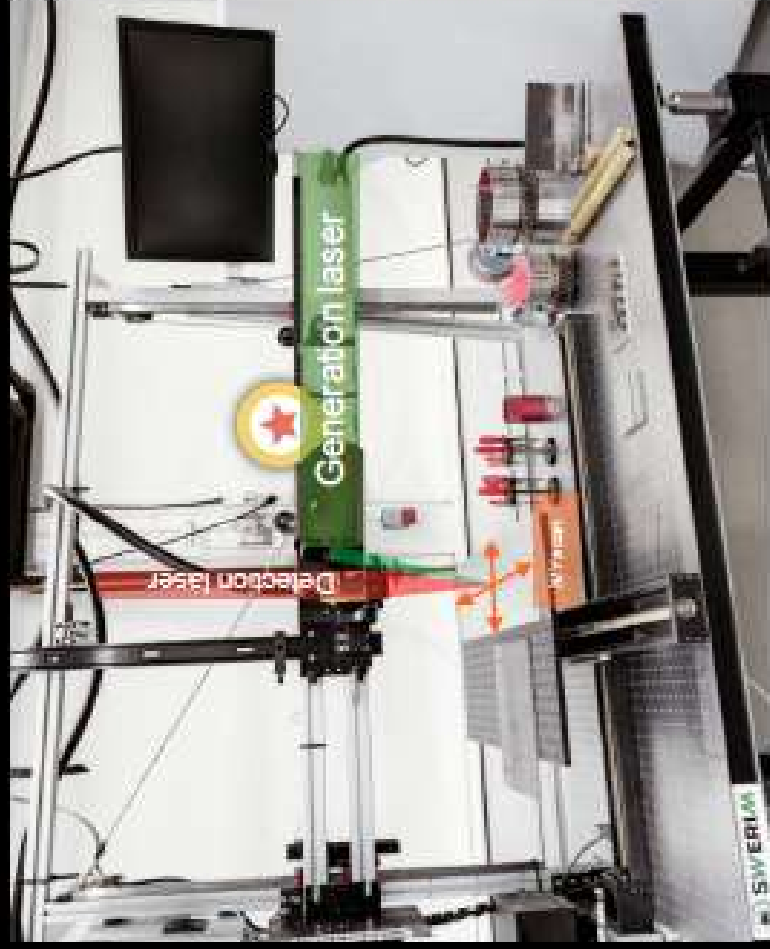
LUS principle B-scan



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Swerim High Power LUS system

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Swetim High Frequency LUS system

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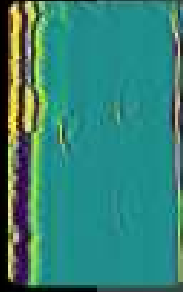


Detection laser system
1030 nm, 0-200 Hz



Generation laser
1064 nm, 0.15-5 ns, 0-30 kHz

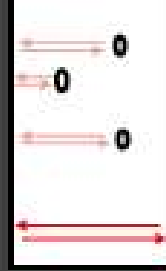




Reflections

(Change in "refractive index")

- Thickness
- Defect detection
- Layer/interface detection

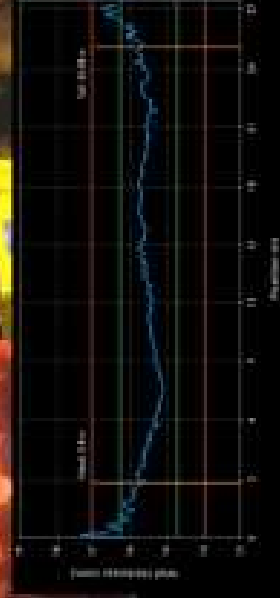
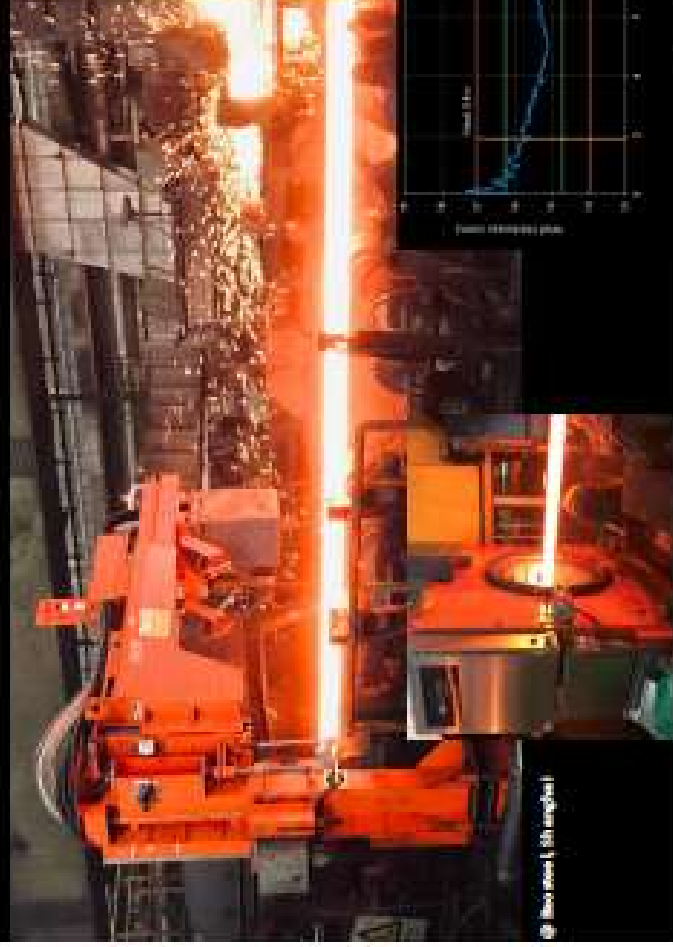


Commercial LUS equipment in industry

Wall thickness of seamless pipes

tecna

SWERIM



LUS equipment in industry Defect detection



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Resource efficiency increase by laser ultrasonics (REAL)



PRODUKTION2030

VINNOVA FORMASIT

SWERIM

LULEÅ
TEKNOLOGI
UNIVERSITET

volvo

SCANIA

Bodycote

SANDVIK

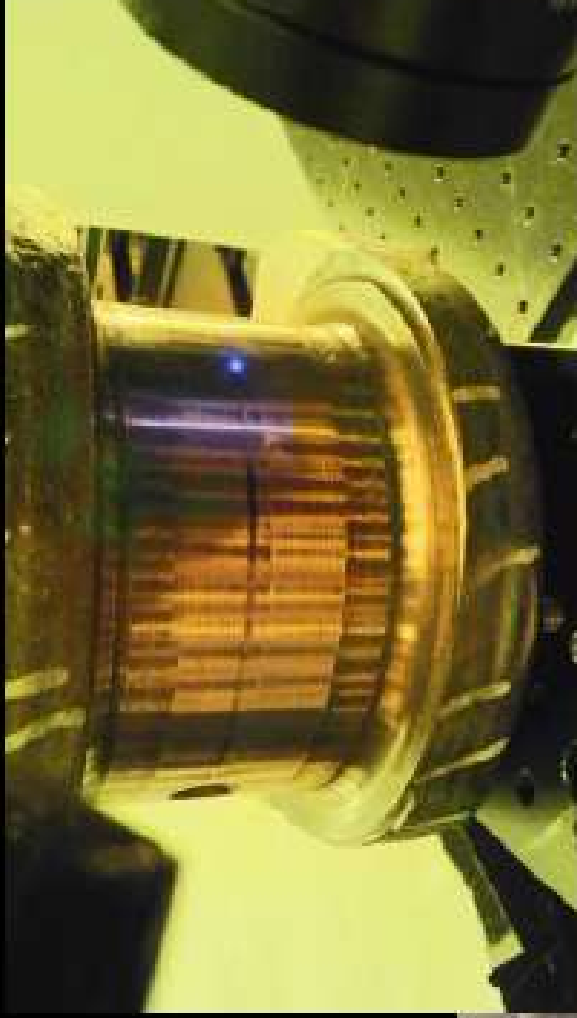


**Samples directly after induction hardening
(i.e., not final surface)**

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Setup

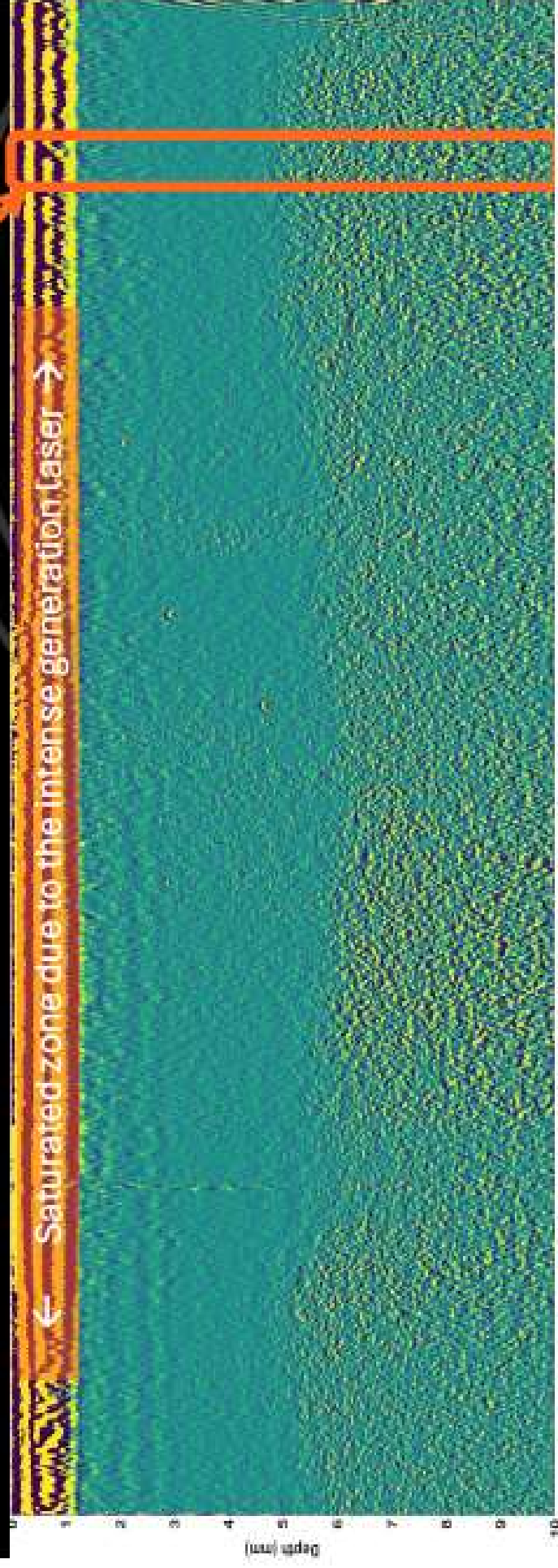
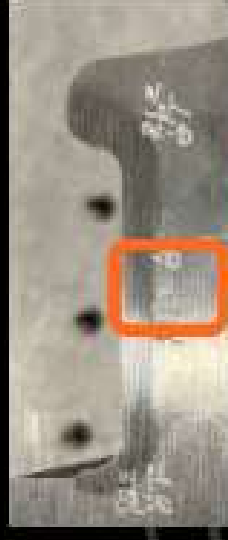


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One measurement = hole edge to hole edge, ~350 degrees



LUS results vs destructive testing (DT) on twin

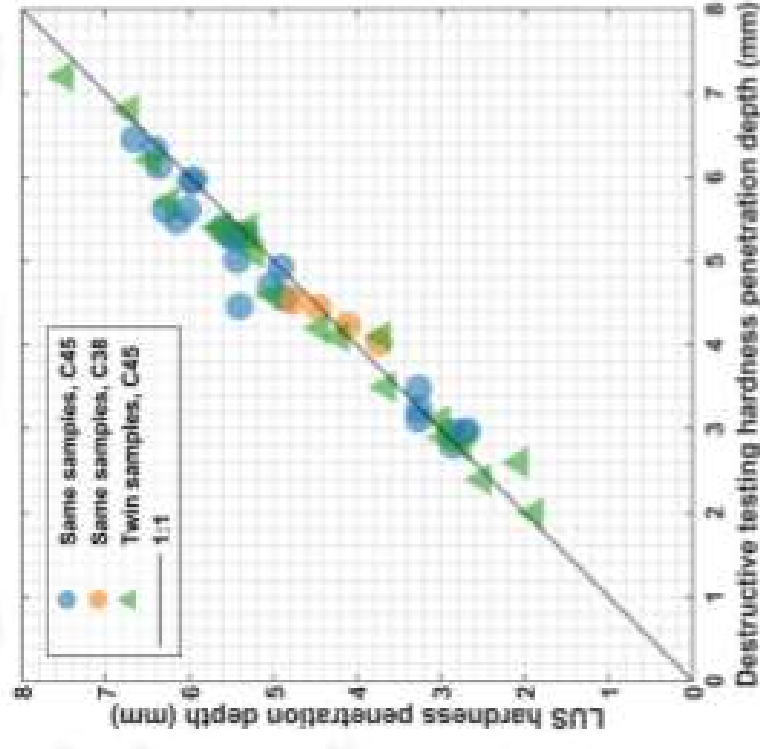
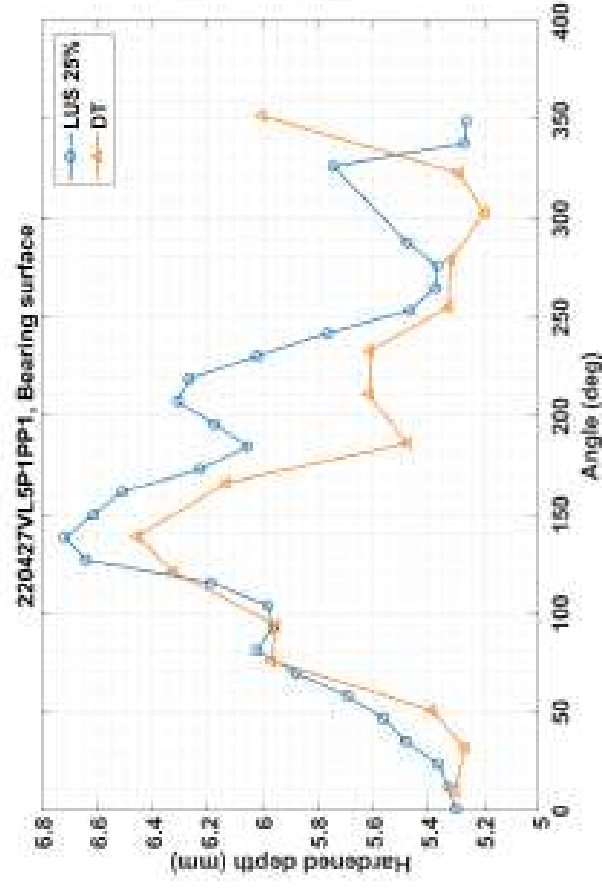


