TUM
TECHNISCHE UNIVERSITÄT MÜNCHEN

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iwb
ANWENDER ZENTRUM AUGSBURG

DETERMINATION OF PROCESS PARAMETERS FOR ELECTRON BEAM SINTERING (EBS)

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Outline

1. Introduction – Electron Beam Sintering (EBS)
2. Objective of the present work
3. Mathematical model
   - Overview
   - Heat Source Model
   - Material Properties
4. Numerical Model
5. Simulation Results and Discussion
6. Conclusion

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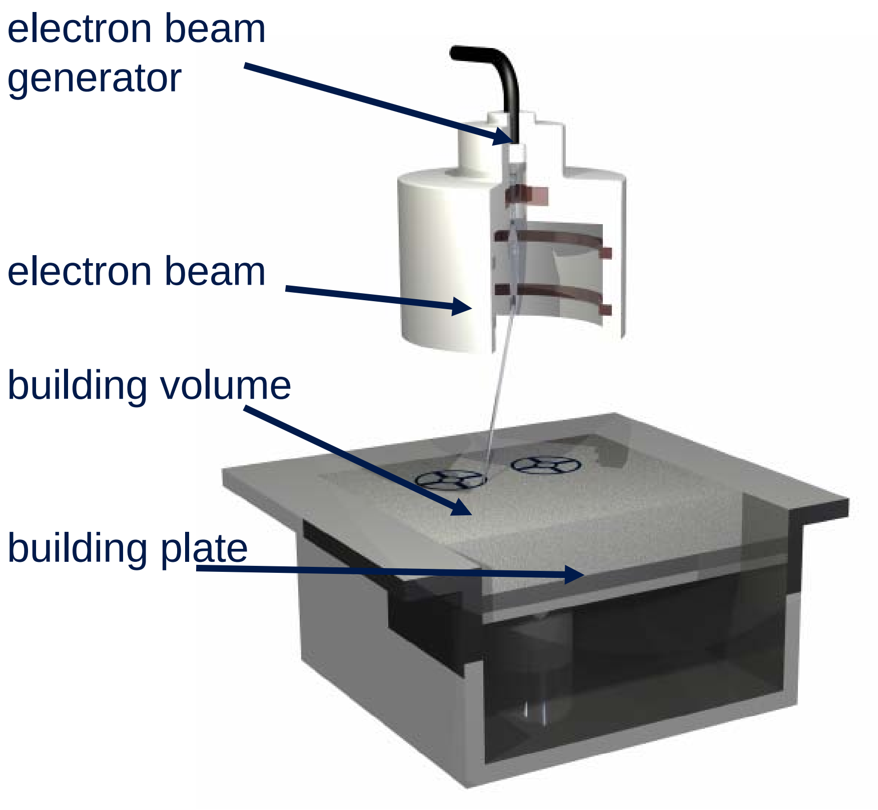
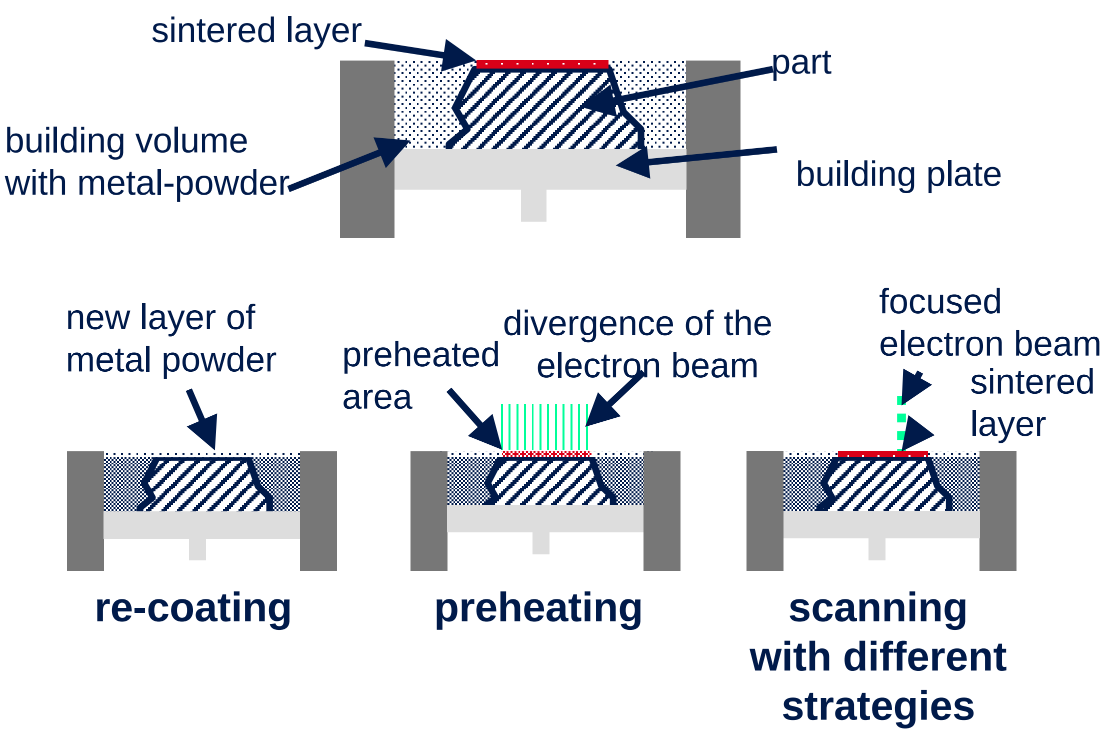
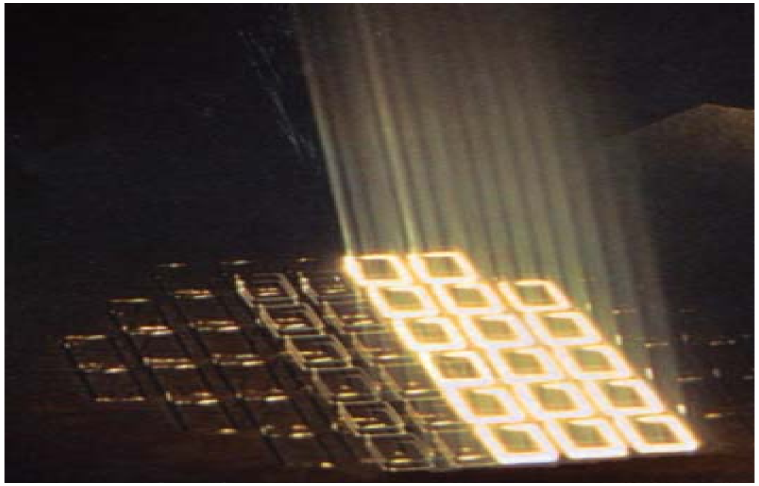
Electron Beam Sintering

