Empirical calibration method for the thermal simulation of $Cu_{47}Ti_{34}Zr_{11}Ni_8$ single tracks in laser powder bed fusion

Lars Bruckhaus

Jan Wegner, Norman Schnell, Hanna Schönrath, Erika Soares Barreto, Maximilian Frey, Nils Ellendt, Ralf Busch, Stefan Kleszczynski

UNIVERSITÄT DES SAARLANDES

IWT Leibniz-Institut für Werkstofforientierte Technologien

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Rapid.Tech 3D | 17.05.2024

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AGENDA

1. Introduction
2. Motivation
3. Materials and methods
4. Results
5. Summary
6. Outlook

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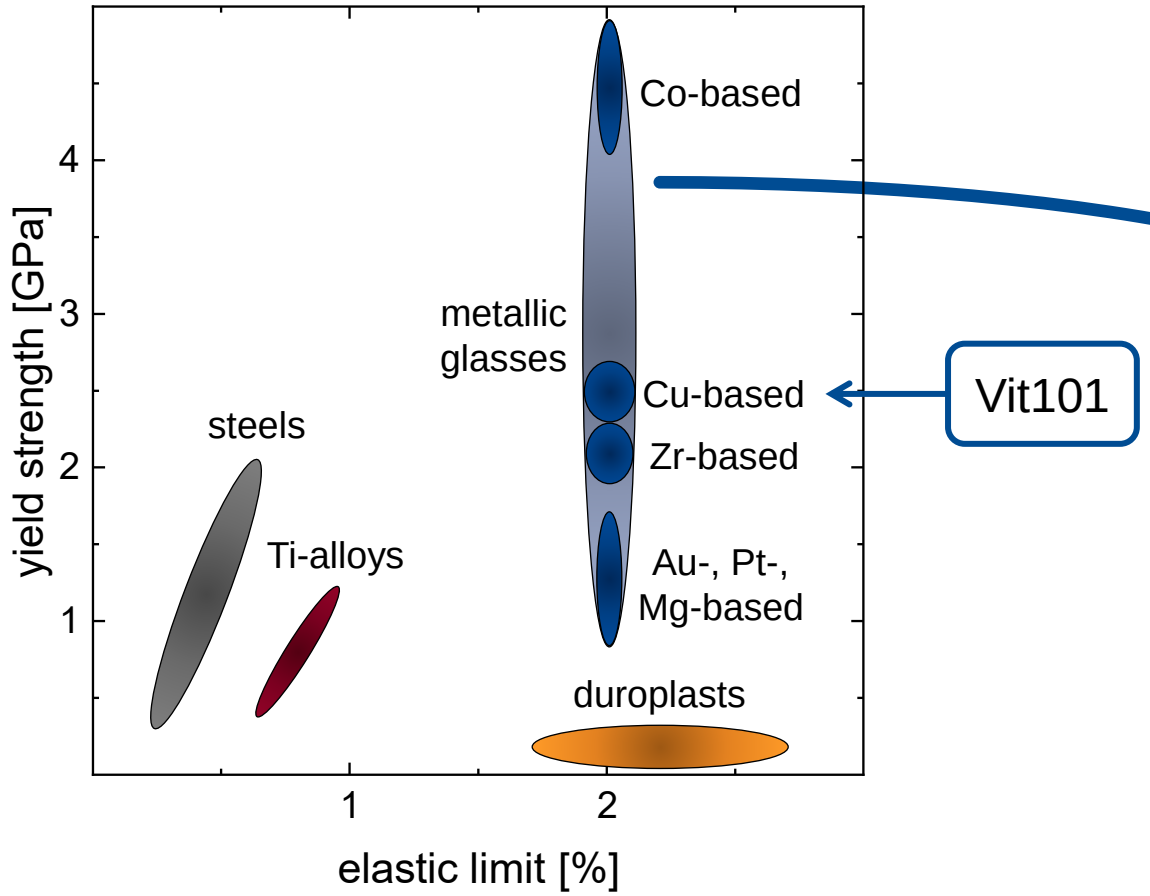
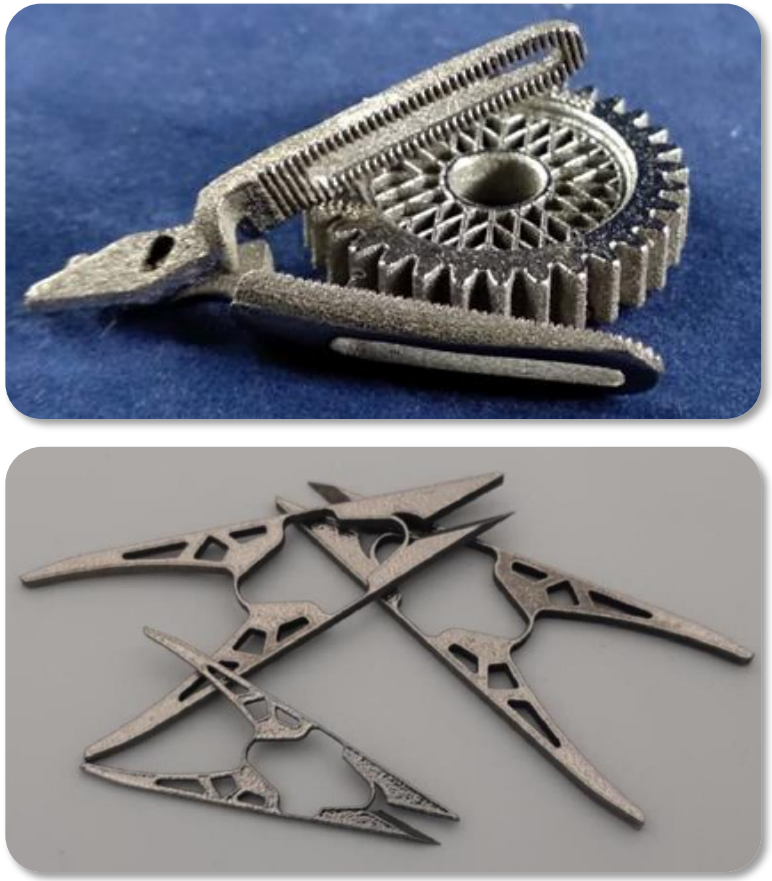
Bulk Metallic Glasses (BMGs)