Rotation angle 0-350°



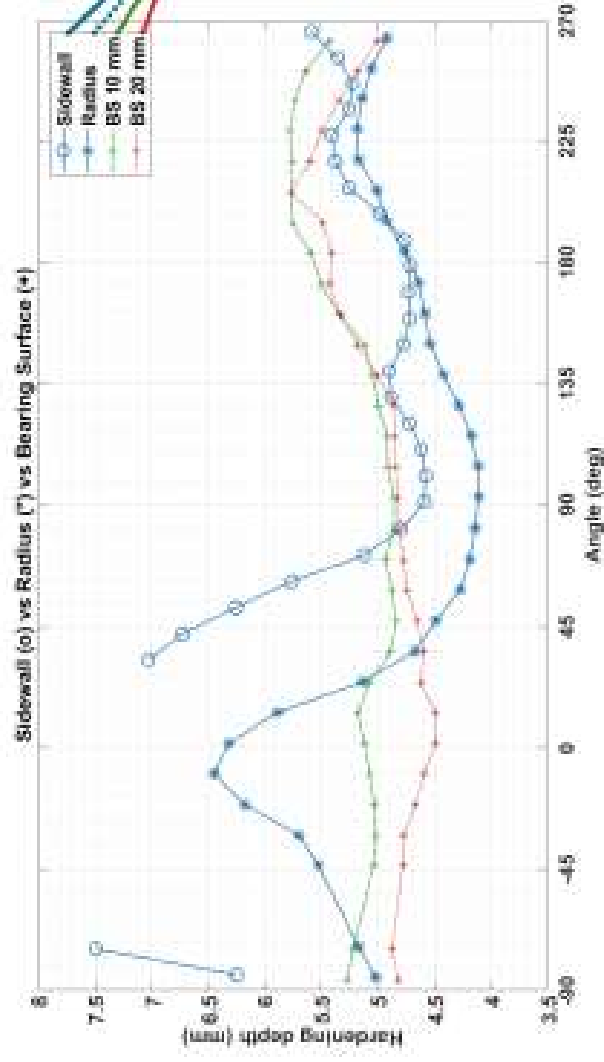
Crankshaft bearing case: HPD

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Crankshaft bearing case: HPD

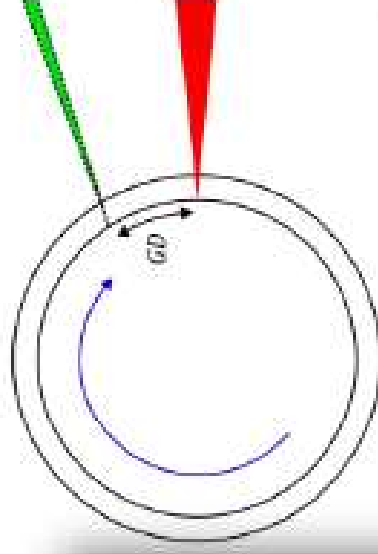
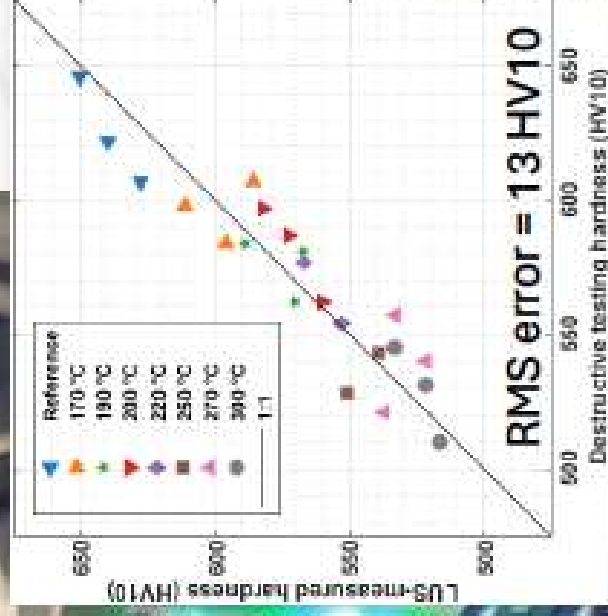
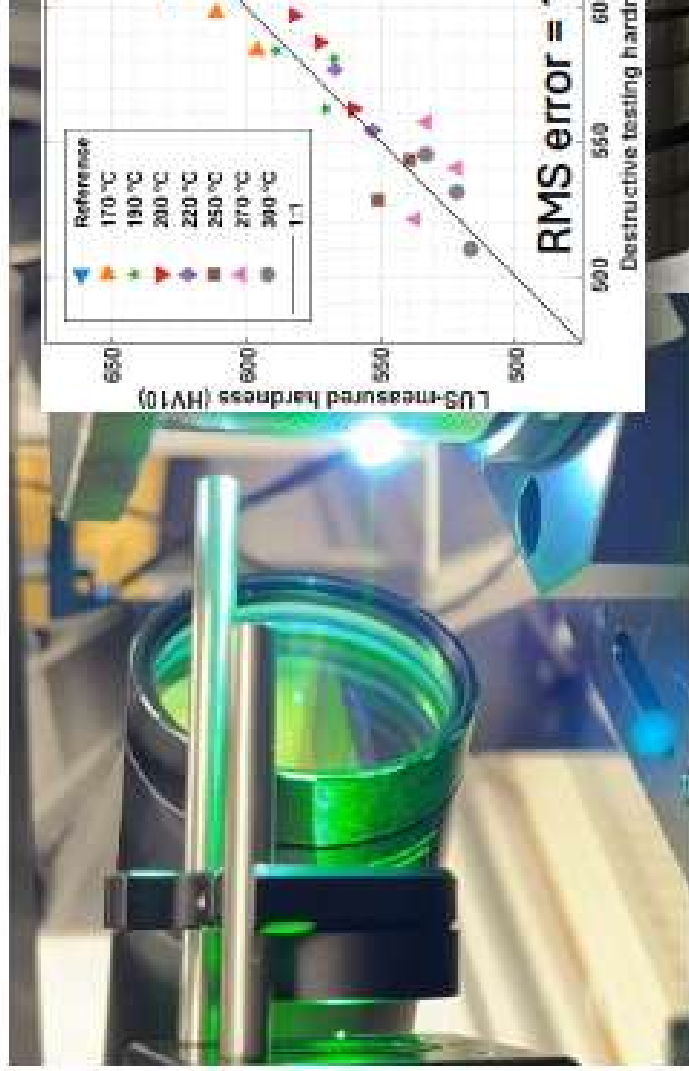
SWERIM



To be published: Hampus Wilmark Kreuger, et al "Induction hardening depth and hardness measurement by laser ultrasonics for automotive industry" NDT and E International.

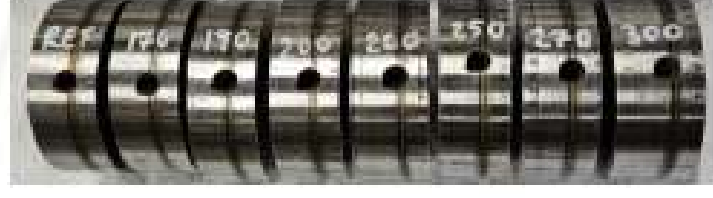
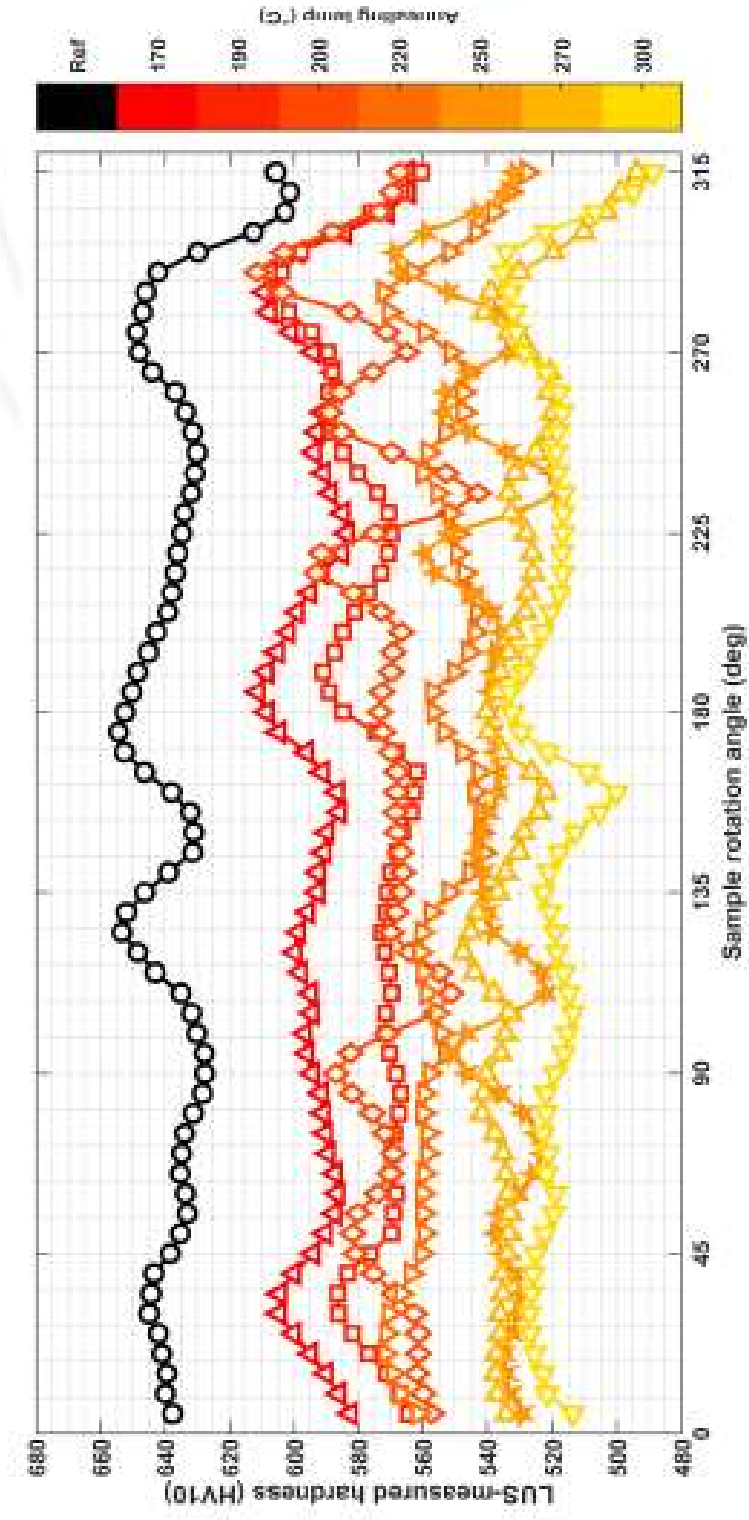
Surface hardness with surface waves

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To be published: Hampus Wilmann Kreuger, et al "Induction hardening depth and hardness measurement by laser ultrasonics for automotive industry" NDT and E International.