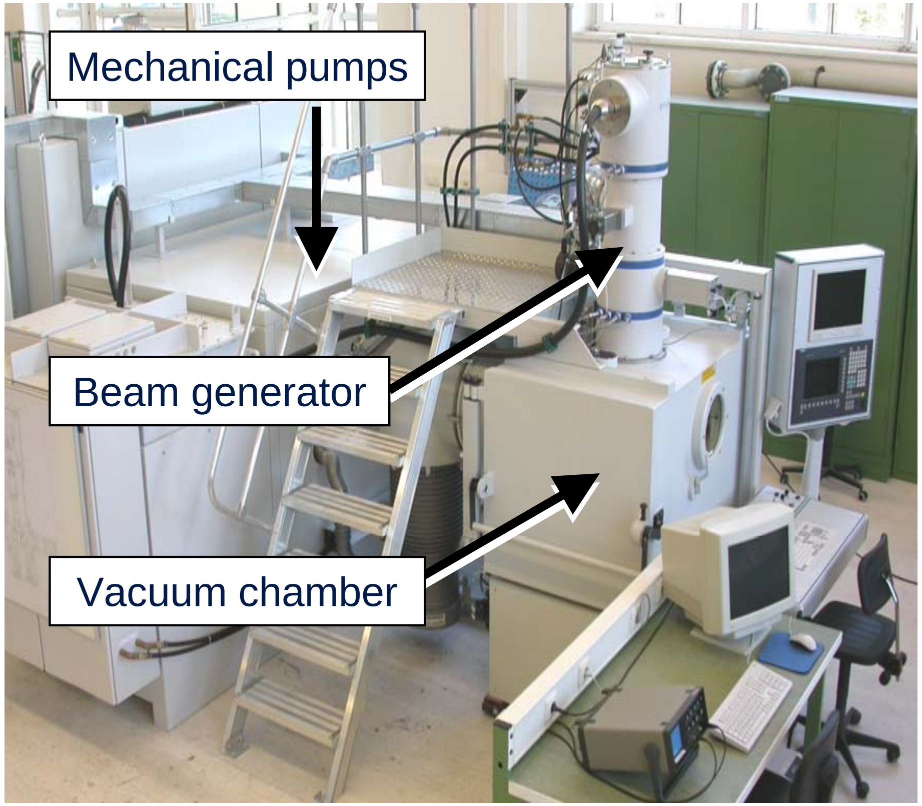




Potentials of the electron beam

- High beam power and energy density
- Fast, massless beam deflection
- „Quasi-simultaneous“ beam exposure
- Uniform insertion of energy
- Open configurable beam figures





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Process stability

- Metal parts production
- Two major deficiencies can be observed
  - Balling
  - Delamination


Balling


Delamination

- Process **cannot be examined** due to accessibility and resolution of thermography unit
- **Understanding of the process** needs to be enhanced
- Analysis of the **beam-material interaction** by means of **FEA**

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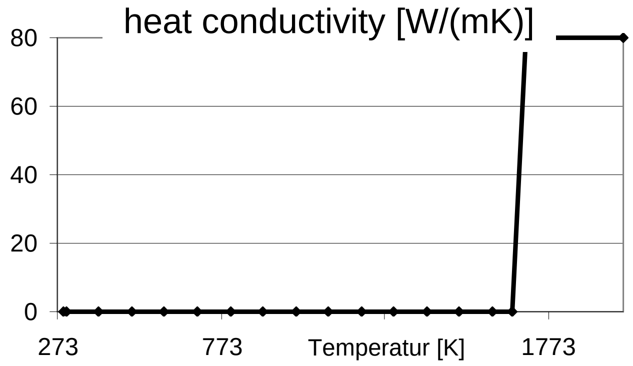
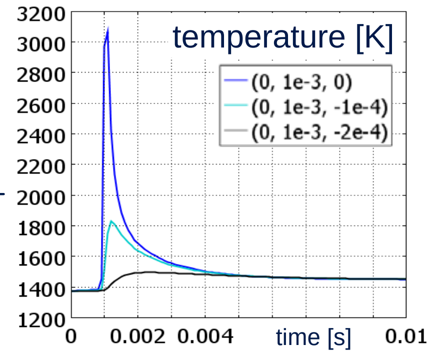
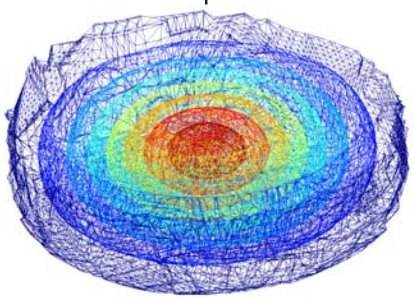
Overview

