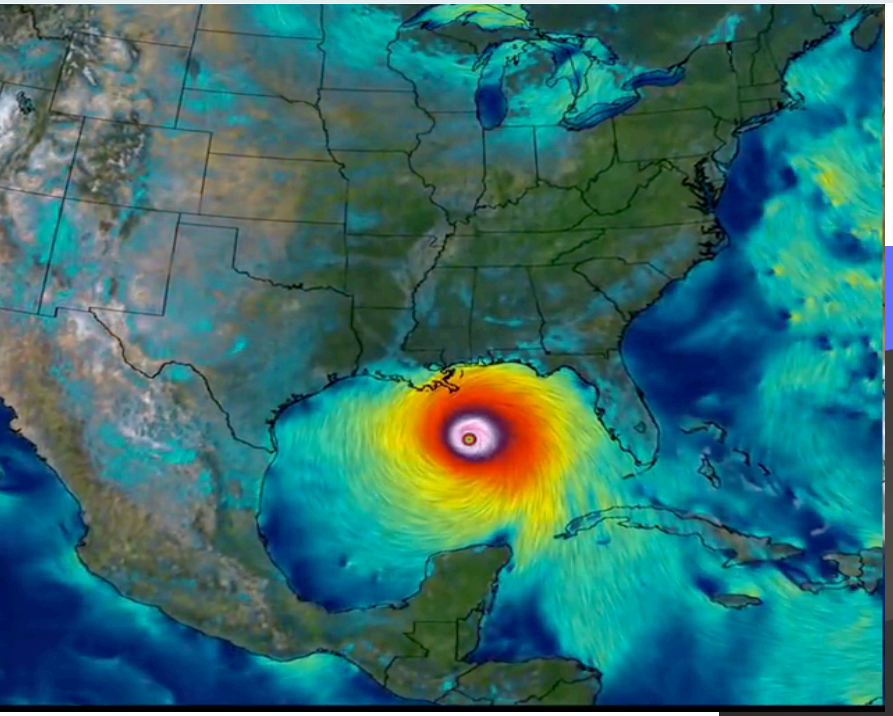
TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

Laser Assisted Manufacturing
Prof. Dr.-Ing. Dipl. Phys. A. Otto

Process Simulations for Optimizing and Planning Laser Material Processing

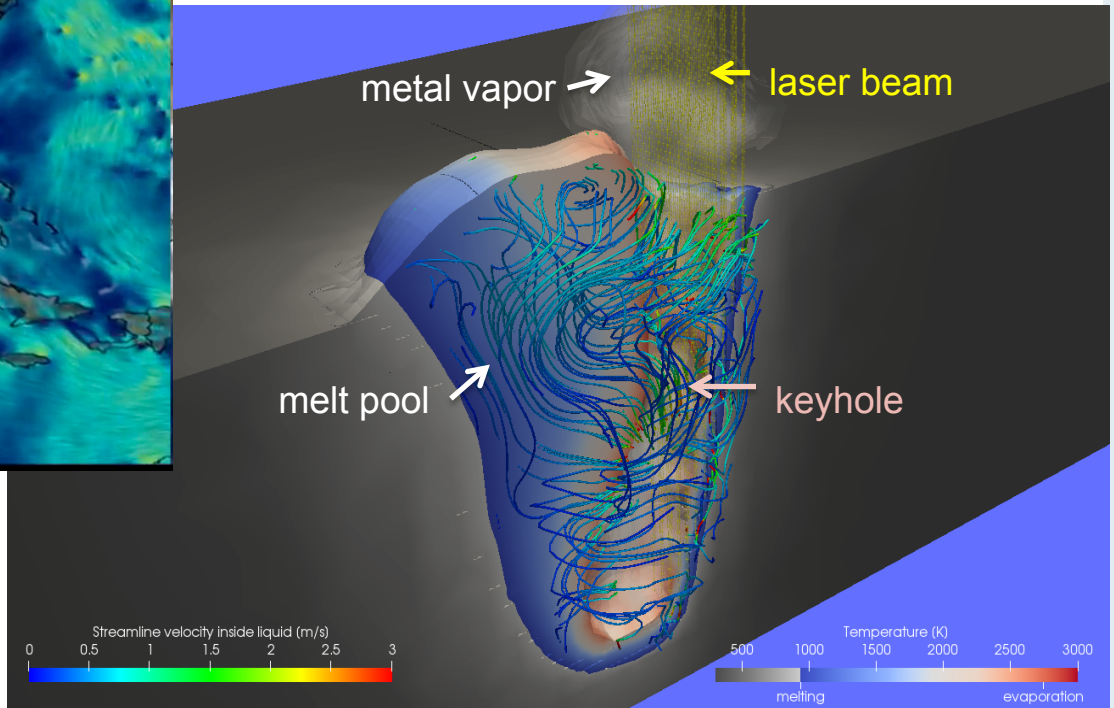
Andreas Otto, Rodrigo Gómez Vázquez

Different Scenarios - Similar Simulation Tasks

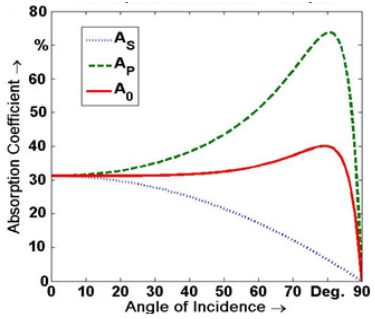


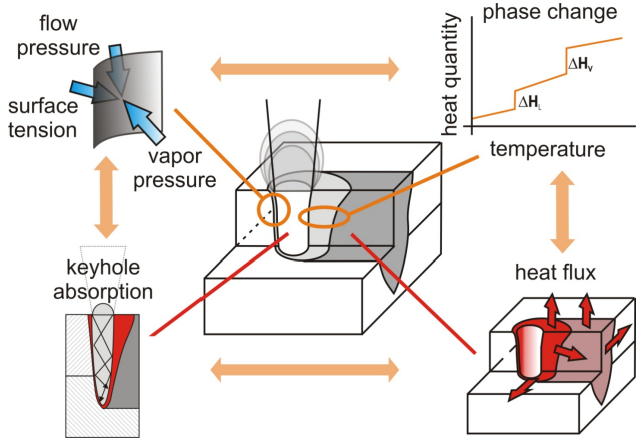
Hurrricane Katrina
Formed August 23, 2005
Dissipated August 31, 2005
Fatalities: 1,245–1,836 total
Damage: $125 billion