M. Telford (2004) 10.1016/S1369-7021(04)00124-5

Vit101



J. Wegner (2021) 10.1016/j.addlet.2021.100019

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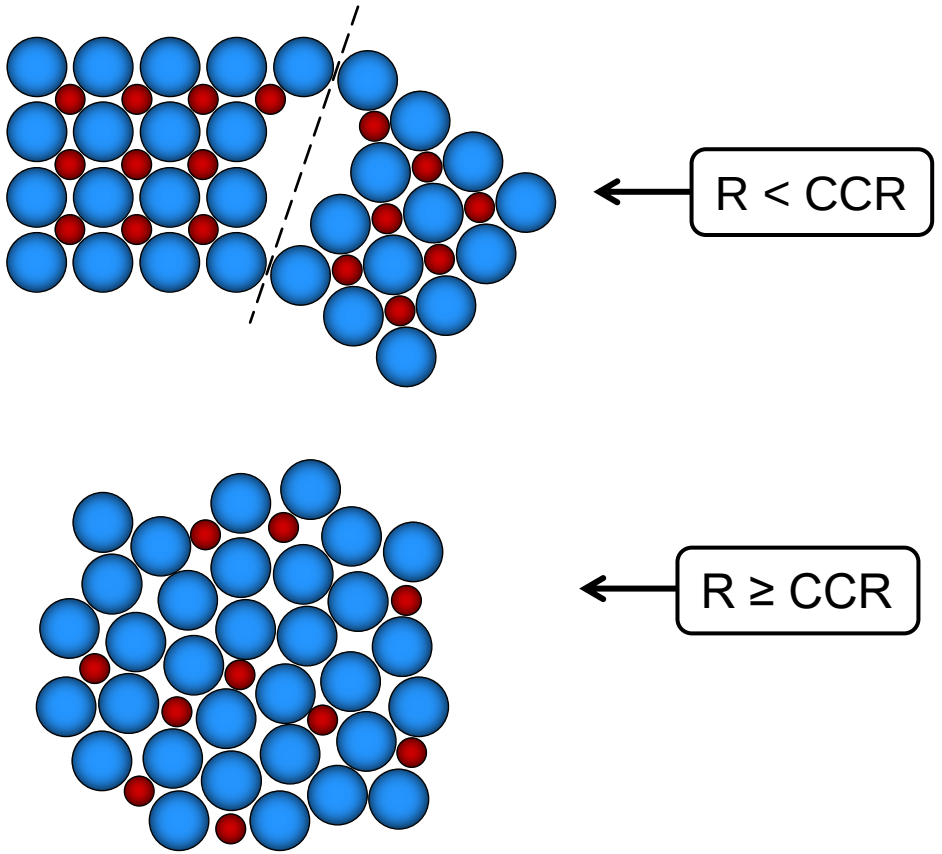
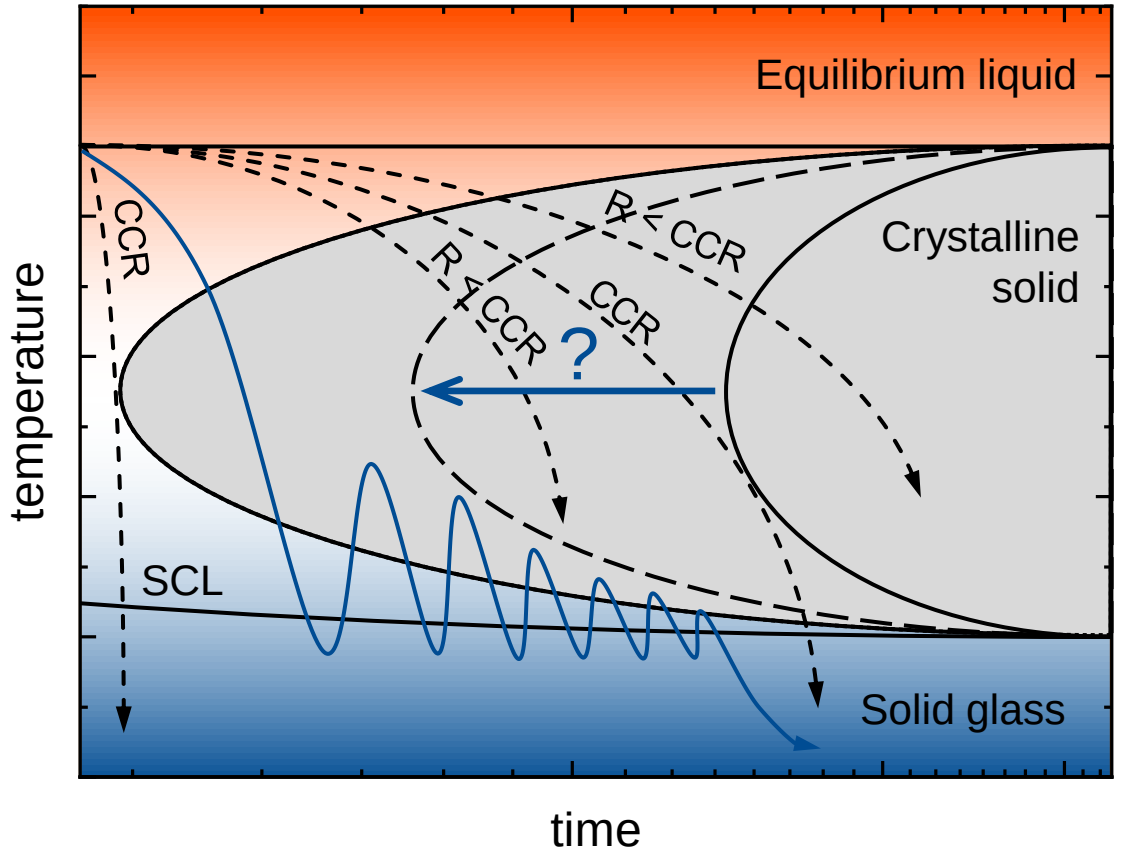
Bulk Metallic Glasses (BMGs)