Surface hardness



AM printed sample with designed defects

SWERIM

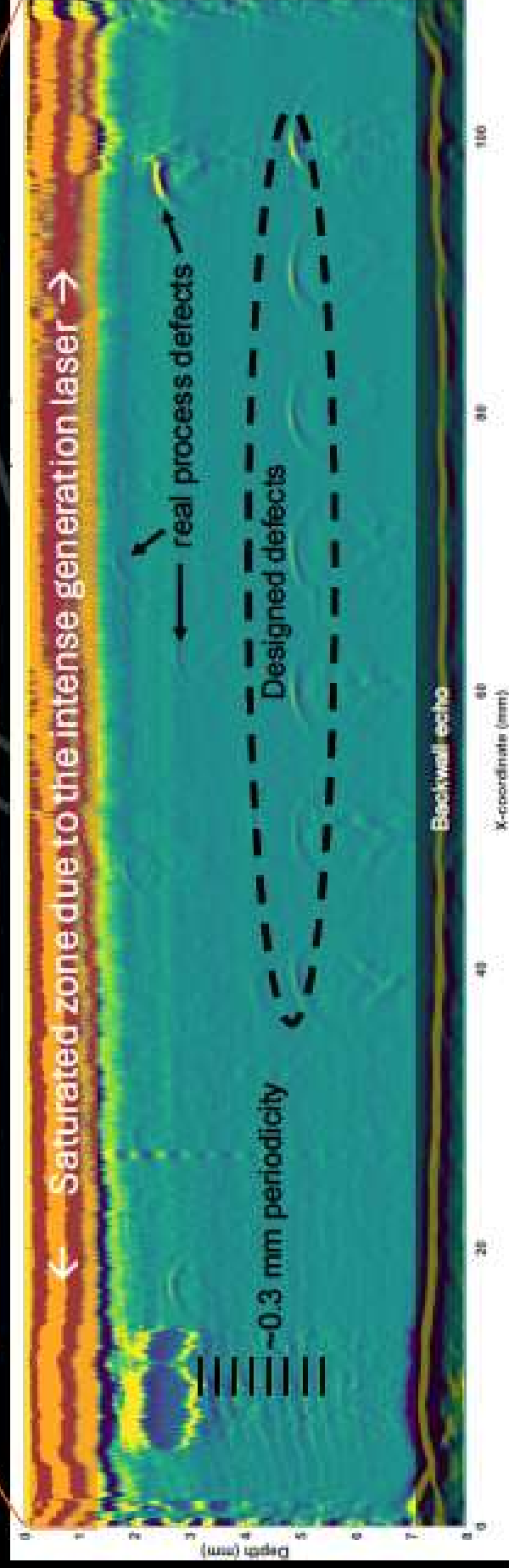


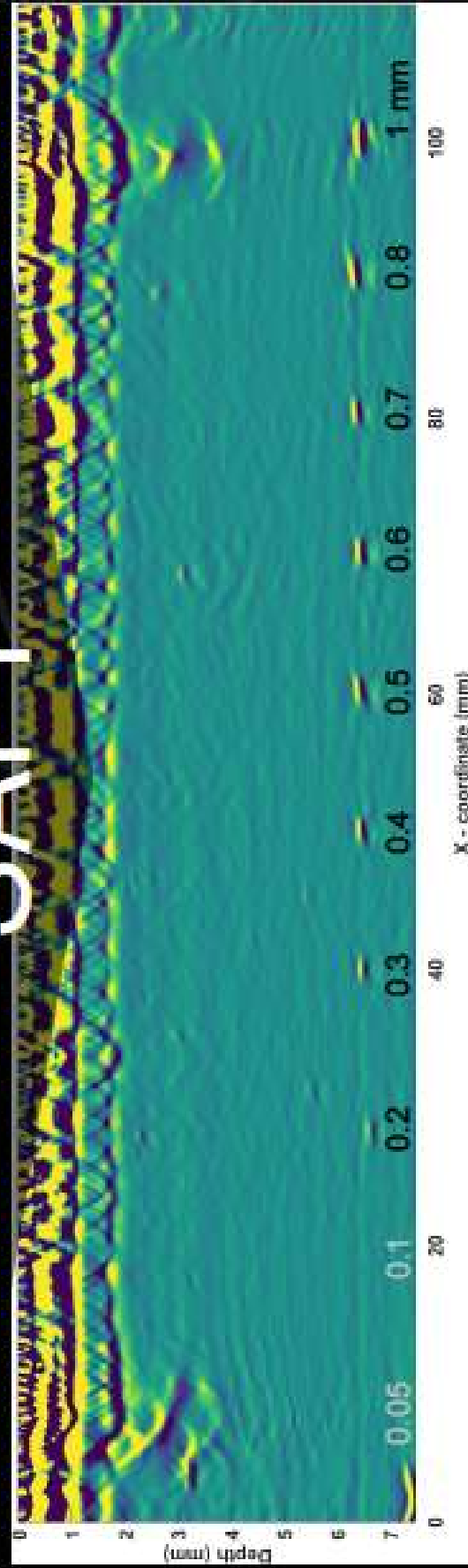
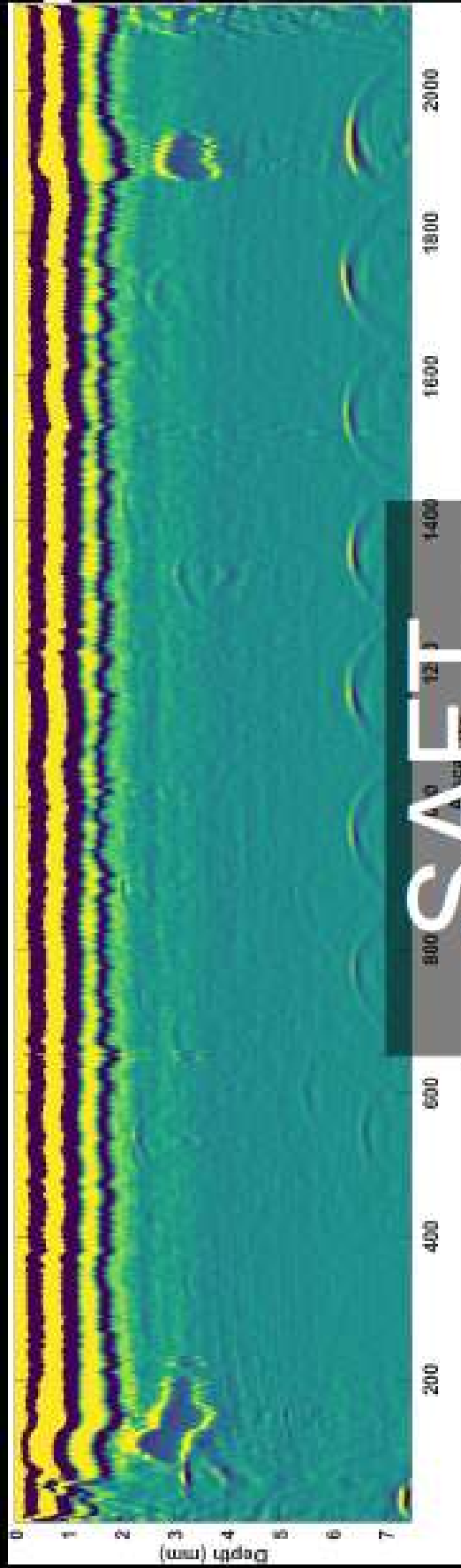
Side view

Designed defects

Defect signatures in B-scan

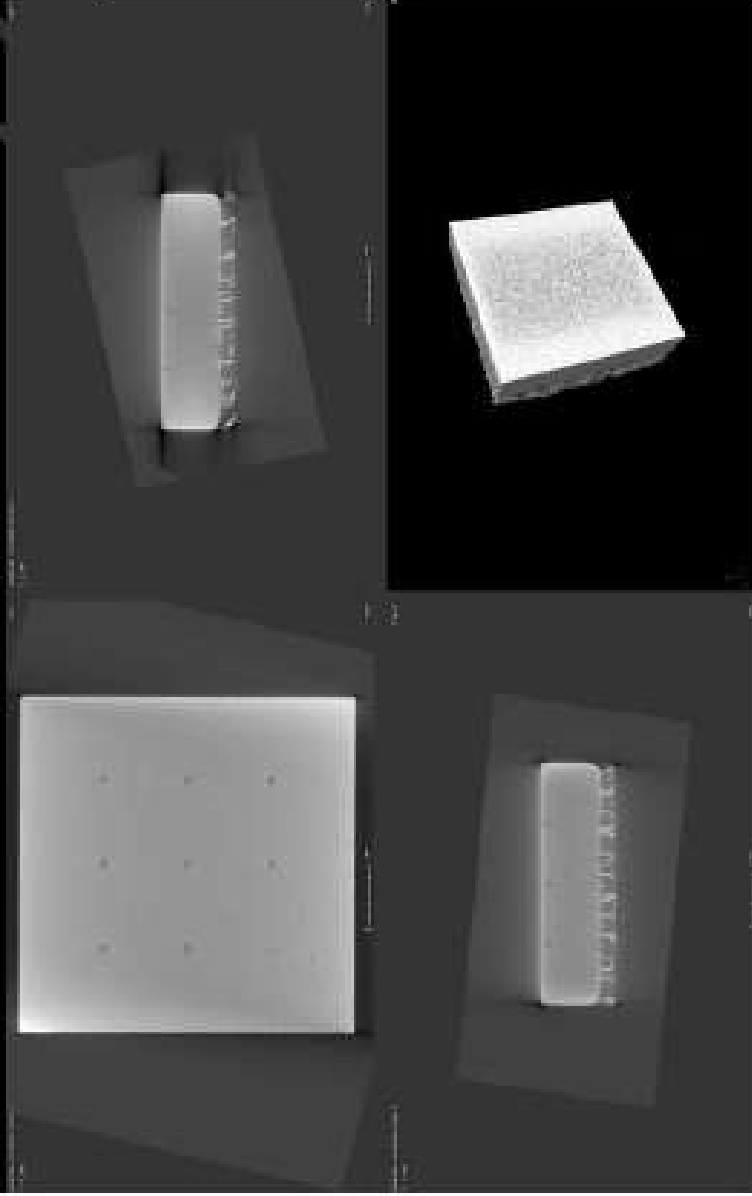
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SLM Samples 316

SWERIM



Defect depth (μm)

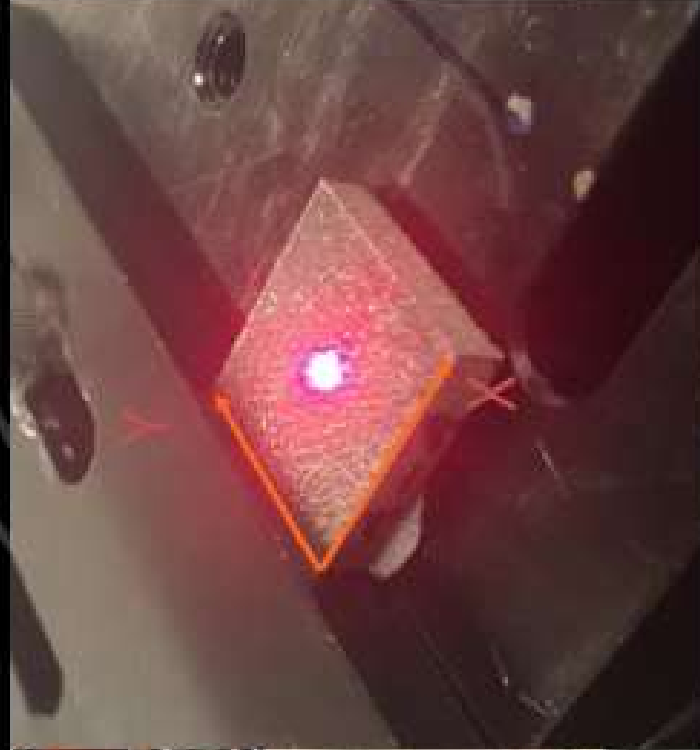
150	100	50
X' and Y' axis might not correspond to x and y axis of the measurement		
200	300	200
50	100	150

Y

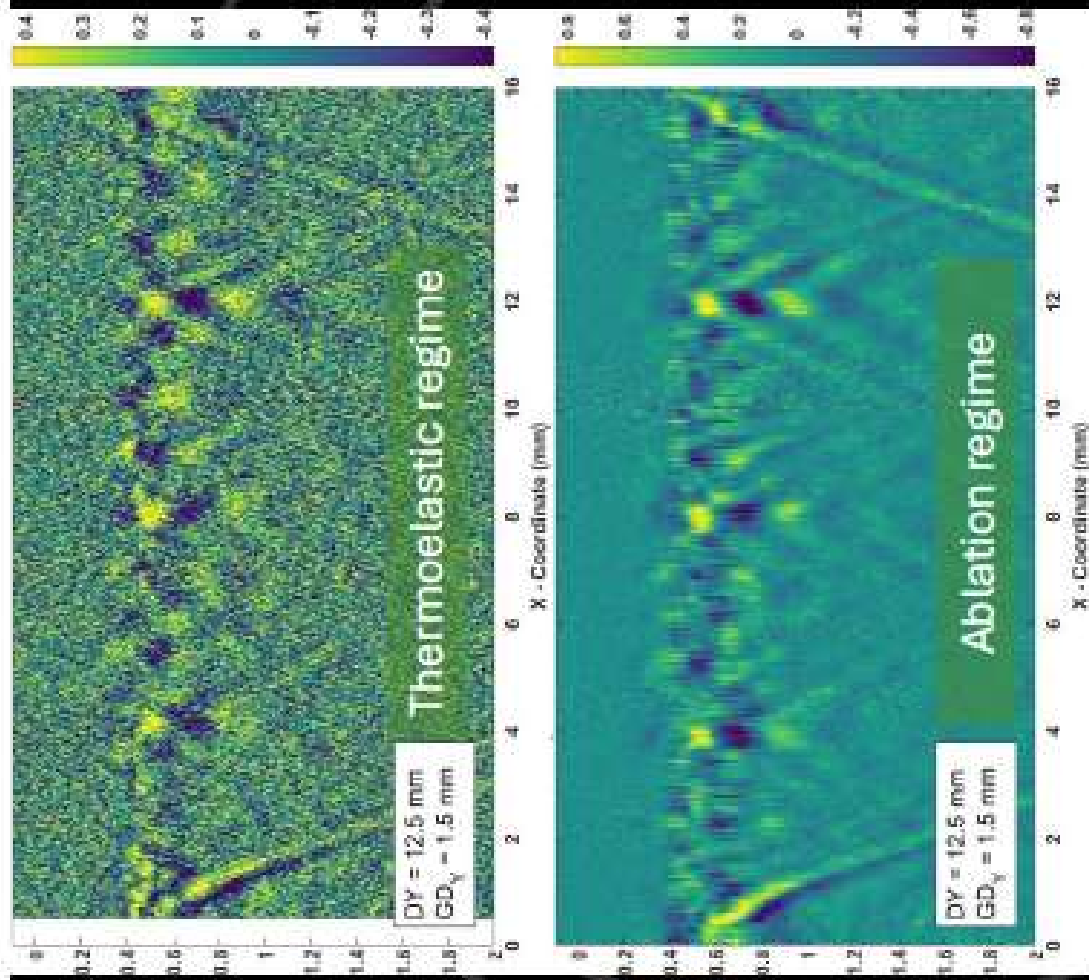
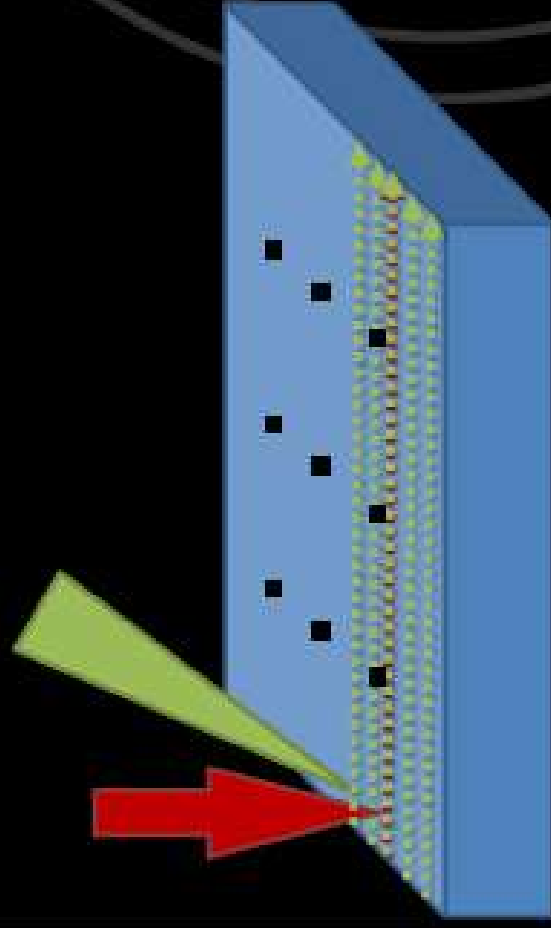
X'