Laser Material Processing

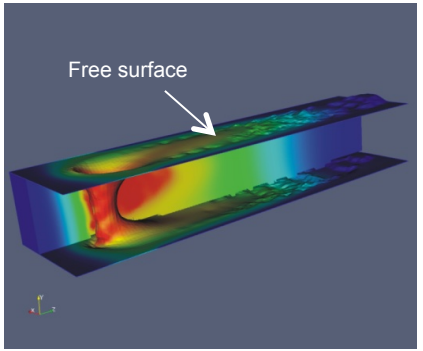


Overview on the Simulation Model



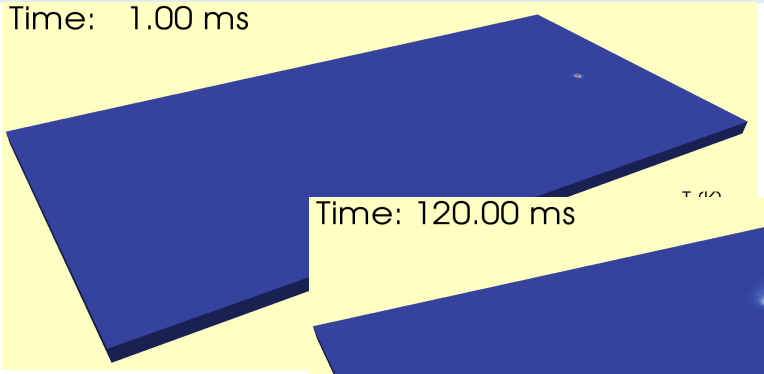


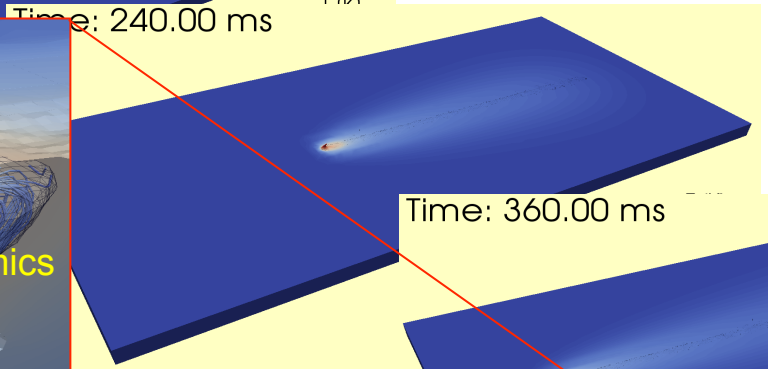
Typical look of a simulation

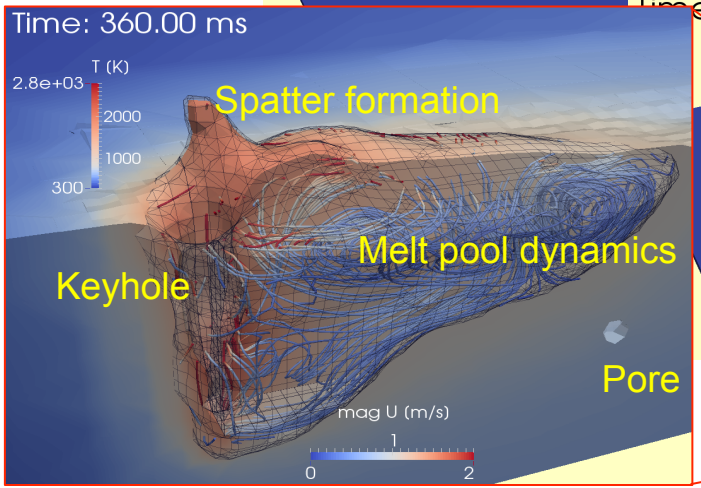


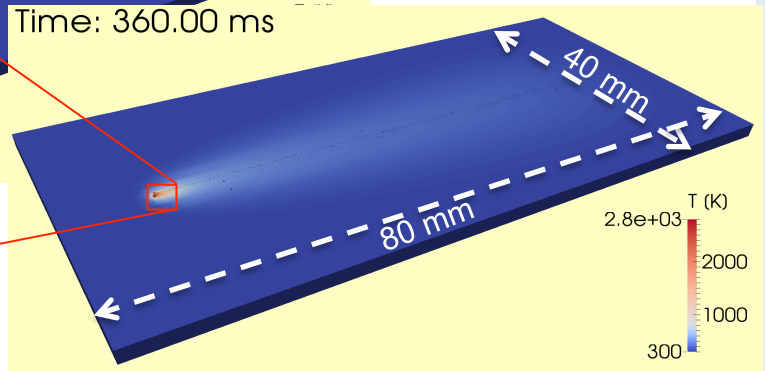
Step	Used	Comment
Calculation technique	FVM	OpenFOAM® environment (GPLv3)
Fluid dynamics	N-S transport equations	Compressible fluid
Free surface tracking	Multi-material VOF-method	Interacting forces: Surface tension, vapor pressure, flow pressure
Laser Beam	Ray casting model	Multiple reflections, spatial energy distribution, divergent beam
Beam absorption/reflection	Fresnel equations	Angle-, polarization- & wavelength-dependent, plasma shielding
Heat Flux	Energy transport equation	Source terms: absorbed power, latent heats
Phase transitions	Enthalpy-porosity technique Clausius-Clayperon	solid <-> liquid liquid <-> vapor

Overview on the Tasks within the Study









Four different parameter sets:

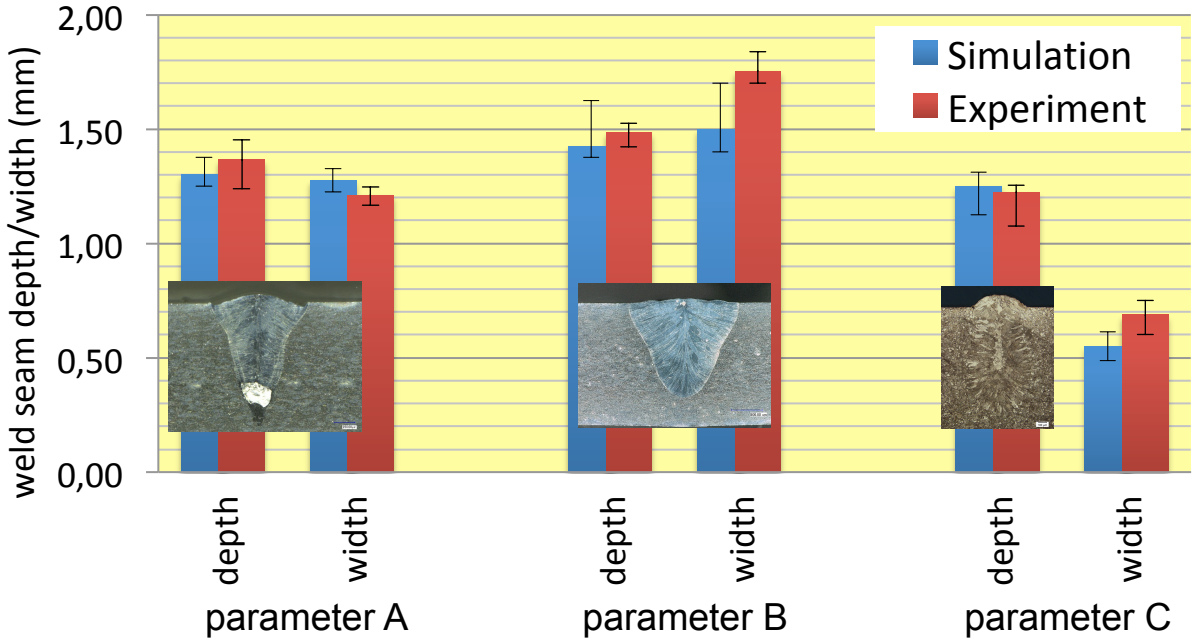
Predict

- weld seam geometry
- temperature field
- welding failures

without knowing experimental results in advance

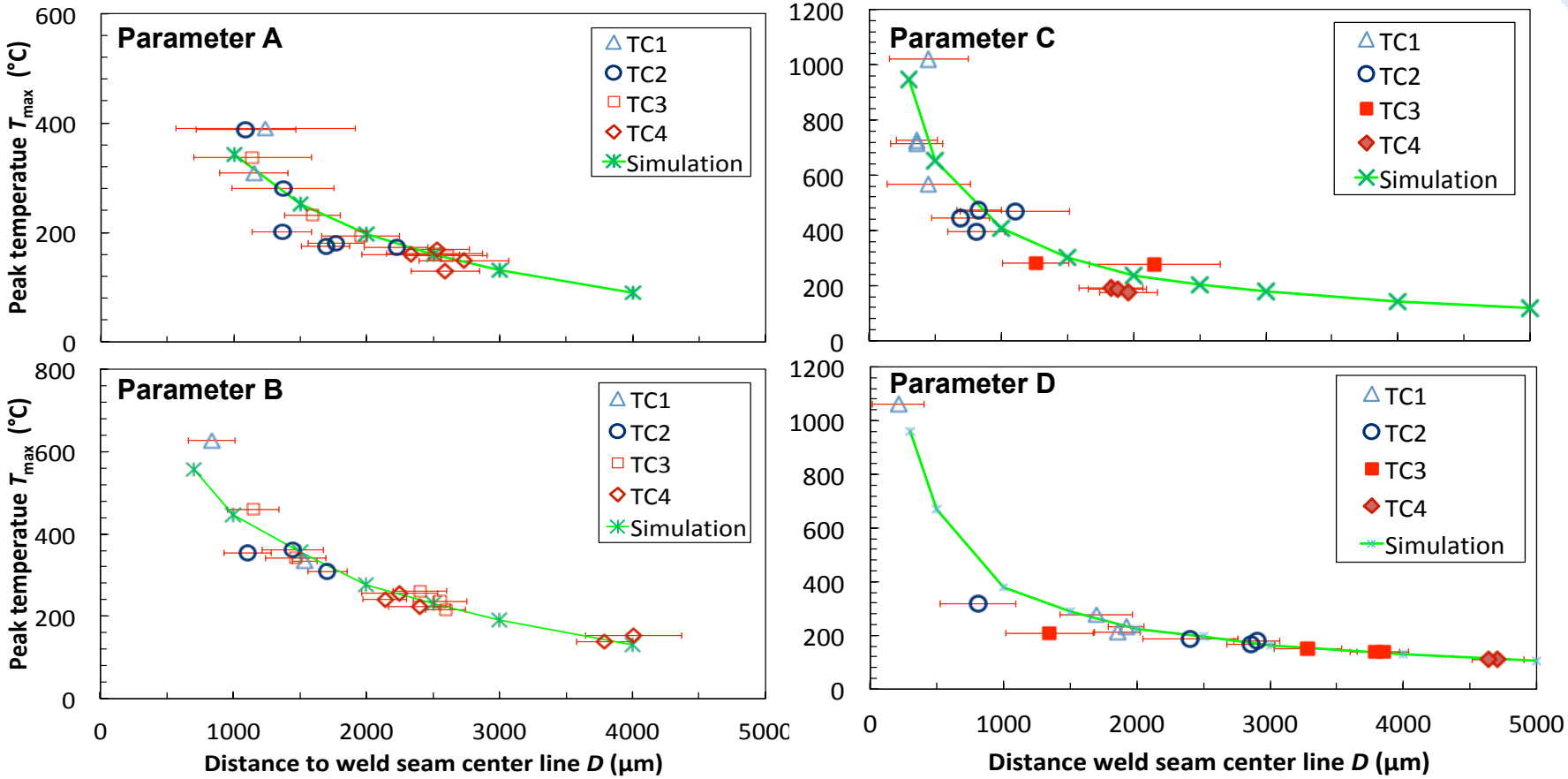
Zoom into laser material interaction zone