J. Wegner (2023) 10.17185/duepublico/78650

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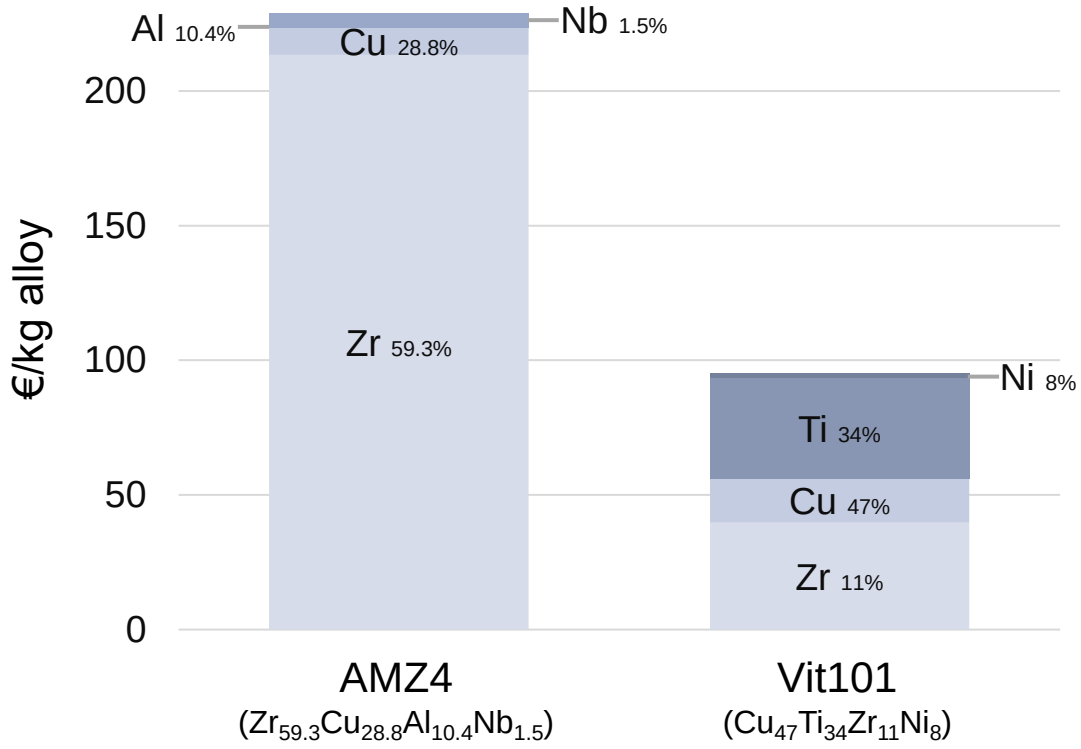
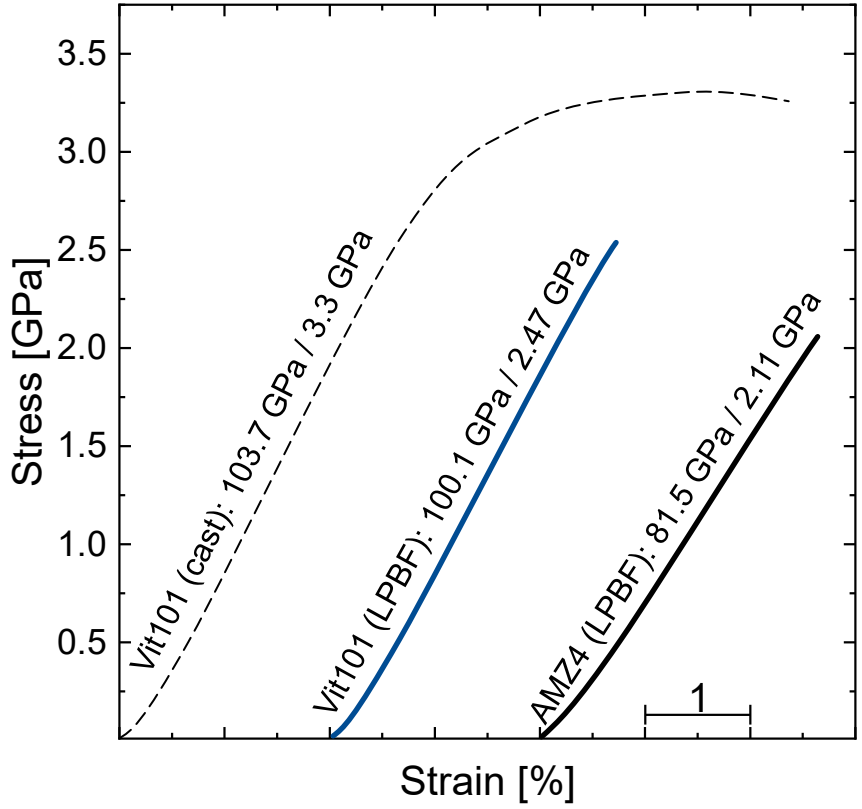
Vit101 (Cu-Ti-based BMG)