LUS Measurement

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Thermal vs Ablation

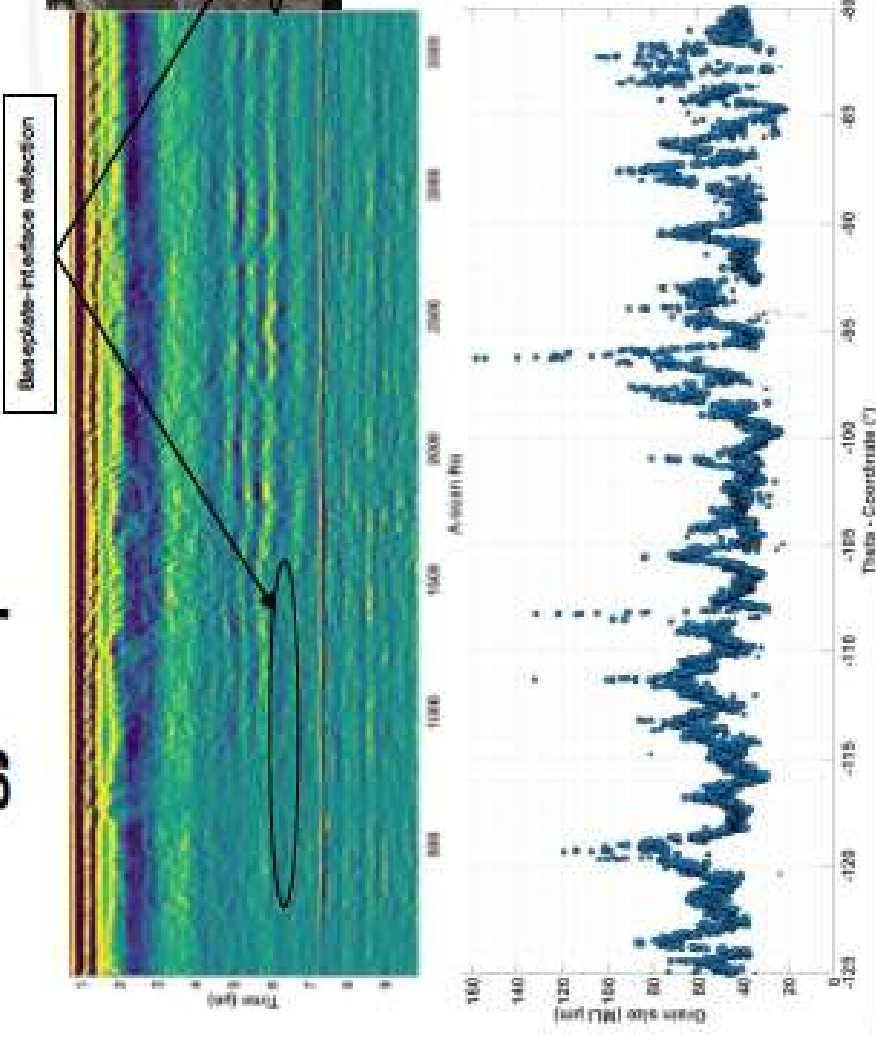


Quantitatively assessment of AM processes with AI integrated ultrasonics (QAI-UT)

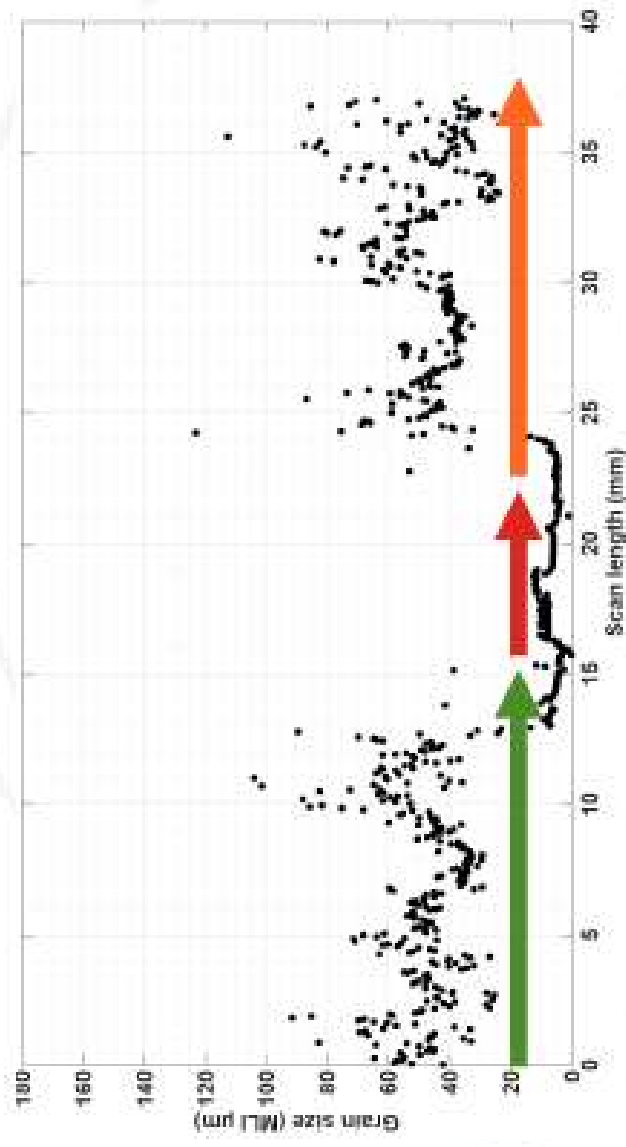
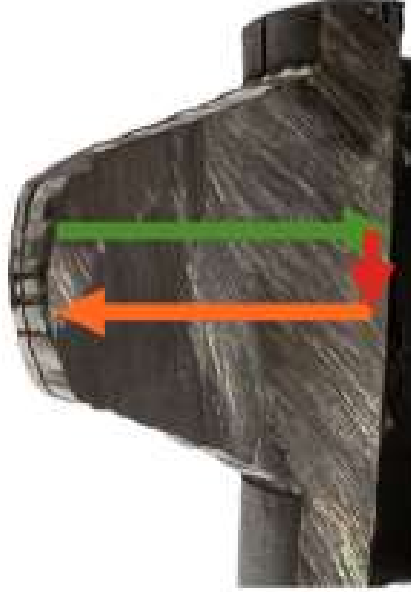
- Luleå University (coordinator)
- GKN Aerospace
- Vattenfall, Forsmark
- Swerim



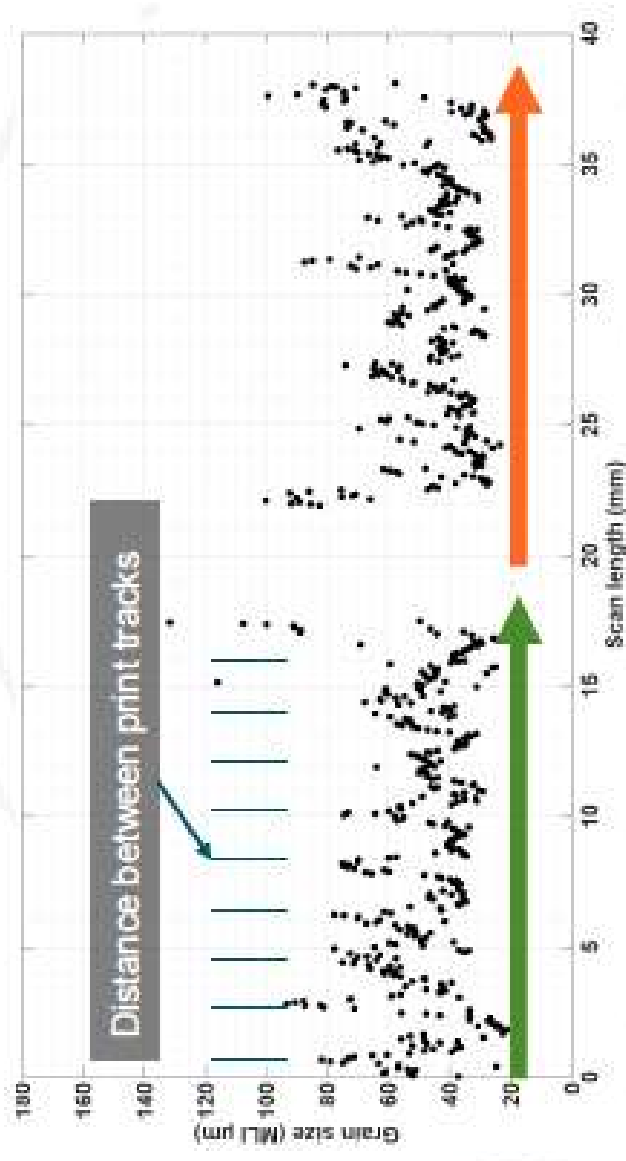
Laser Direct Energy Deposition Inconel samples



Cross-section scan

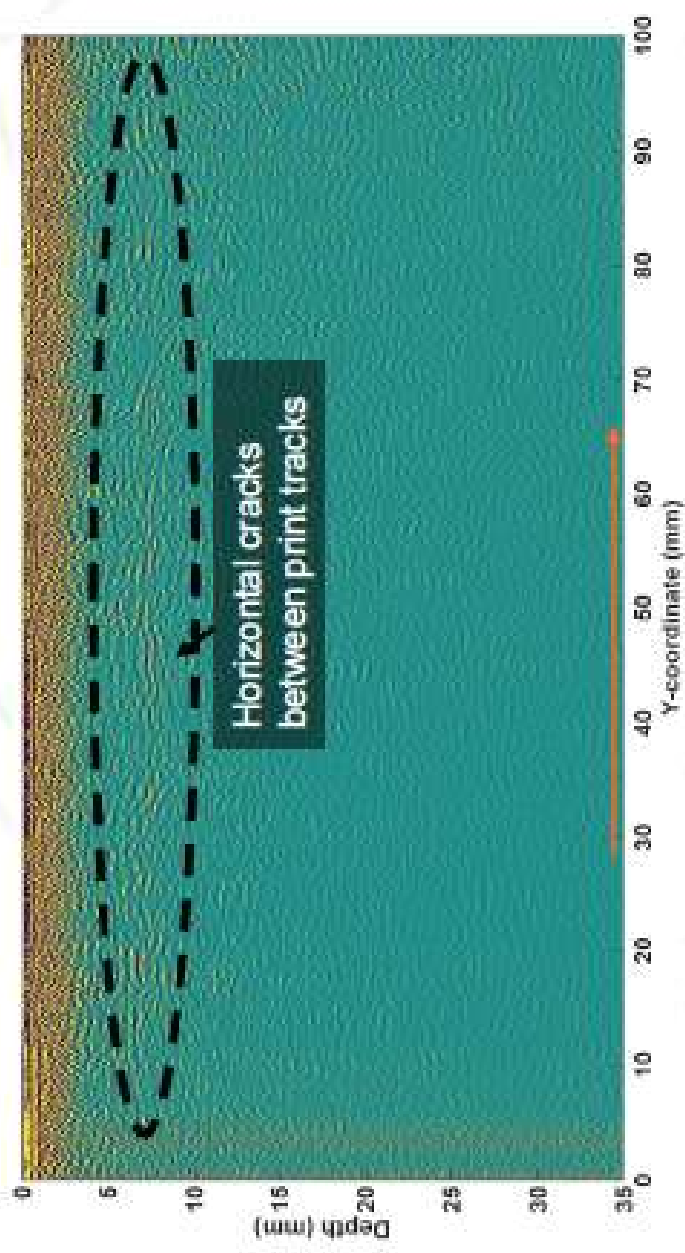
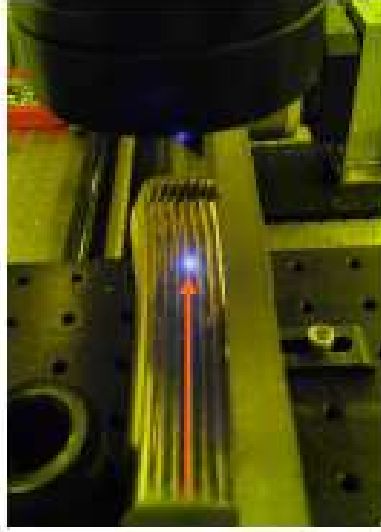