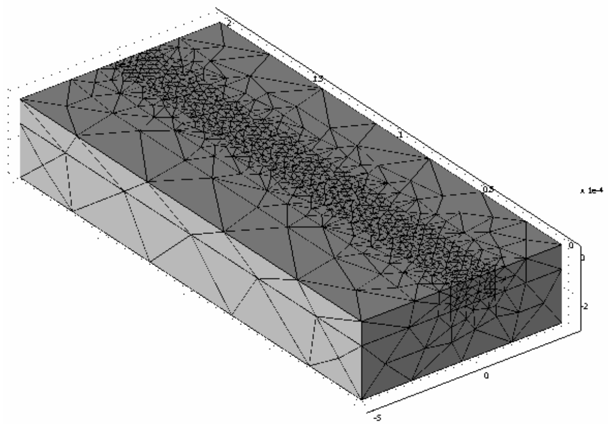


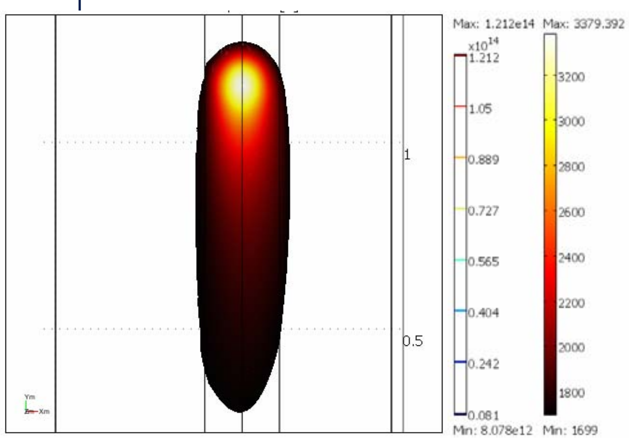


Validation

Mathematical Model → Powder properties → FEM-Simulation → Result analysis → Knowledge to use in real process