Parameters under Examination



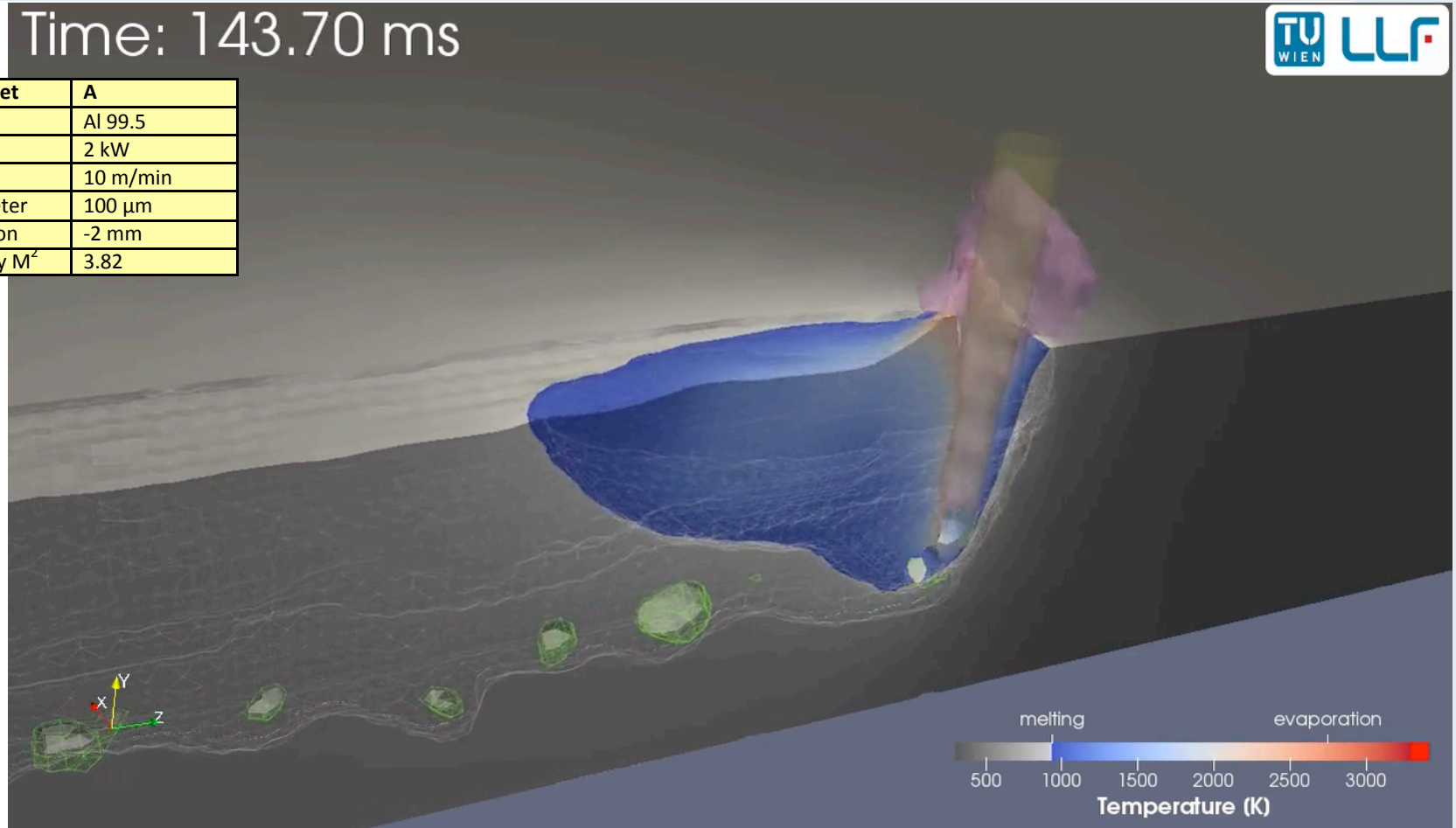
Parameter set	A	B	C	D
Material	Al 99.5	Al 99.5	Cu-ETP	Cu-ETP
Laser power	2 kW	5 kW	3 kW	4 kW
Feed rate	10 m/min	16 m/min	10 m/min	16 m/min
Focus diameter	100 µm	400 µm	100 µm	50 µm
Focus position	-2 mm	0 mm	0 mm	0 mm
Beam quality M^2	3.82	15.28	3.82	1.91

Comparison of Thermocouple Measurements with Simulation Results



Parameter Set A

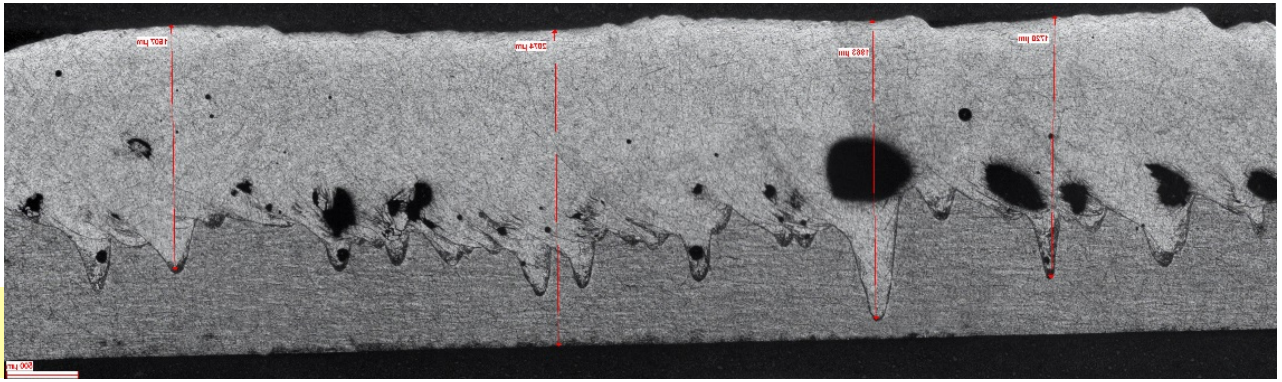
Parameter set	A
Material	Al 99.5
Laser power	2 kW
Feed rate	10 m/min
Focus diameter	100 µm
Focus position	-2 mm
Beam quality M^2	3.82