Cross-section scan



Horizontal features from the side-wall

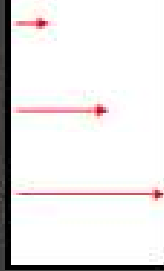
SWERIM





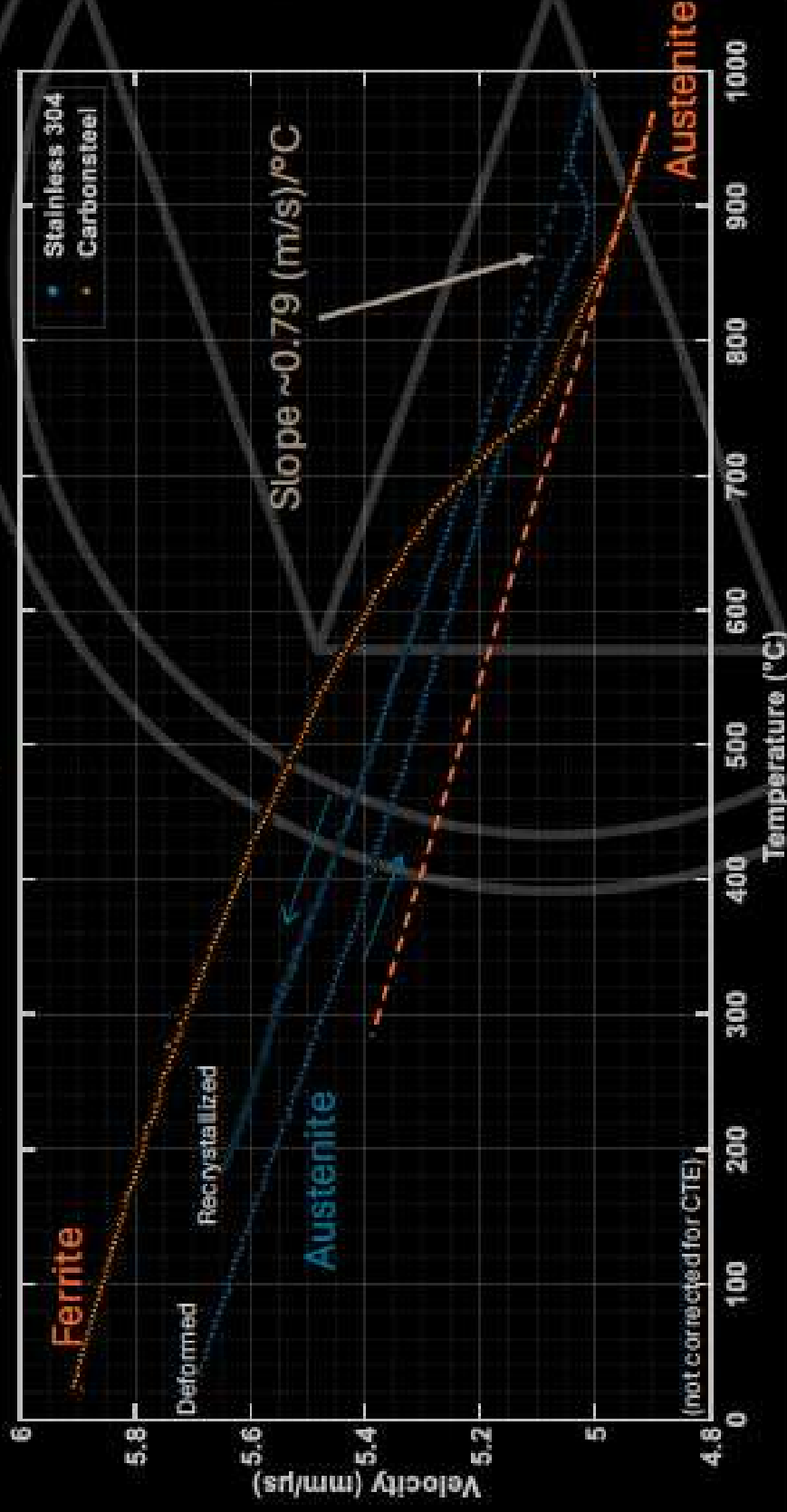
Velocity (Elasticity)

- E-modulus
- Mechanical strength
- Texture
- Phase transformation/
recrystallization



Velocity temperature dependence

SWERIM

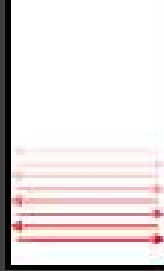




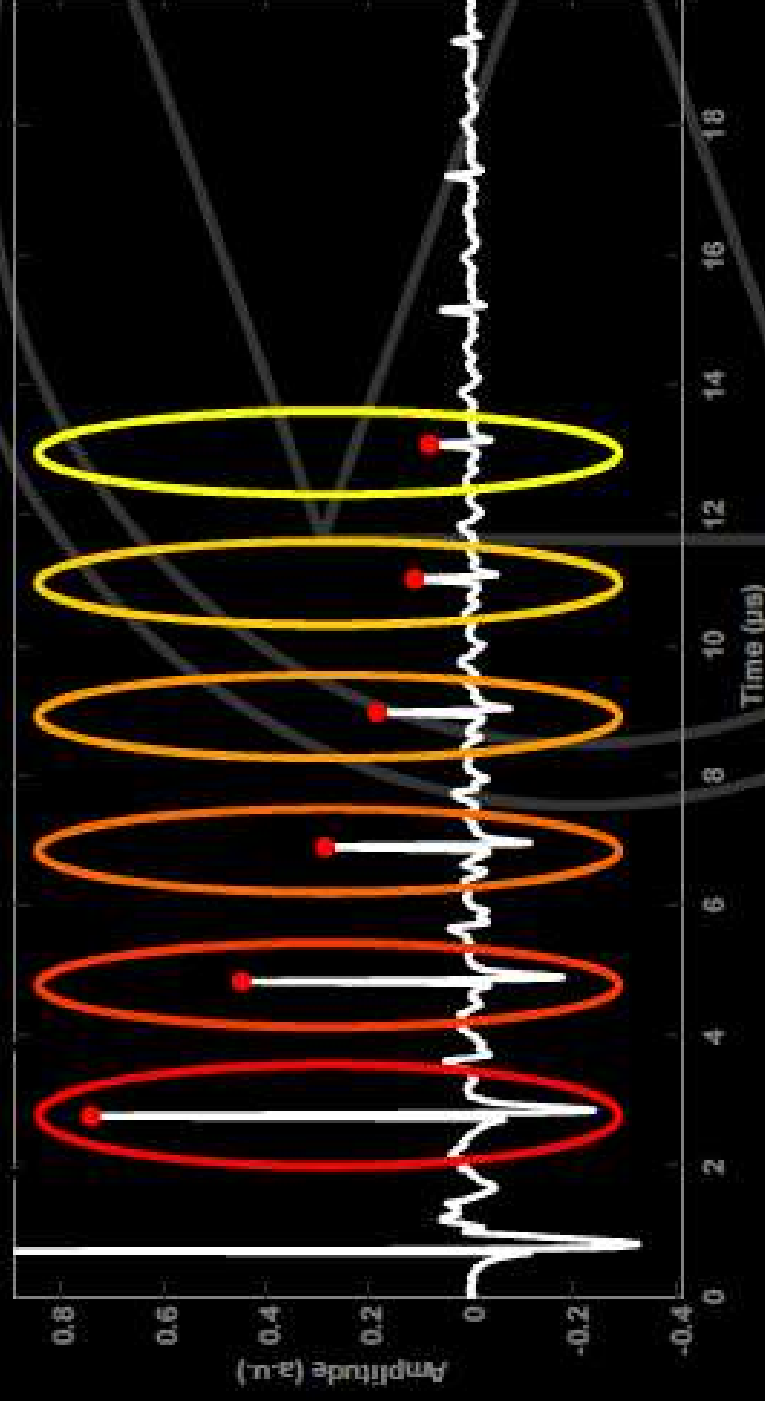
Attenuation

(Scattering, Absorption)

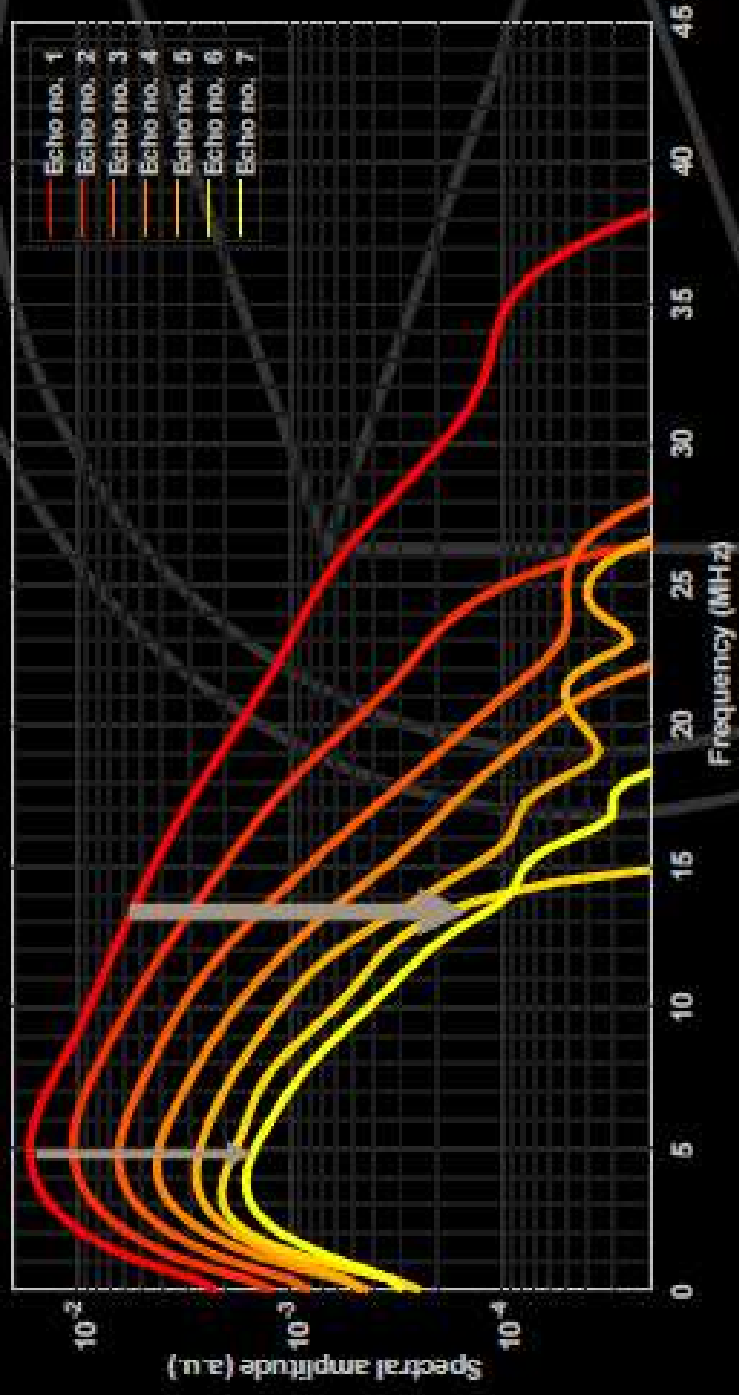
- Microstructure
- Grain size
- Mechanical strength
- Phase fraction



Frequency content of echos

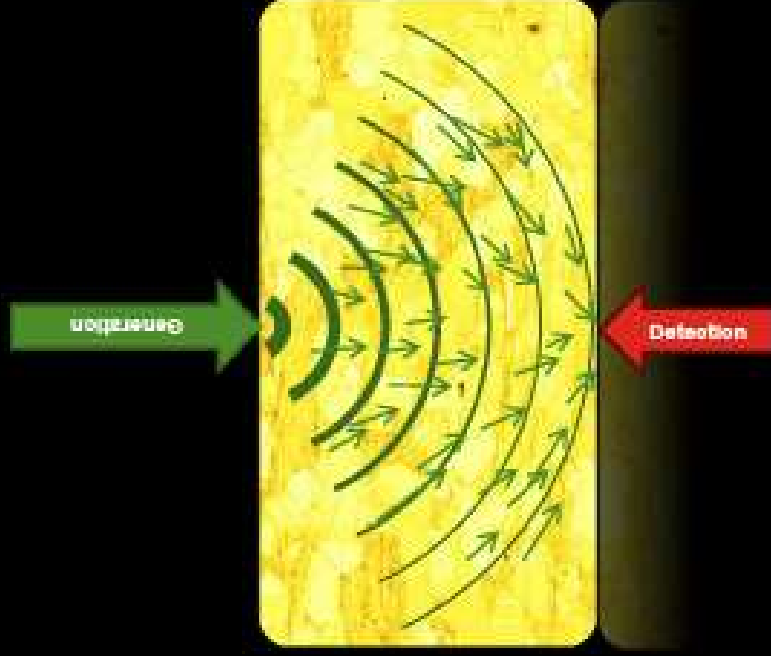
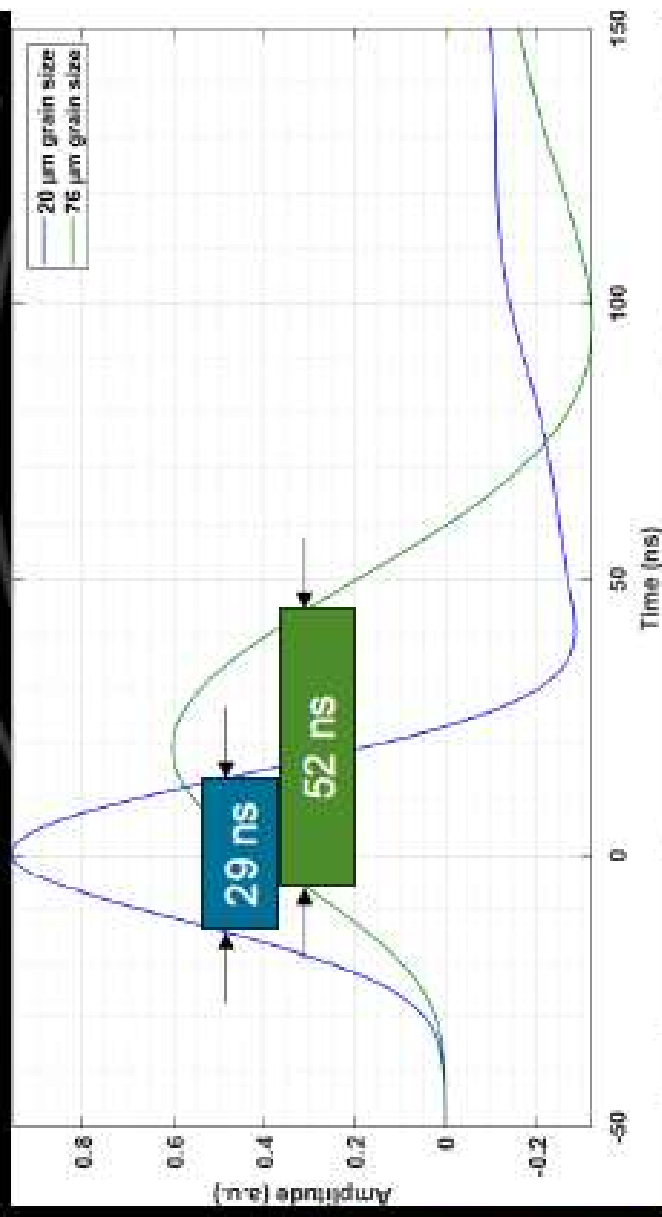