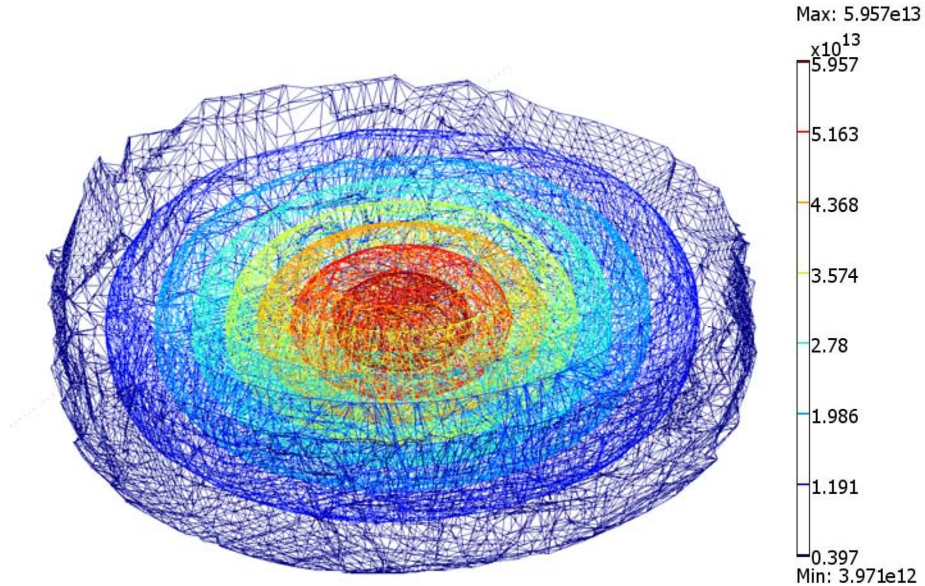




Heat Source Model

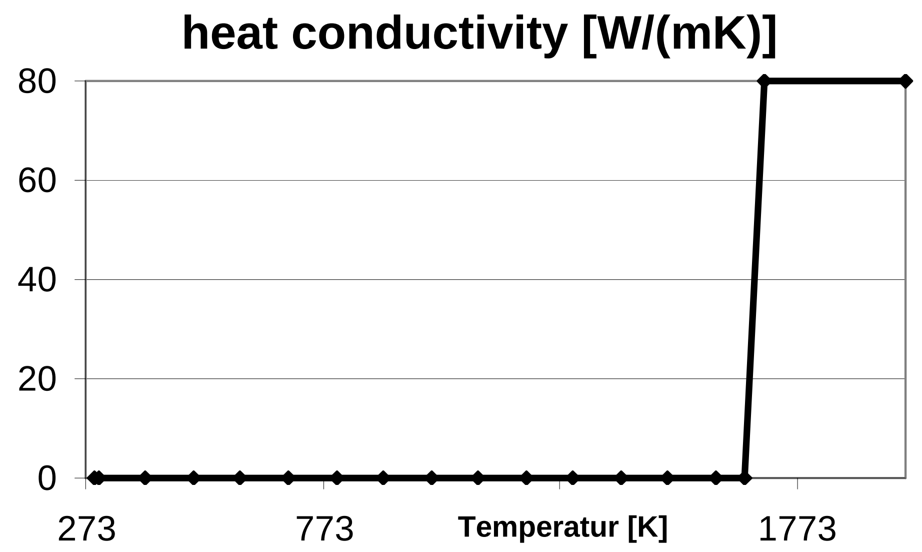
- Horizontal intensity according to a Gaussian distribution
- Vertical intensity follows a 2nd degree polynom
- Power efficiency: 78%
- Superposition
- Penetration depth at given accelerating voltage and powder density: 62 µm
- Moving Heat Source at constant velocity

time=0.002
isosurface: heat source [W/m³]



Temperature Dependence of Material Properties

- Thermomechanical properties of metal powders are not common knowledge due to trade secrets and multitude of powders
- Experiments and analytical models available
- Heat capacity is similar to that of massive material
- Heat conductivity and emissivity modelled and validated