M. Frey (2023) 10.1016/j.addma.2023.103467

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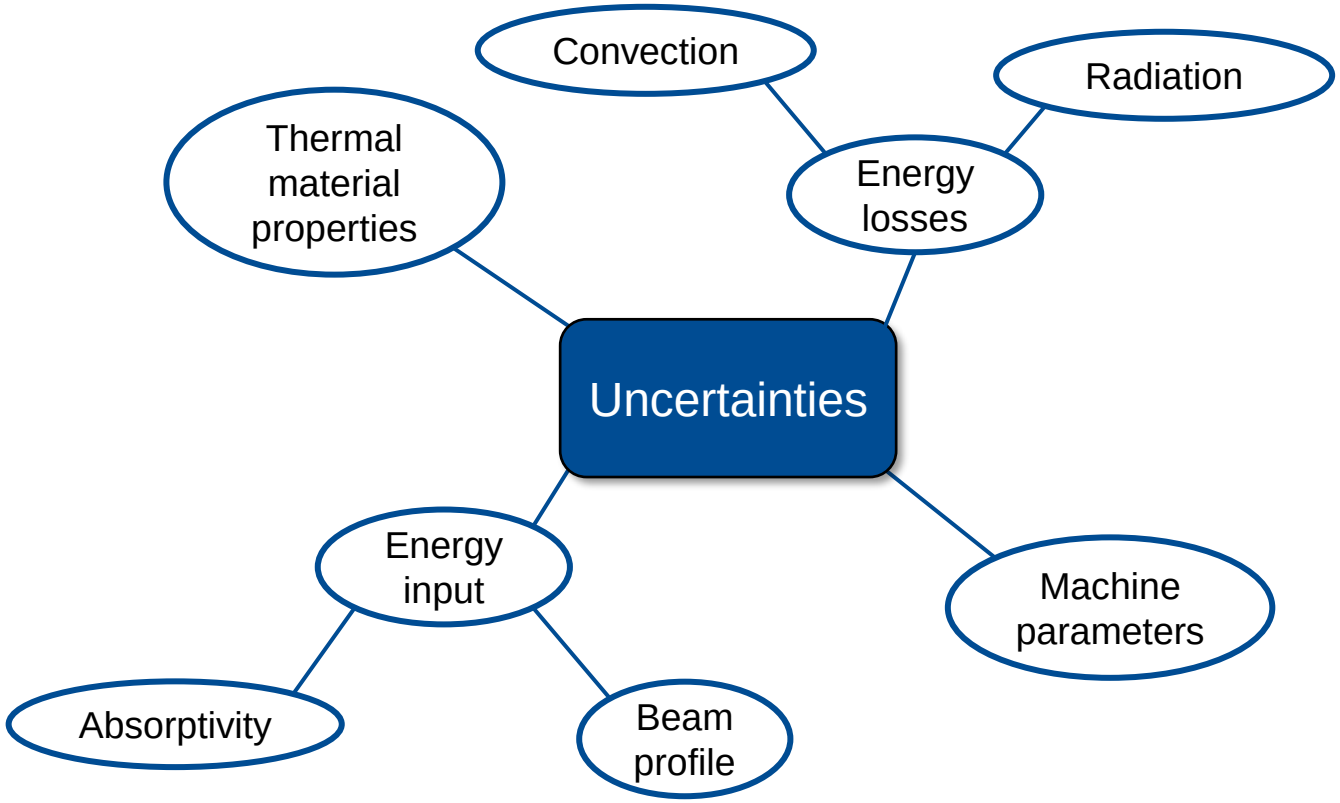
PBF-LB/M of BMGs

Can an amorphous structure be achieved despite the challenges posed by the alloys' limited GFA through AM?

- trial and error
- simulation



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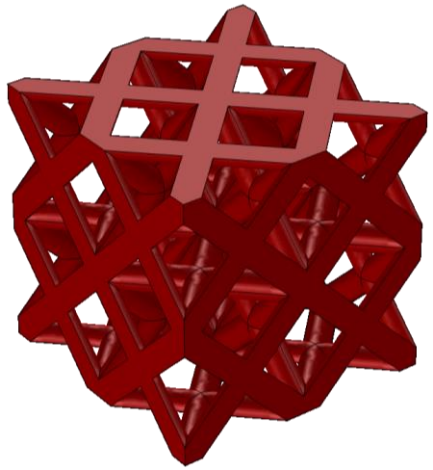
Thermal simulation of PBF-LB/M

Part



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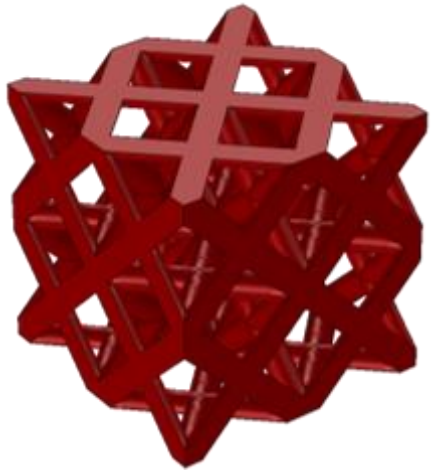
Thermal simulation of PBF-LB/M