Spectral content

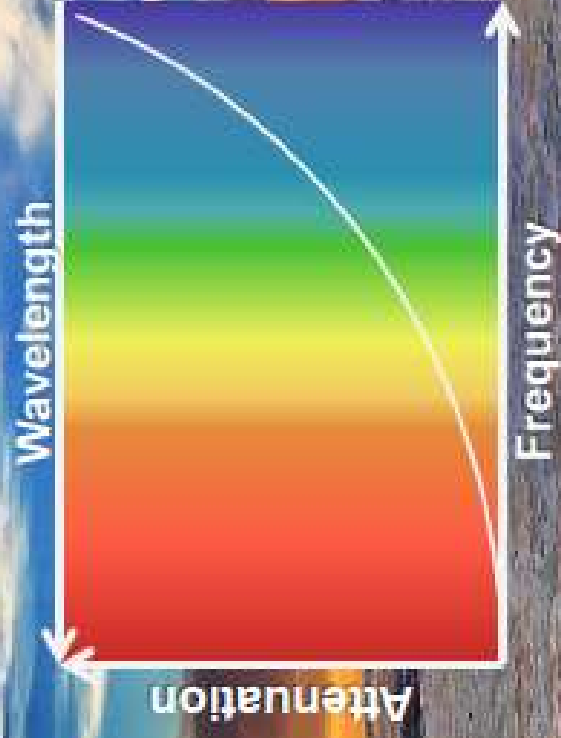


Grain scattering → pulse broadening

SWERIM



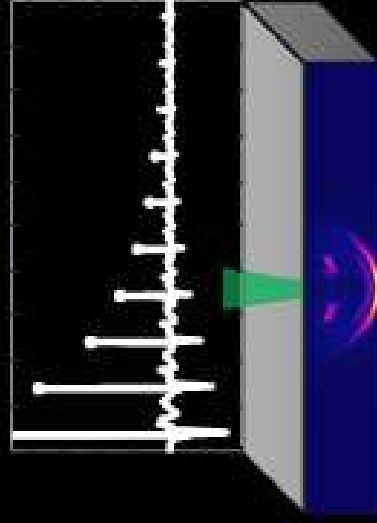
Spectral attenuation in scattering media



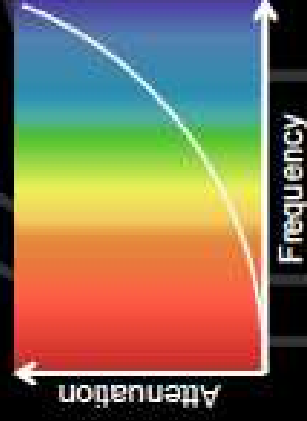
Grain size measurement with LUS

SWERIM

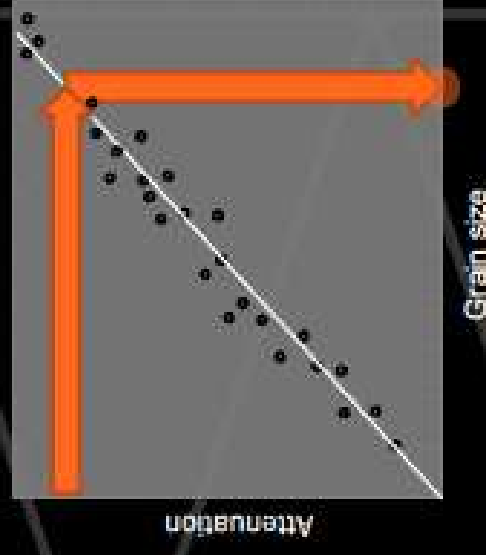
Measure



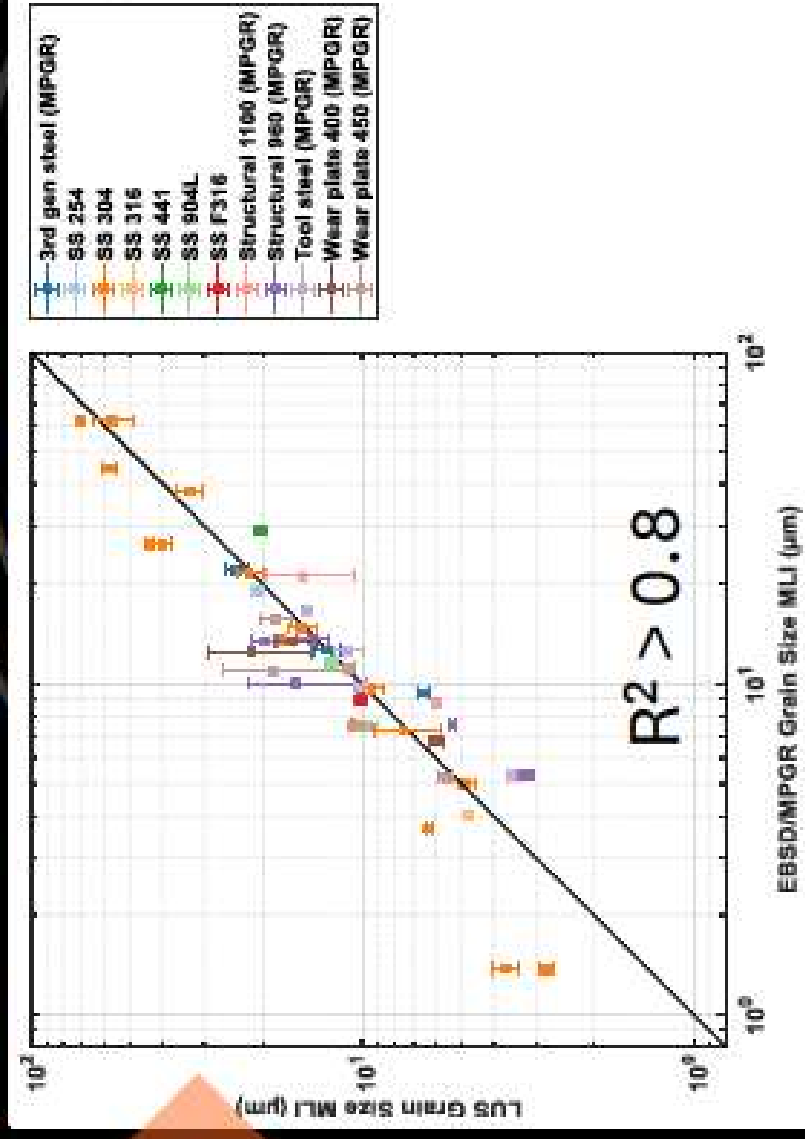
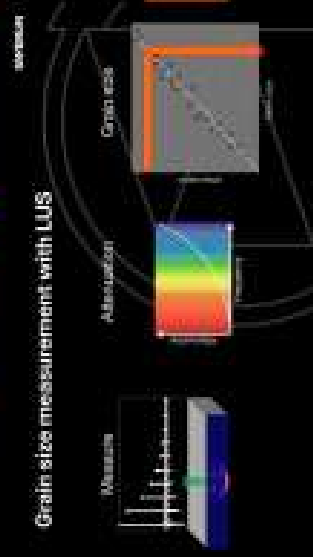
Attenuation