emissity of metal powder

T [K]	333	481	569	680	755	1208	1396
ε	0,78	0,8	0,81	0,83	0,86	0,94	0,98

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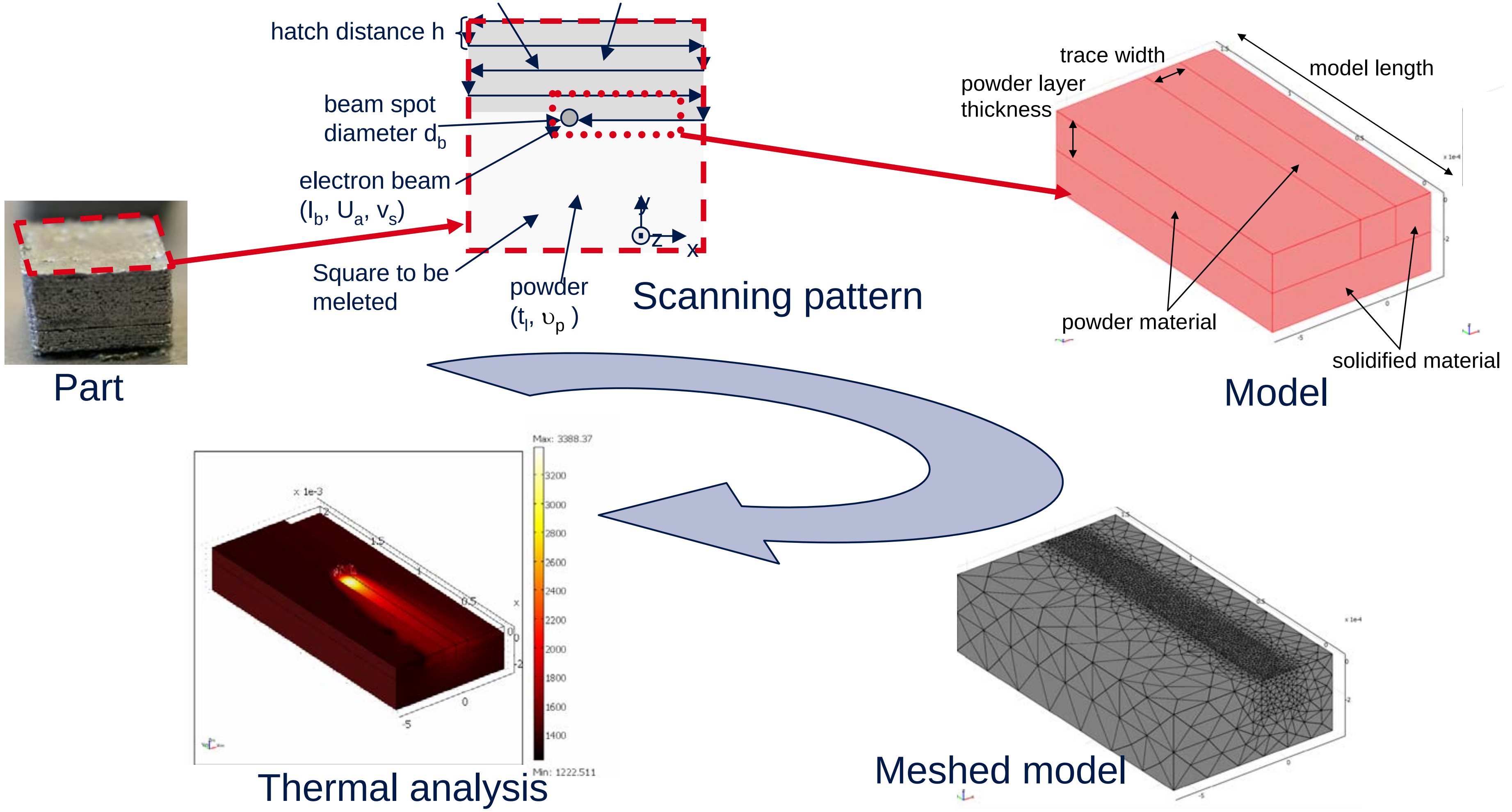
Numerical Model



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Objective of the Simulation

- Calculation of the size and shape of the melt pool
- Simulation of the heat distribution within one melt line

Starting Conditions and Process Parameters

Model parameter	Variable	Value
EB penetration depth	S	$6.2 \cdot 10^{-05}$ m
trace width		$2.0 \cdot 10^{-04}$ m
model length		$2.0 \cdot 10^{-03}$ m
powder layer thickness		$1.0 \cdot 10^{-04}$ m

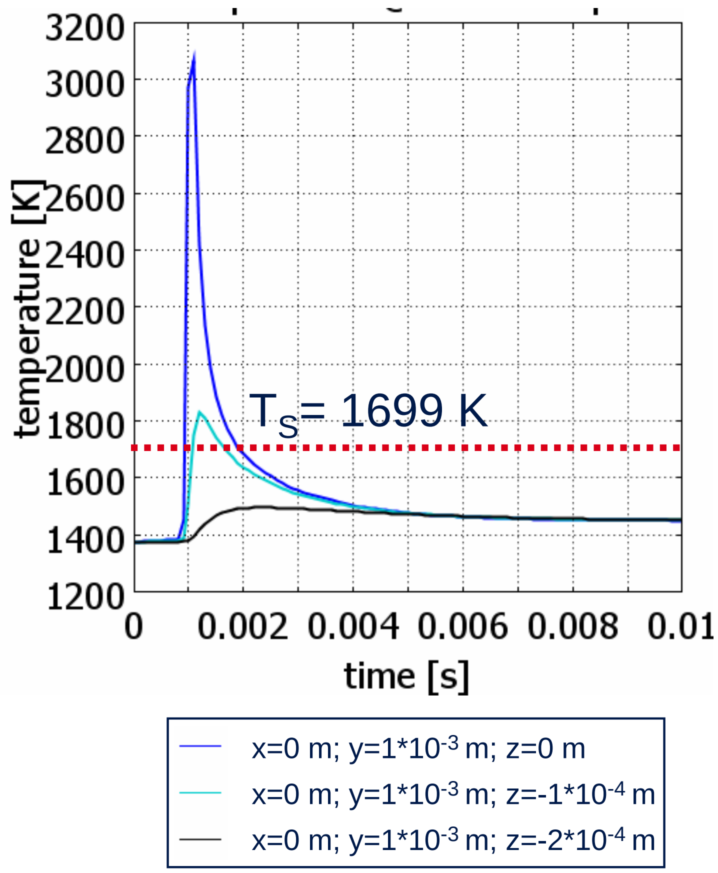
Material parameters	Value
Material	316L (1.4404)
Density	Powder: 3.4 g/cm³ Massive: 7,9 g/cm³
Grain Size	20-63 µm