Part



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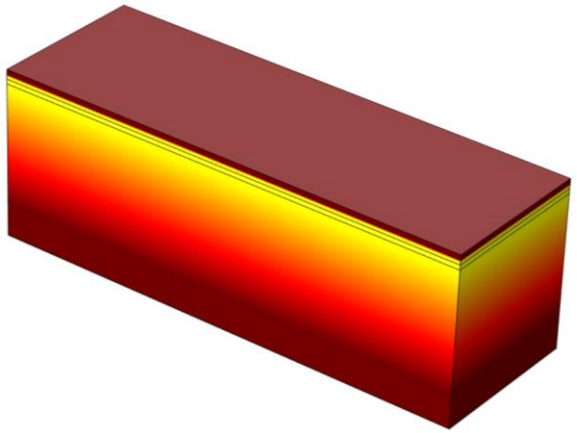

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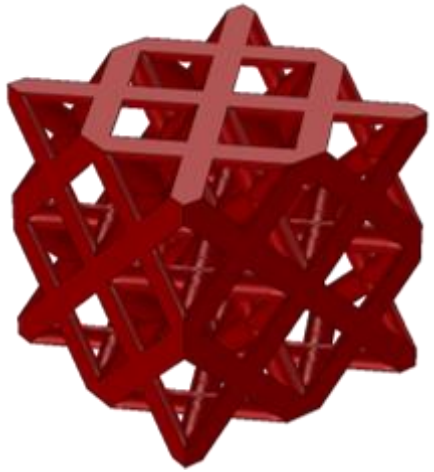
Thermal simulation of PBF-LB/M

Part



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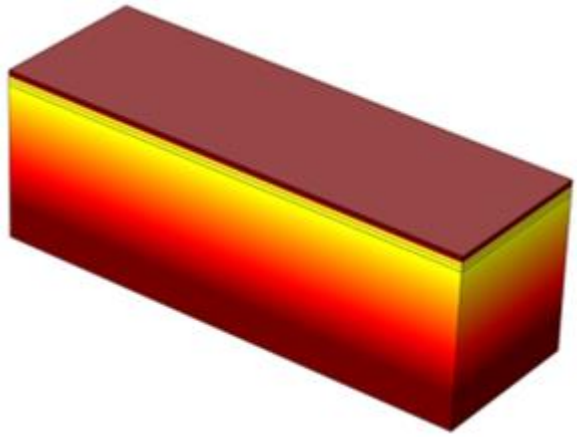
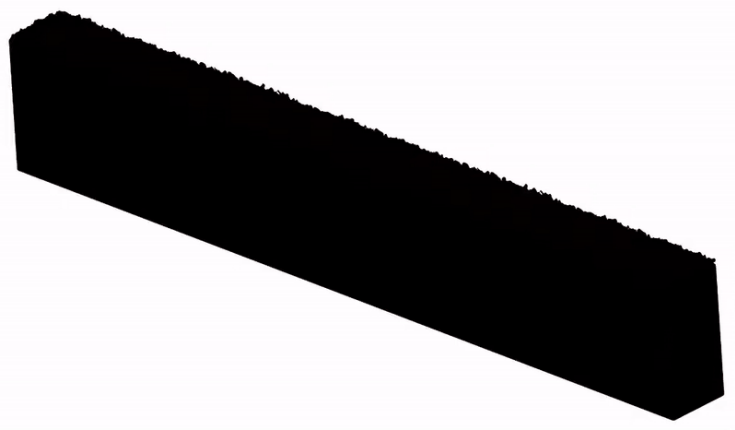


Melt pool



M. Bayat (2019) 10.1016/j.addma.2019.100835

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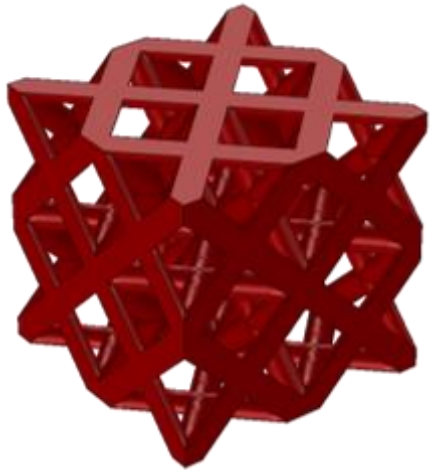
Thermal simulation of PBF-LB/M

Part



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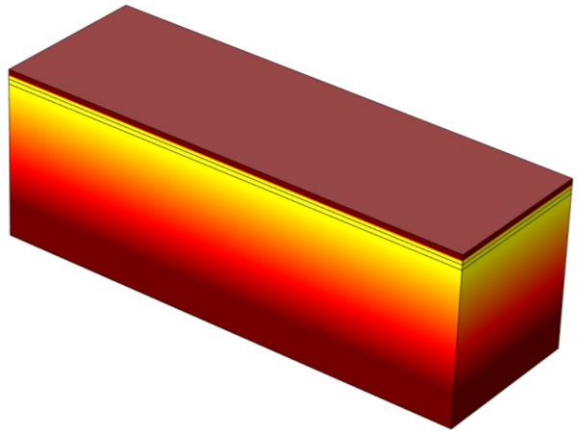