Spikes and Pores for Parameter A

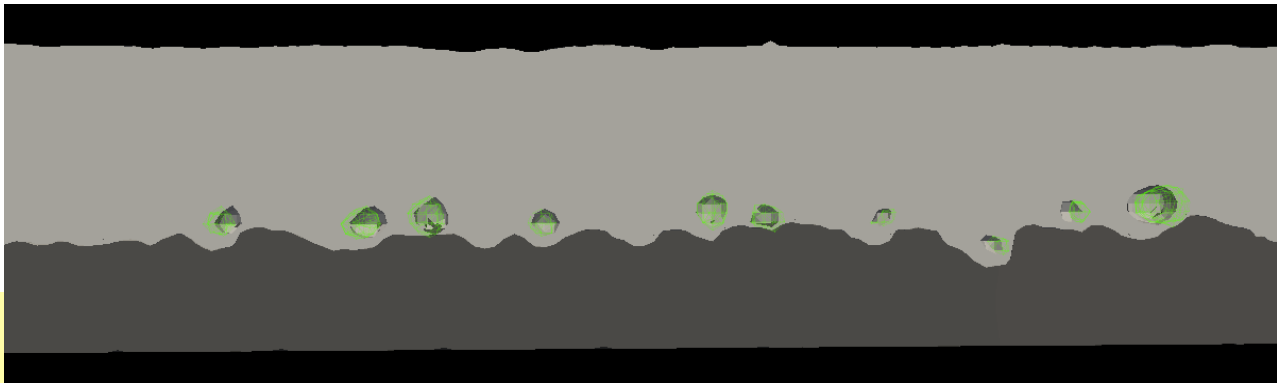
Longitudinal section

Experiment



2mm

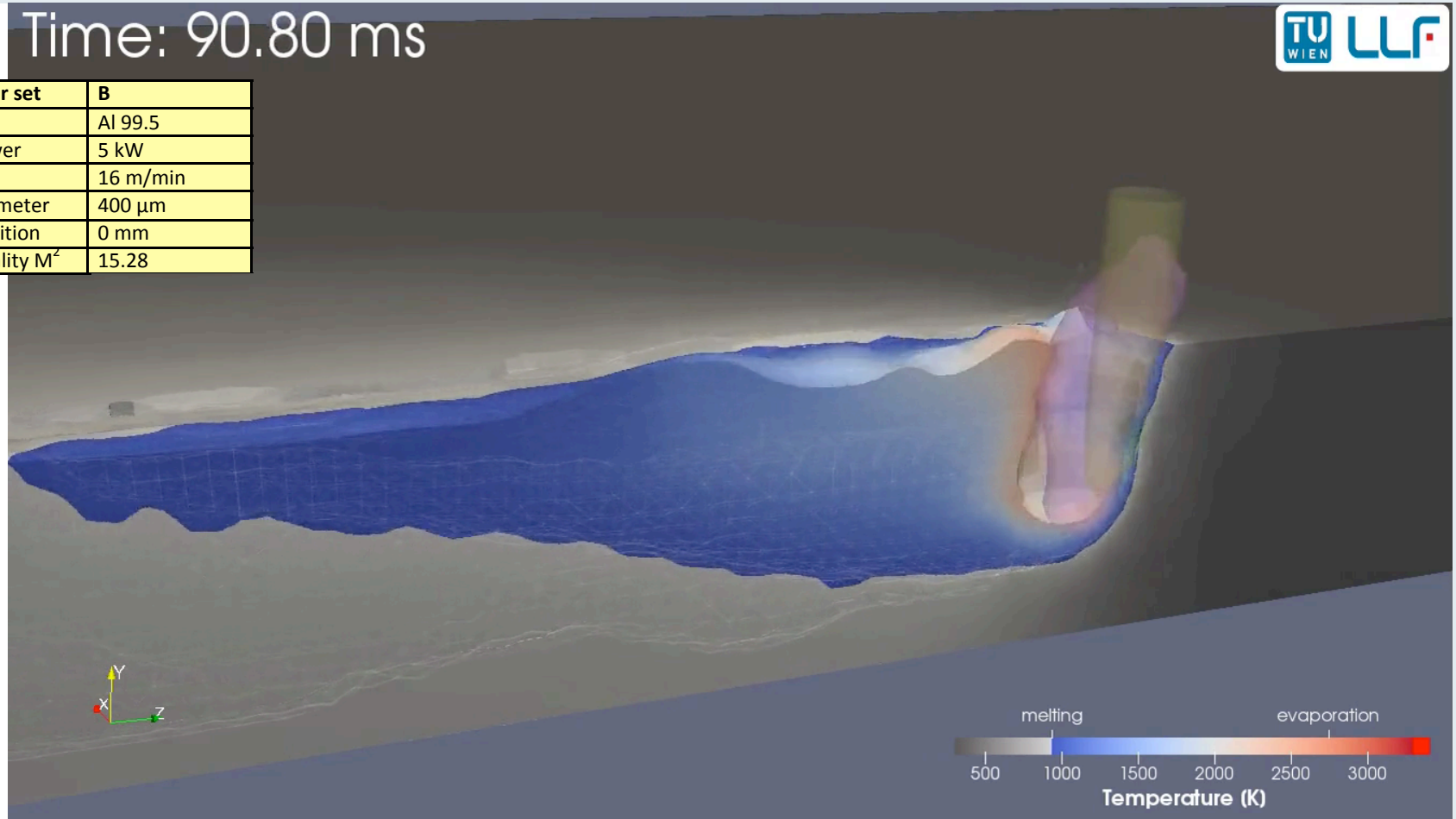
Simulation



2mm

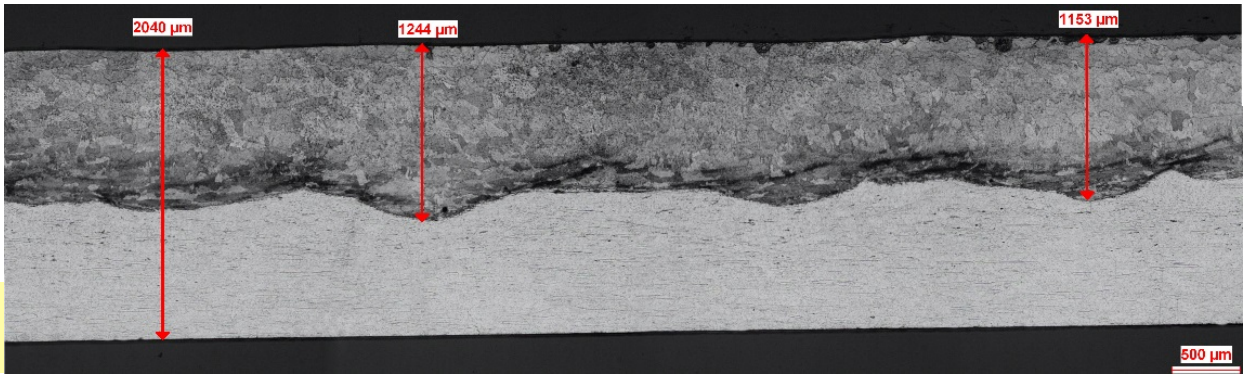
Parameter Set B

Parameter set	B
Material	Al 99.5
Laser power	5 kW