Grain size



LUS grain size vs EBSD/MPGR grain size, from RT to > 1100 °C, chemistry agnostic

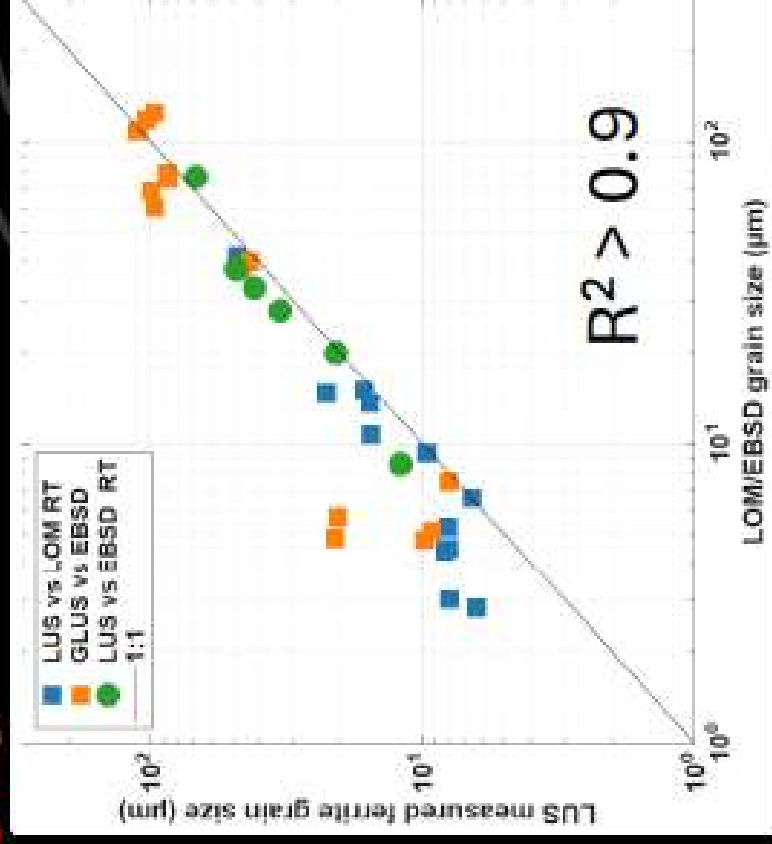


EBSD
Electron Back-Scattering Diffraction

MPGR
Martensite Parent Grain Reconstruction

LUS grain size vs LOM/EBSD Ferrite RT to > 1100 °C

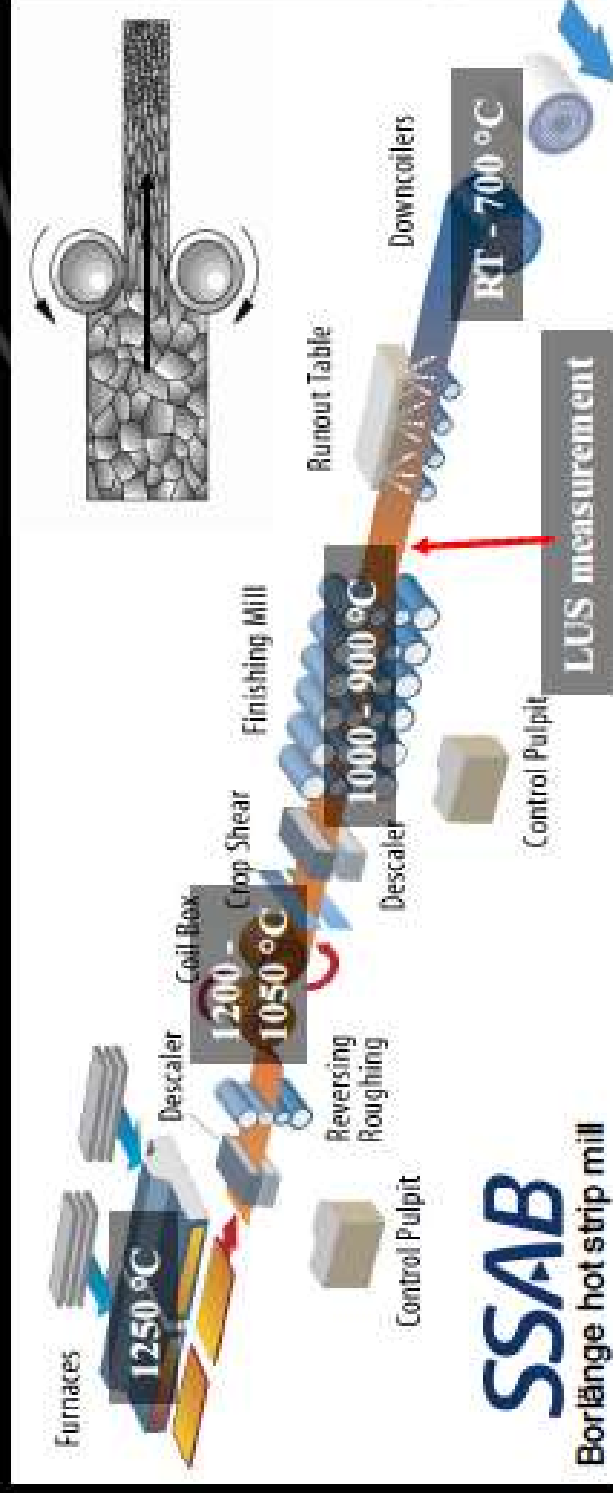
SWERIM

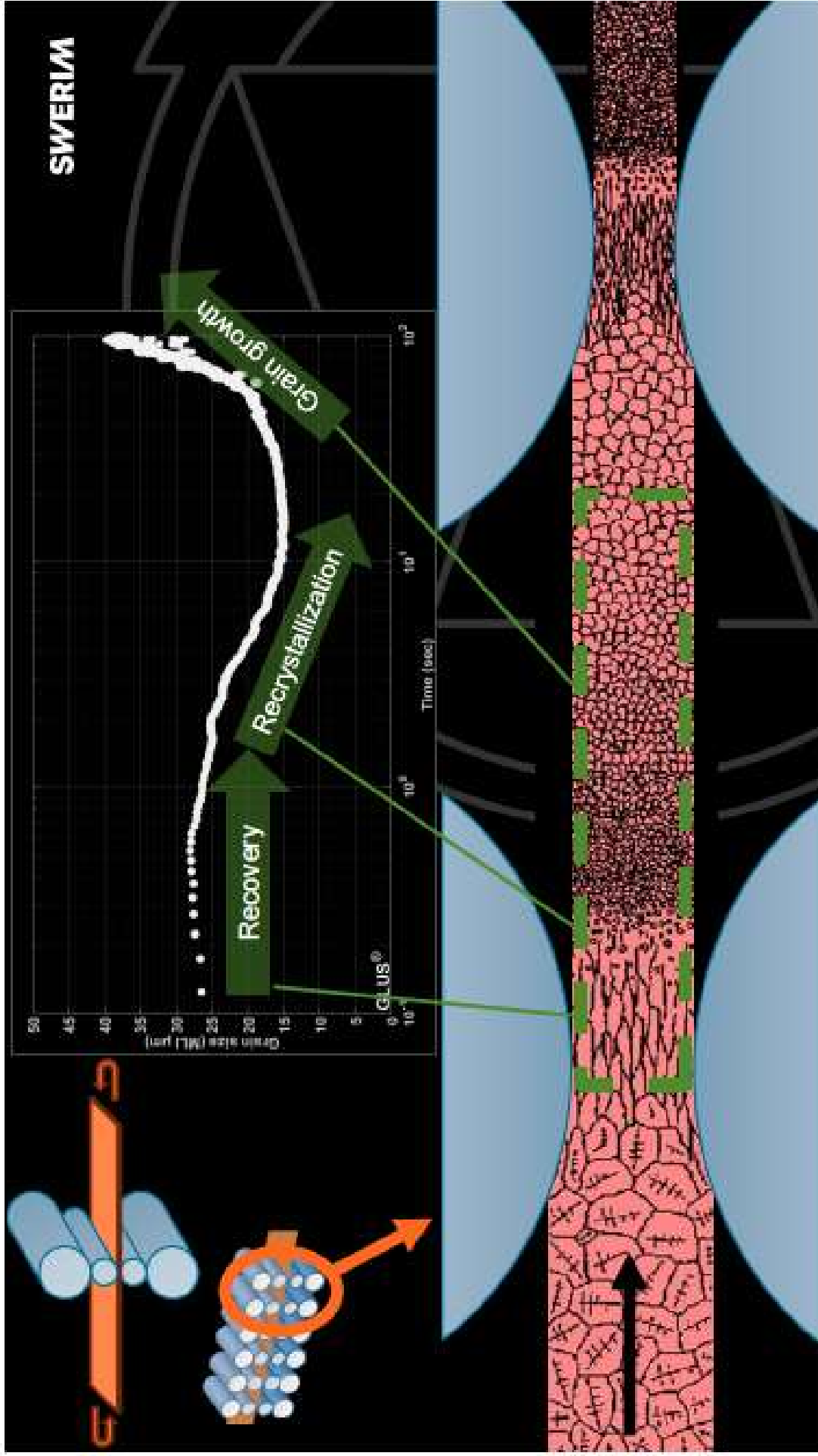


EBSD
Electron Back-Scattering Diffraction
LOM
Light Optic Microscopy

LUS grain size gauge

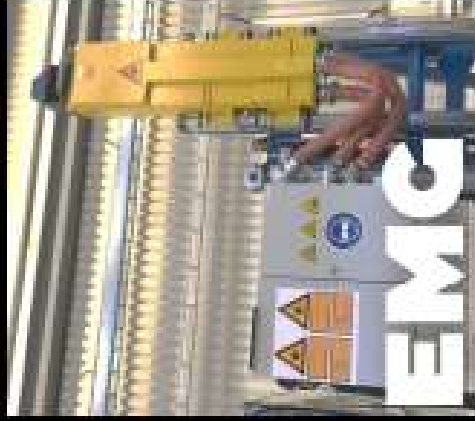
SWERIM





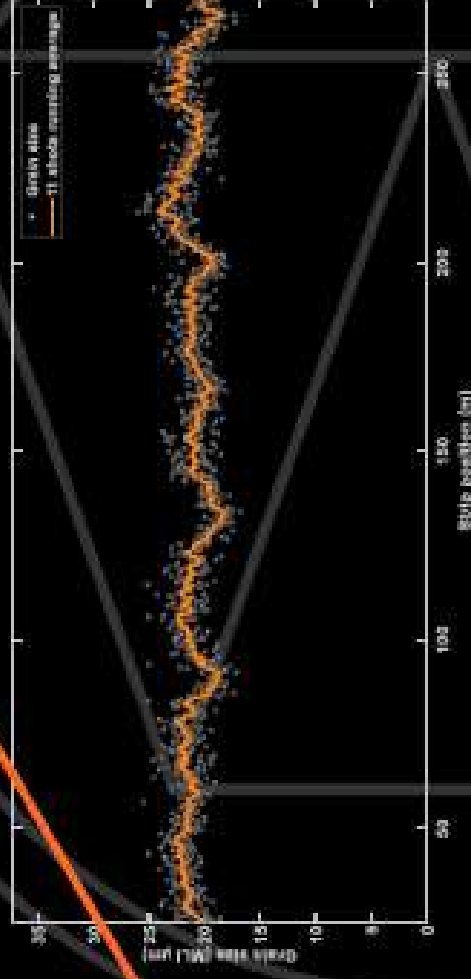
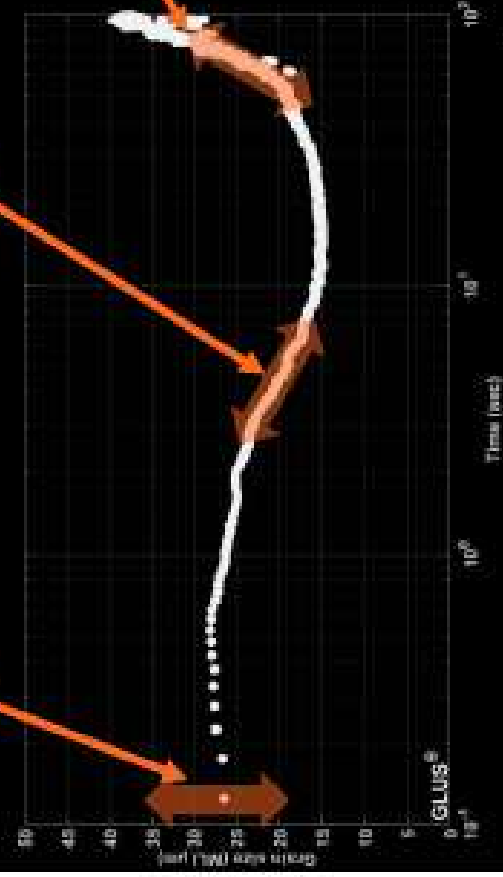
New grain size gauge

SWERIM





Start value, recrystallization or grain growth?



Reheating furnace at SSAB

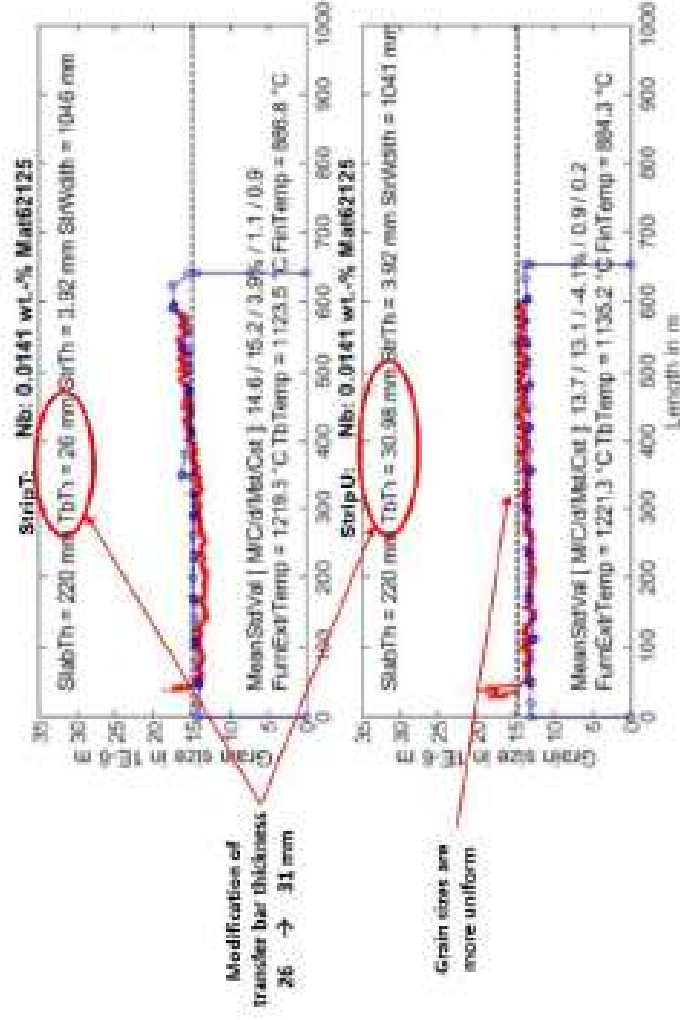


SWERIM

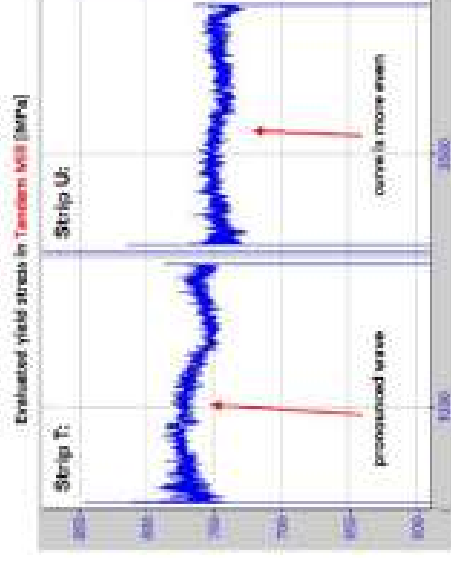


Walking beams the cause of skidmarks

Online LUS data for optimization of process



Change of transfer bar thickness has effects on further process steps!