Melt pool

M. Bayat (2019) 10.1016/j.addma.2019.100835

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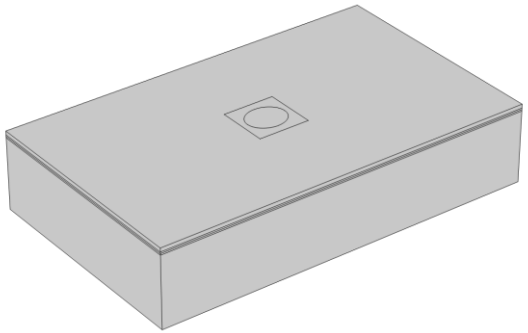
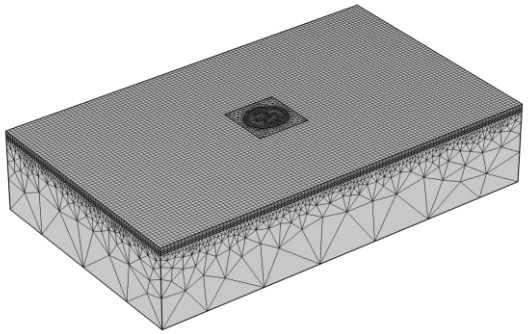
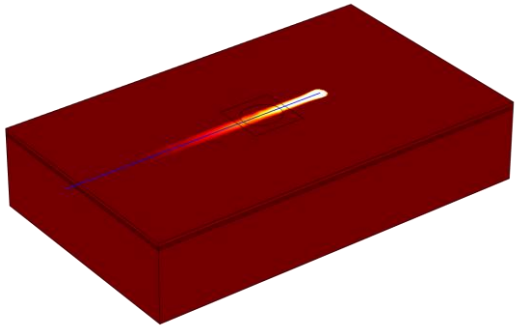
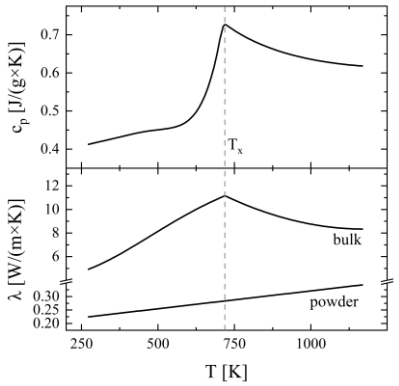
Simulation basics