Process parameter	Variable	Value
accelerating voltage	U_a	100 kV
beam current	I_b	1 mA
beam spot diameter	d_b	200 µm
layer thickness	t_l	100 µm
preheating temperature	υ_p	1353 K
scan speed	v_s	0.1 m/s
hatch distance	h	0.1 mm

Heat distribution within one melt line

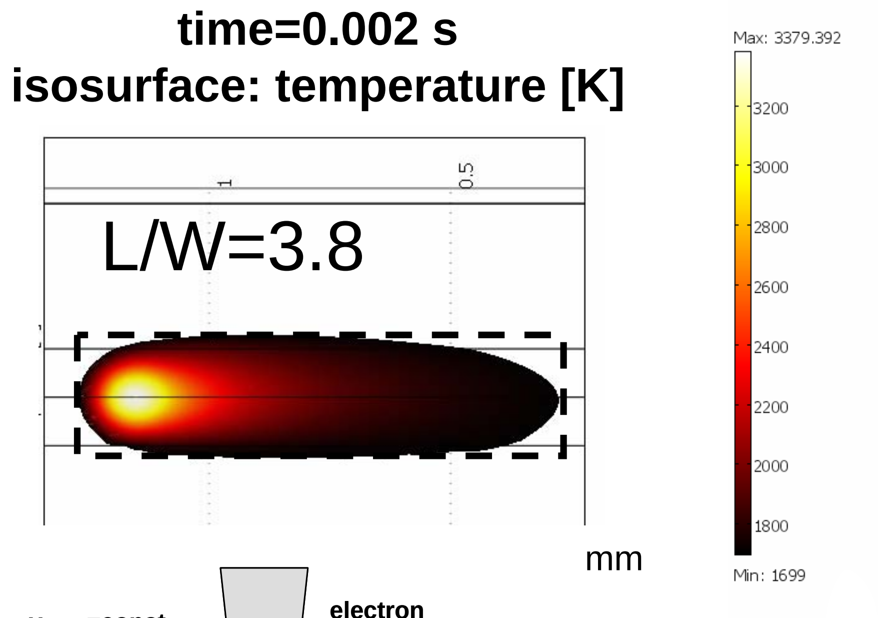
- Simulation of the transient temperature distribution in the center of a melt line at various depths
- Complete melting of a layer at point z=-1*10^{-4} m (= layer thickness)
- After the powder has reached melting temperature, the layer thickness decreases proportional to its density increase