Feed rate	16 m/min
Focus diameter	400 µm
Focus position	0 mm
Beam quality M^2	15.28



Minor Fluctuations in Depth for Parameter Set B

Longitudinal section



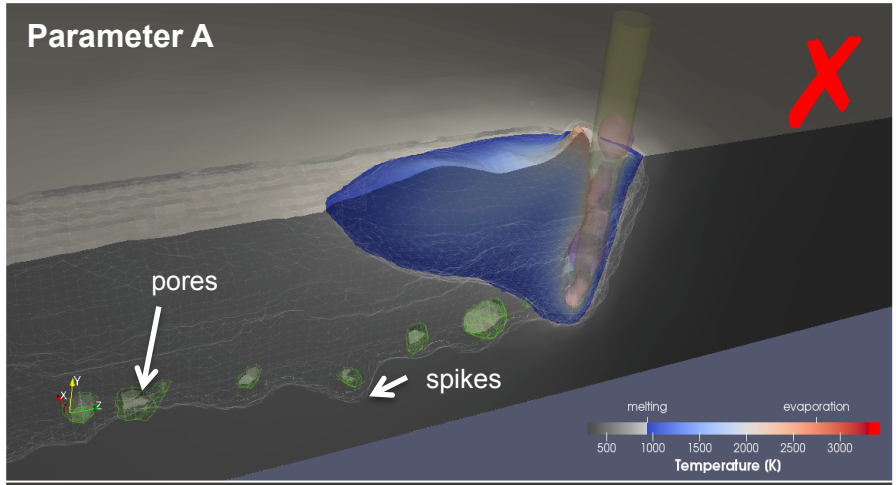
Experiment

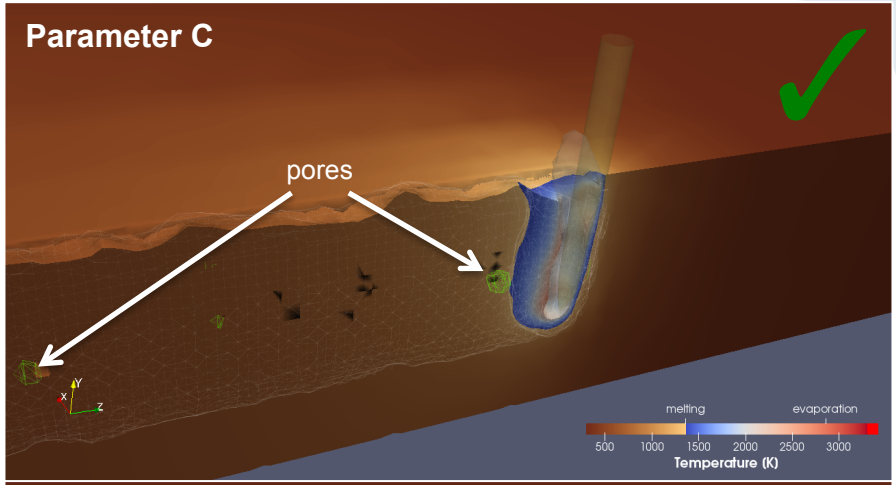
(section a little bit out of the center)