Geometry → Constrains → Mesh → Solver → Solution





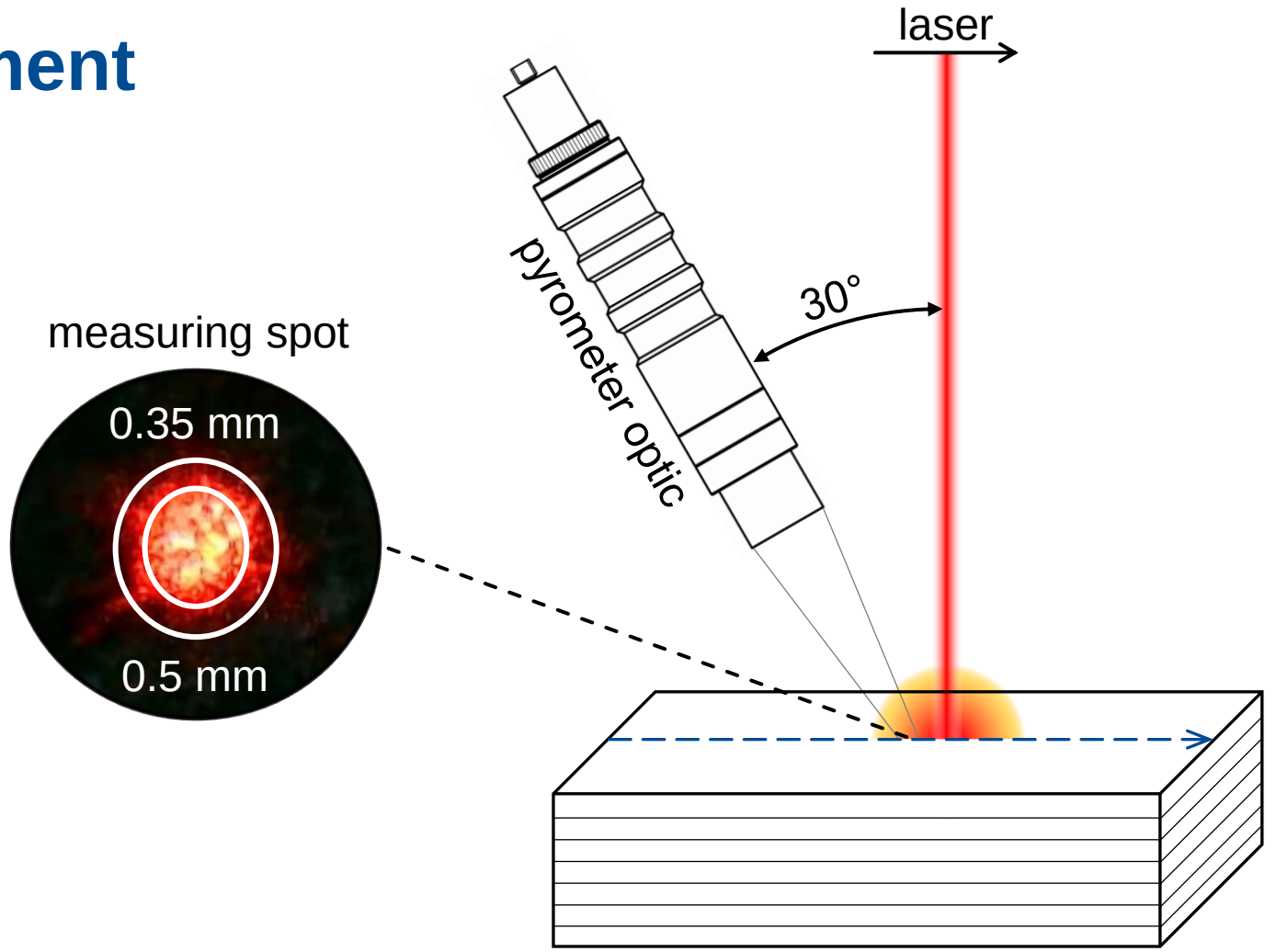




$$[c] * \{\dot{T}\} * [k_{th}] * \{T\} = -\{Q(t)\}$$

Temperature measurement

T-range: 673-1473 K



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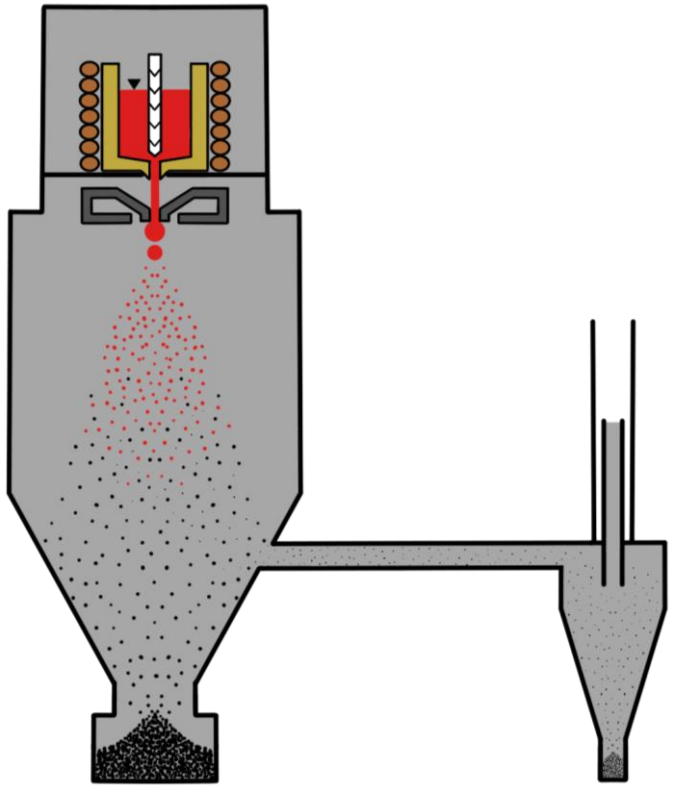
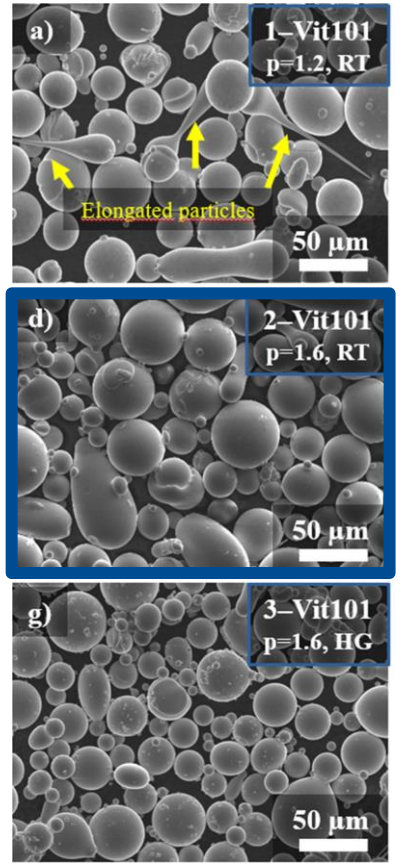
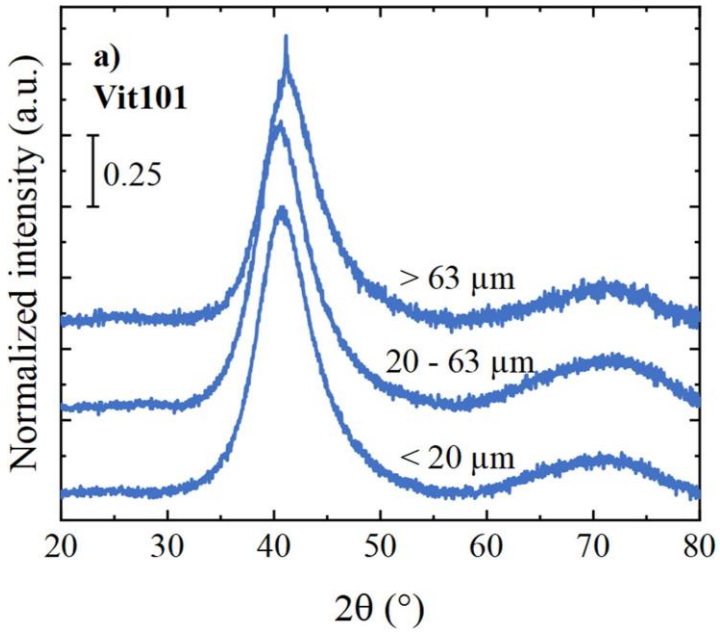
Vit101 powder







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E. Soares Barreto (2022) 10.1016/j.matdes.2022.110519