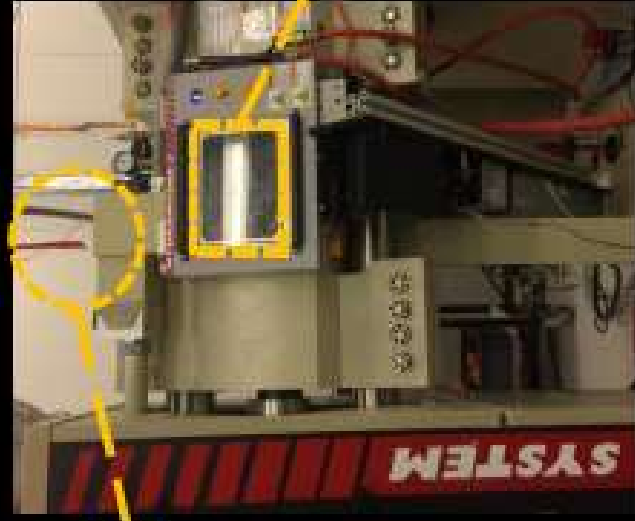




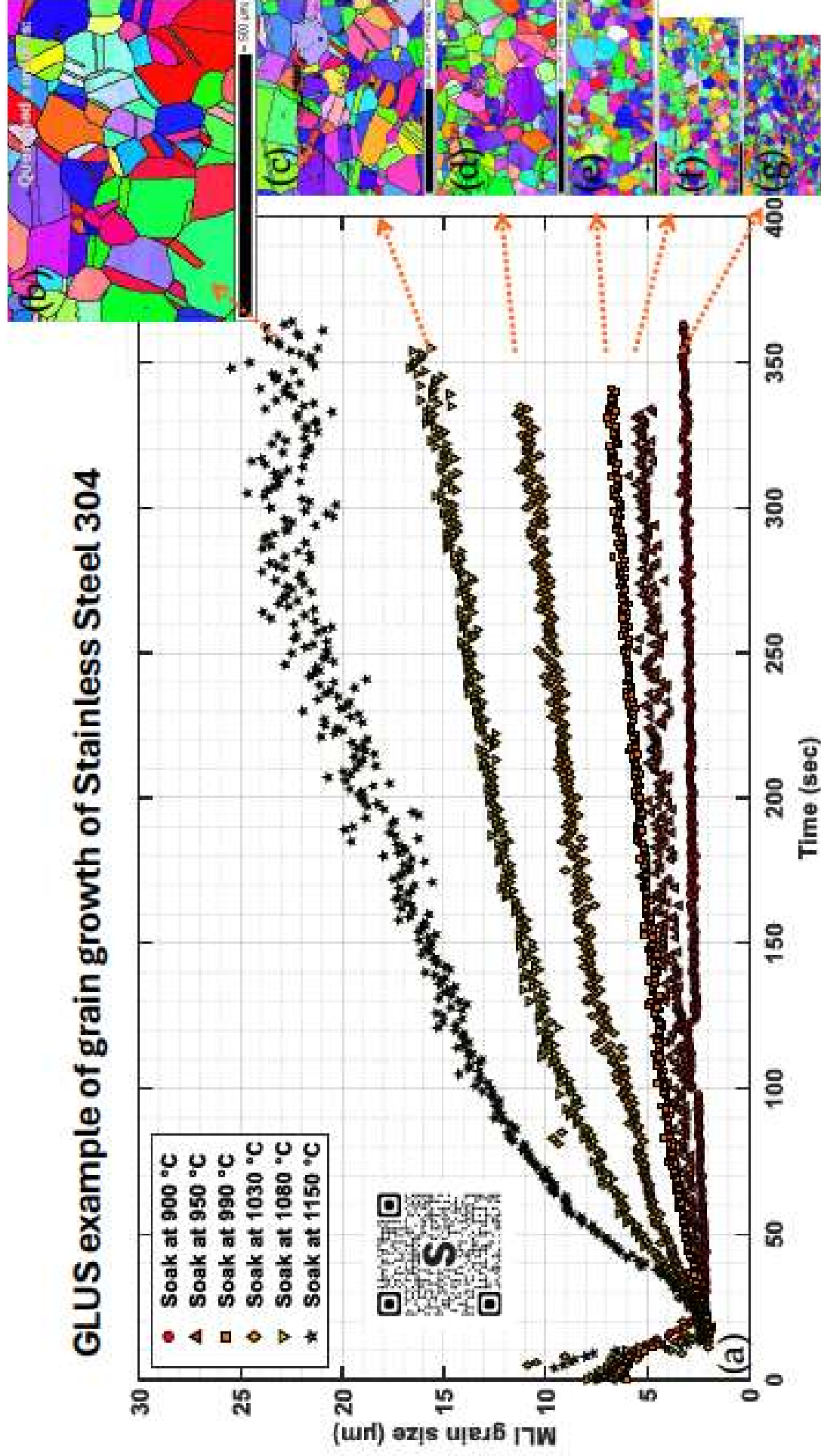
GLUS[®] and annealing

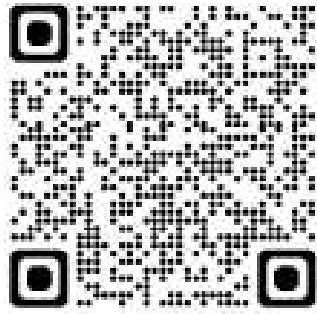
SWERIM

GLUS® @ Swerim Kista



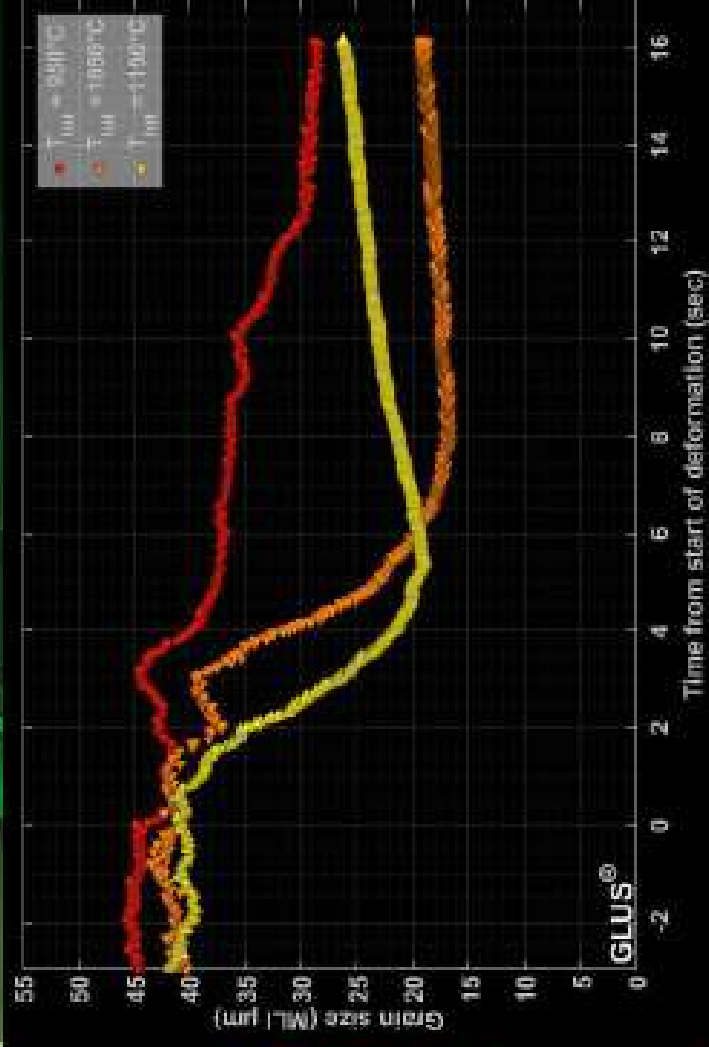
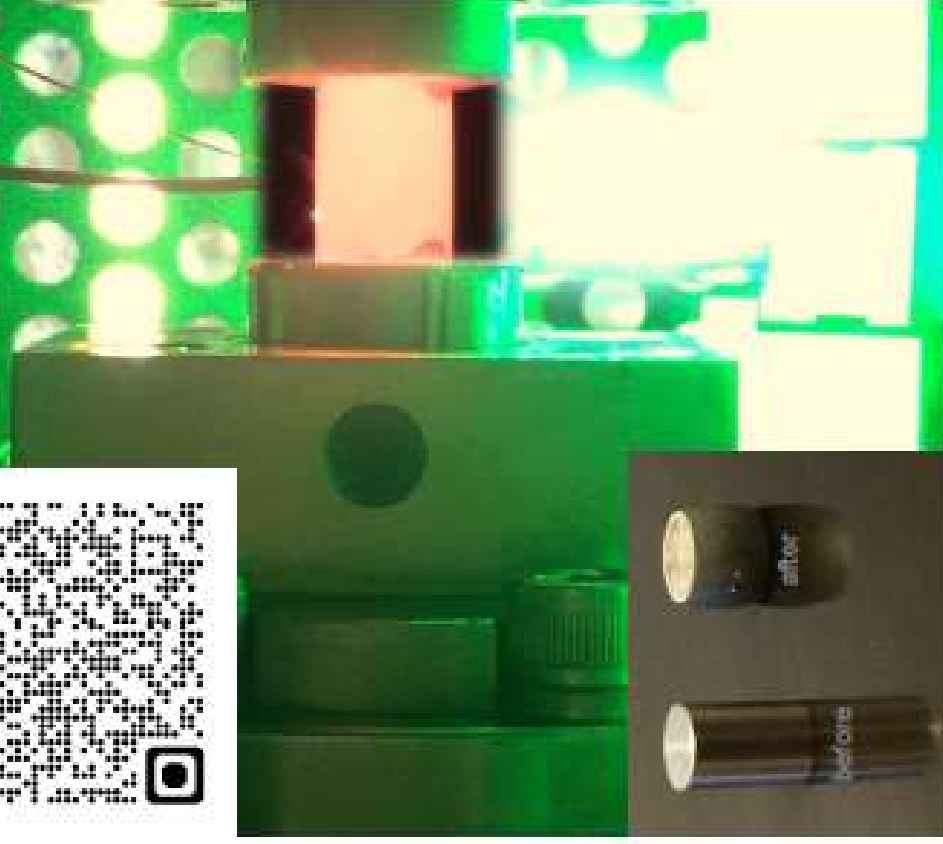
GLUS example of grain growth of Stainless Steel 304



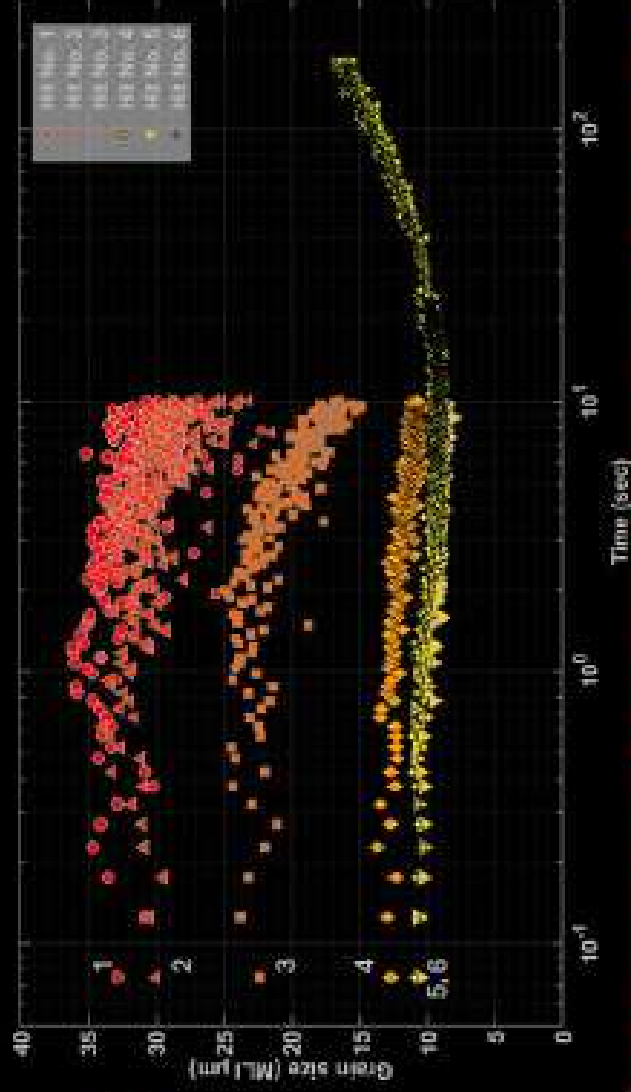


GLUS® with stress-relaxation

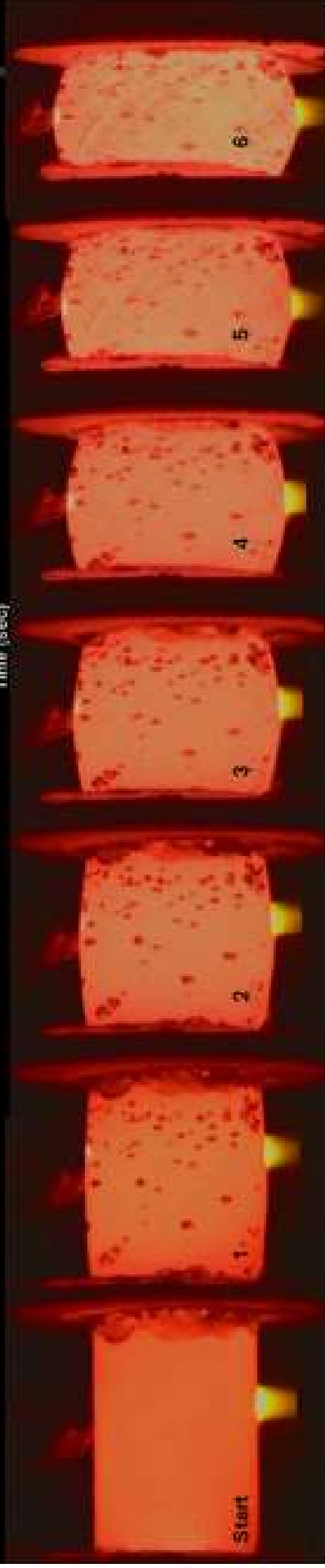
SWERUM



GLUS Data Multi-hit trials



SWERIM



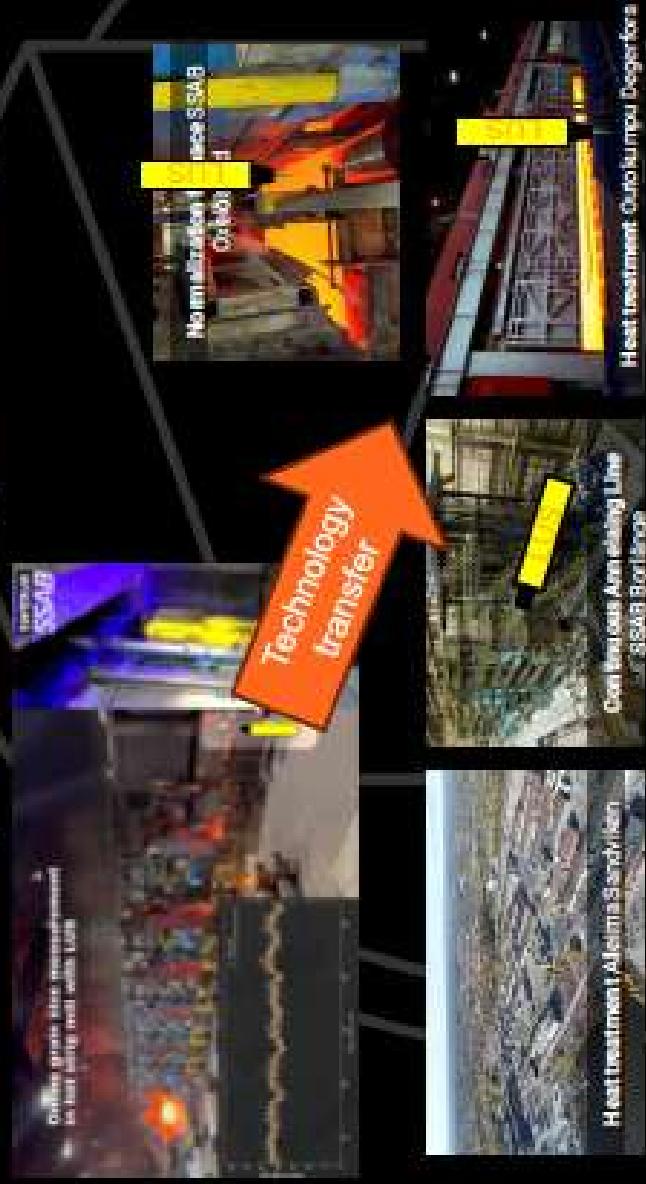
SWERIM

Alleima

SSAB

outokumpu

Laser ultrasonics for microstructure verification of heat treatments and thermal processes (ILUMHEAT)



Financed by Impact Innovation – the Swedish Metals and Minerals program – an initiative by the Swedish Energy Agency, Formas and Vinnova Sweden's Innovation Agency

Non-destructive AI enhanced online grain size evaluation (NAICE)

SWERIM

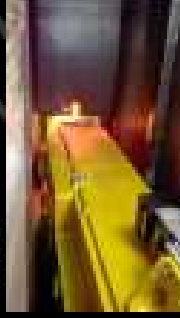
SSAB

EMC

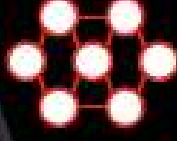
SMS  **group**

SWERIM

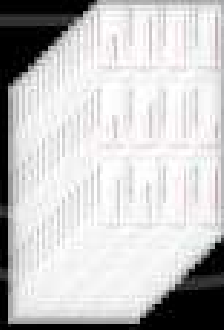
Upgrade device



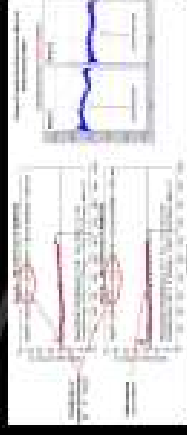
AI signal processing



More measurements



More process optimization



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