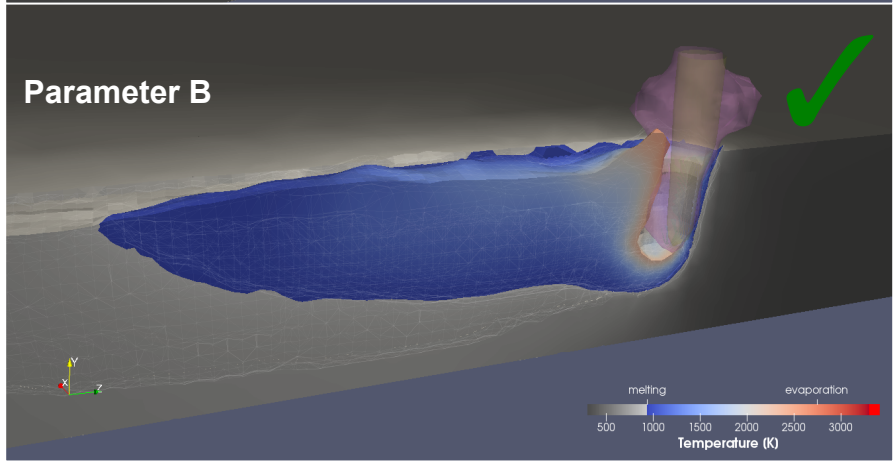


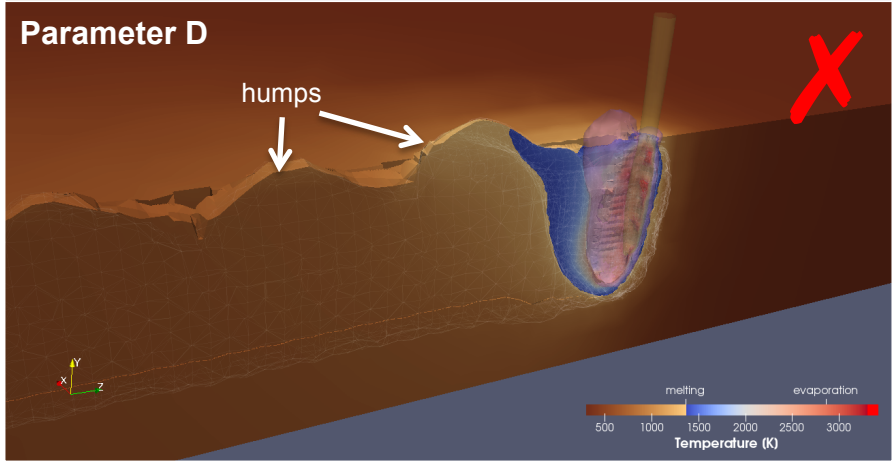
Simulation

Overview on the Process Dynamics

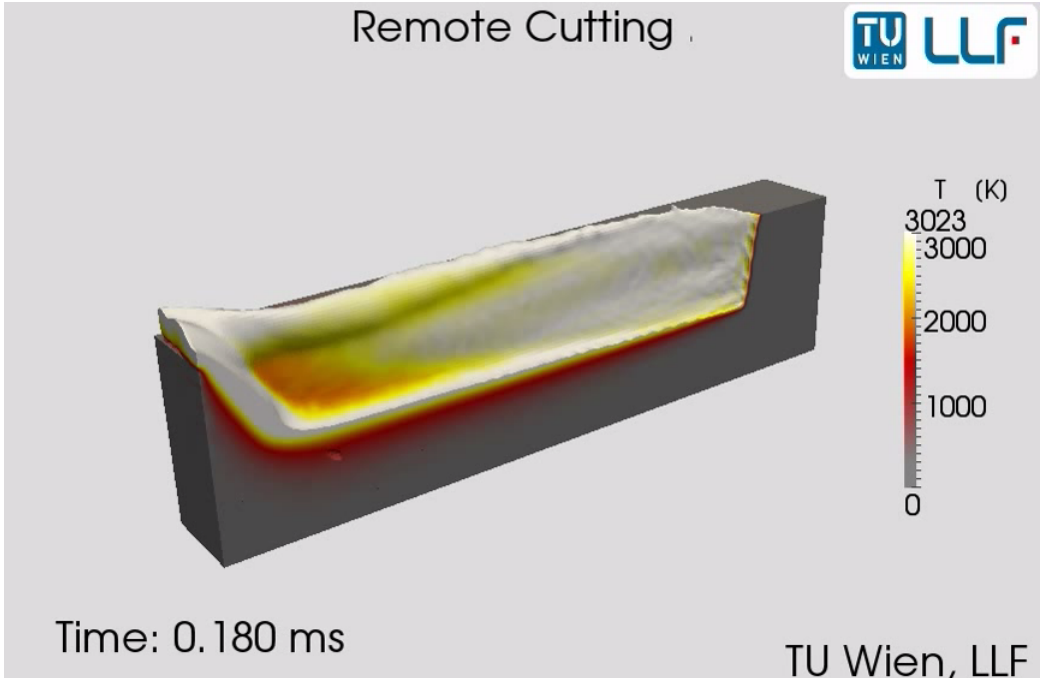


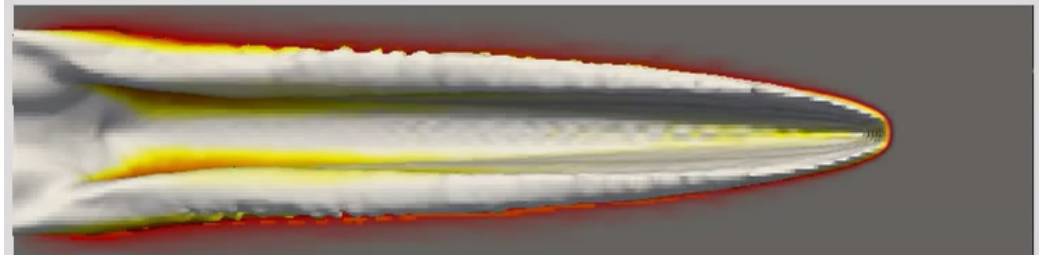






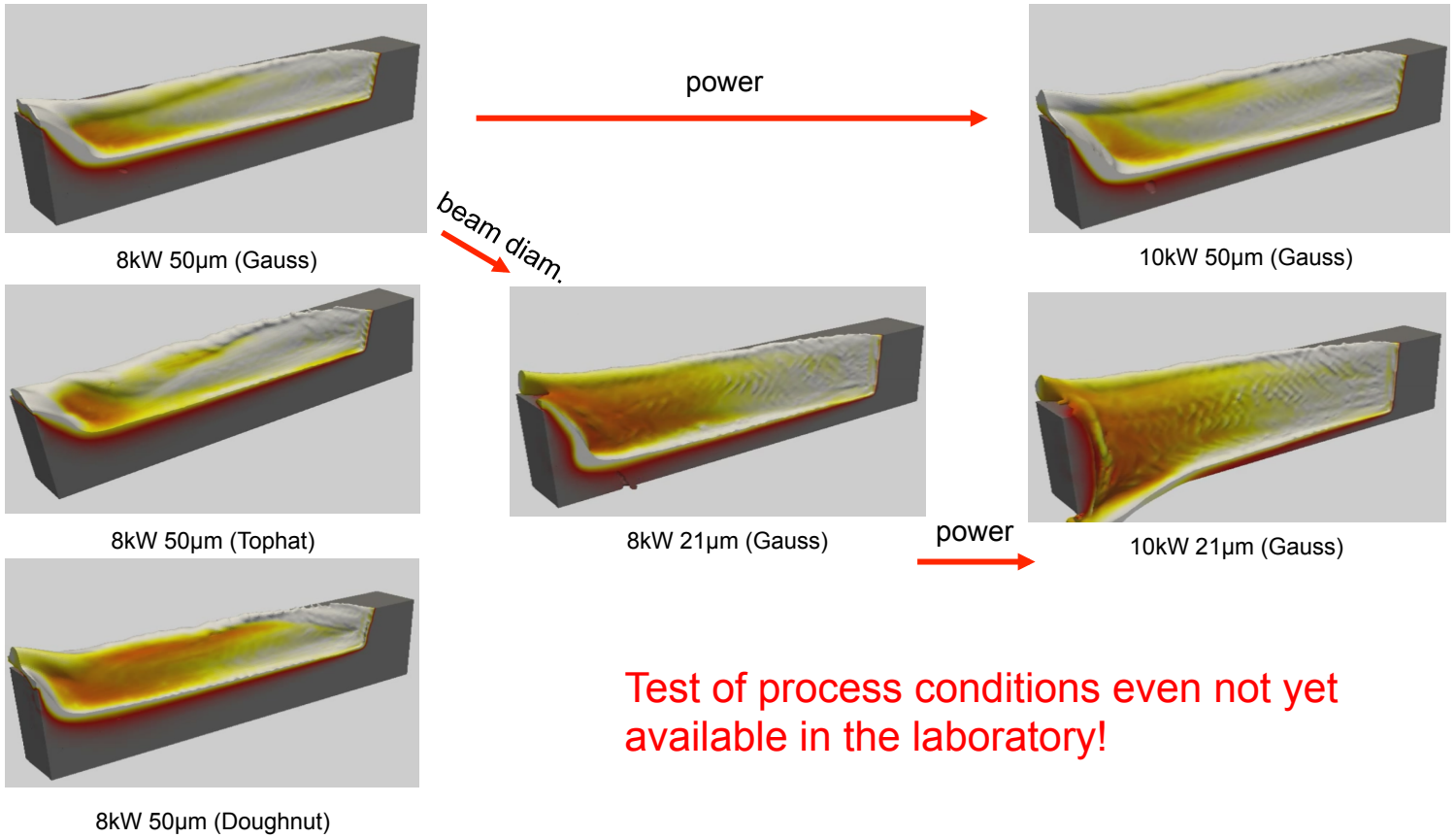
From Process Analysis ...





P = 8 kW
v = 8 m/s
d = 50 µm
thick. = 0.5 mm

... to Process Optimization