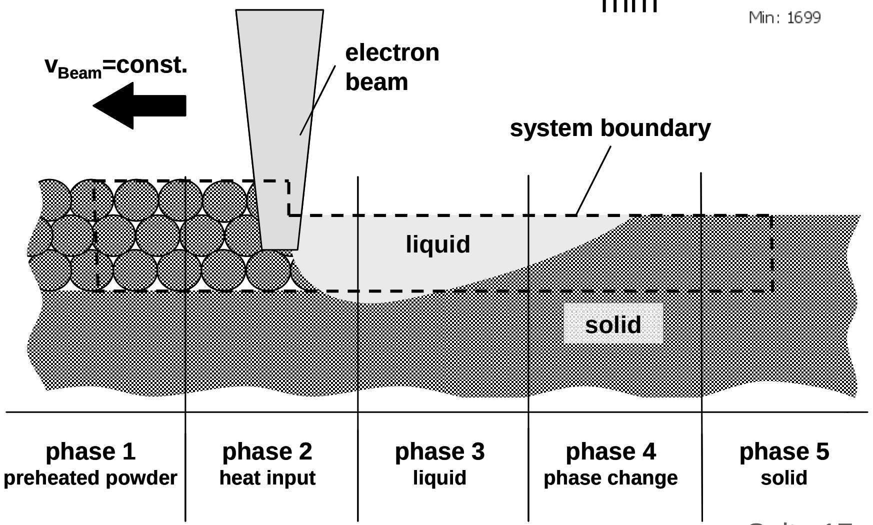
temperature [K] @ various depths



Calculation of the size and shape of the melt pool

- Calculation of the Size and shape of the melt pool according to real process parameters
- L/W-ratio is 3.8, no balling observed
- in comparison: 2.1 in laserbeam-based processes (SLM, DMLS, etc.)
- Possible reasons:
  - preheating temperature
  - vacuum in the process area
  - different beam-material interaction
- Research efforts to be done





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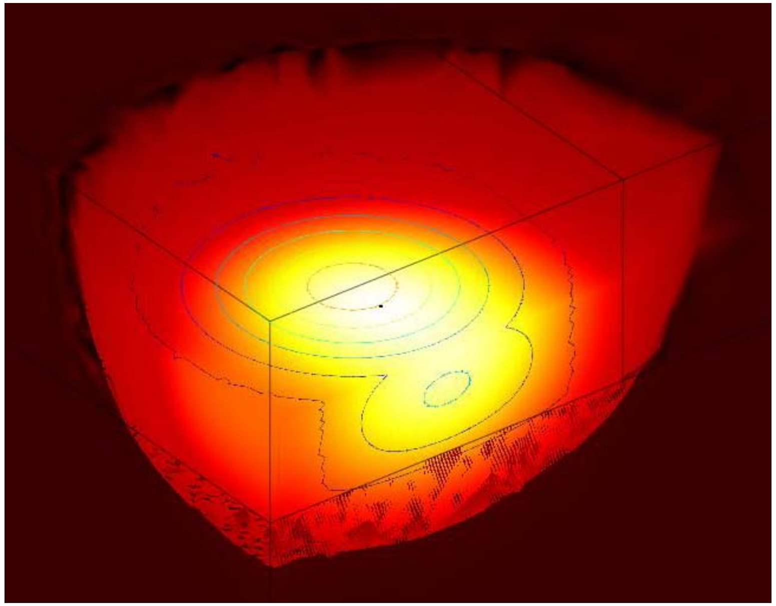
Conclusion

- Manufacturing of EBS parts only possible with considerable process knowledge
- Simulation carried out in order to evaluate necessary beam power and other process parameters
- FE-Modelling of the energy input based on a mathematical abstracted heat source and a discretized powder bed is an effective tool
- Differences between Laser- and Electron Beam-based processes discovered
- Model can be transferred to alternative additive layer manufacturing technologies



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Mega-trends:

- Demand for individualization of products increases (“mass customisation”)
- Products become more complex
- Life cycles shorten

❯ **innovative technologies** for an **economic** manufacturing of complex parts (powder based manufacturing methods – SLM, DMLS, EBS)

❯ wide **range** of processable **materials** (high quality steel, titanium alloys, aluminum alloys)

❯ **efficient** numerical methods for virtual design of manufacturing processes – Finite-Element-Analysis (**FEA**)