Test of process conditions even not yet available in the laboratory!

New Physics:

- Ultrashort Pulsed Laser Processing
- Solidification Phenomena
- Thermomechanics

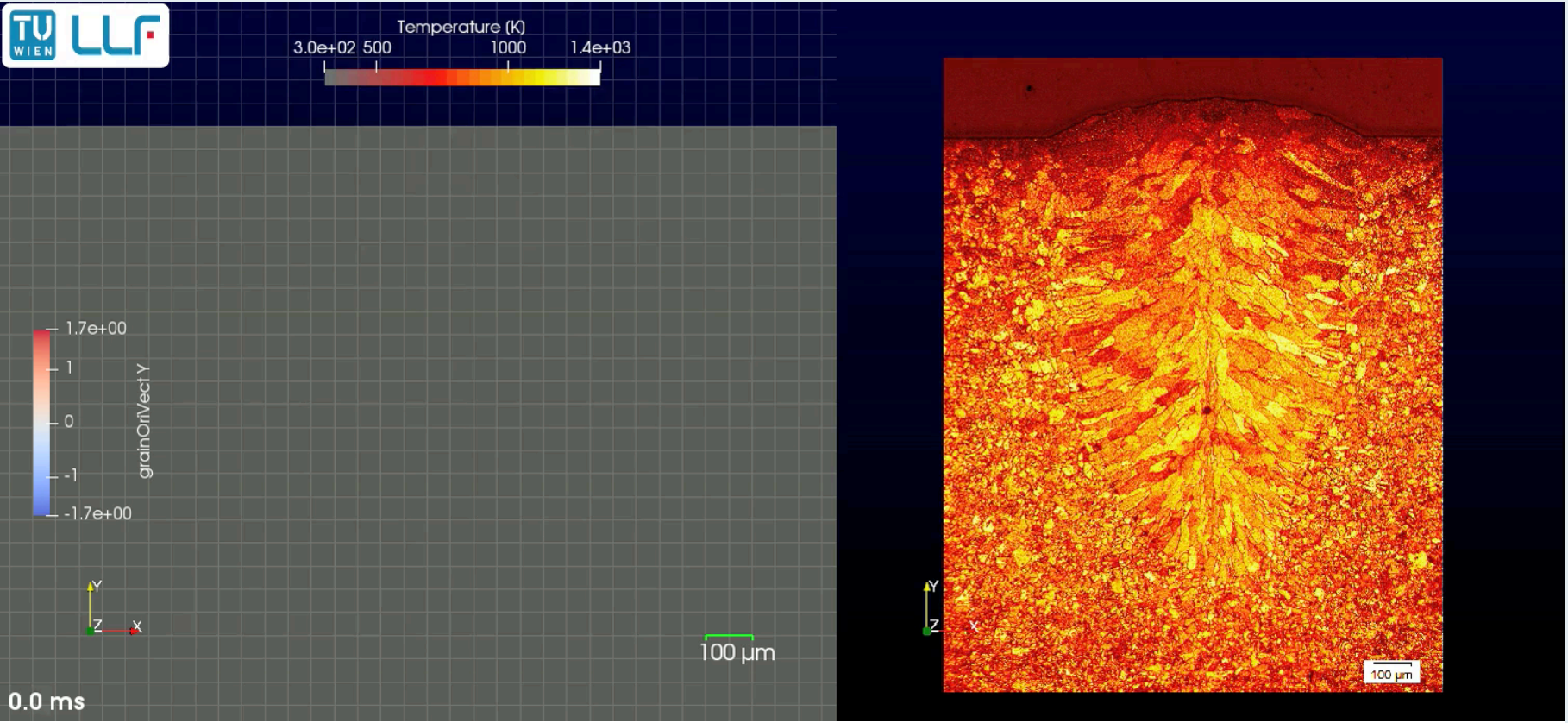
Additive Manufacturing:

- Laser Cladding
- Selective Laser Melting

Automised Process Optimization

Improvement of Calculation Efficiency

Solidification Phenomena: Grain Growth



keyhole + meltpool + grain formation