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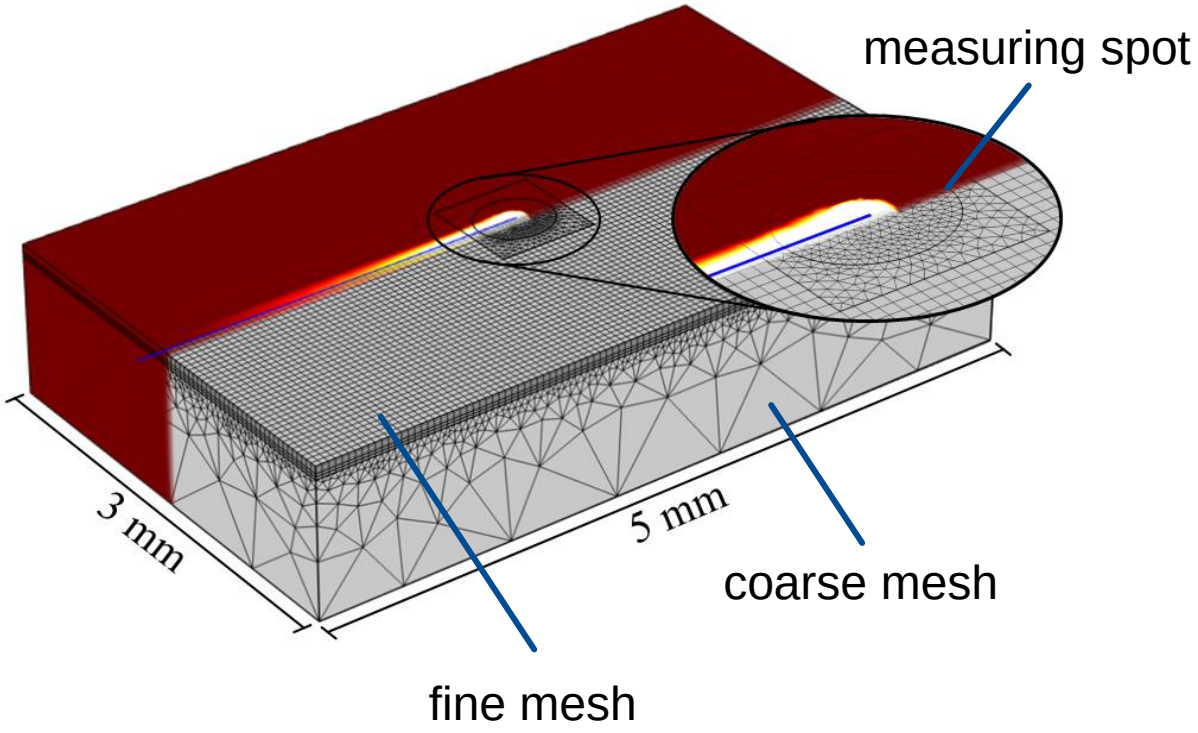
Numerical model



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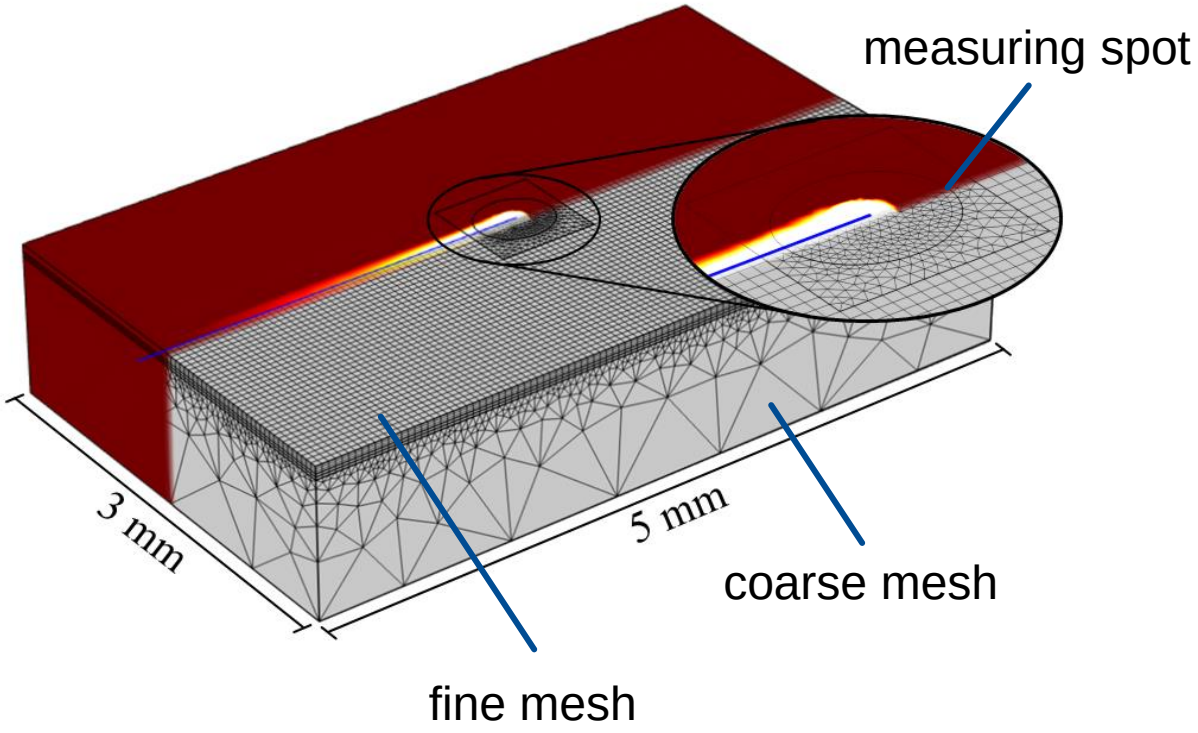
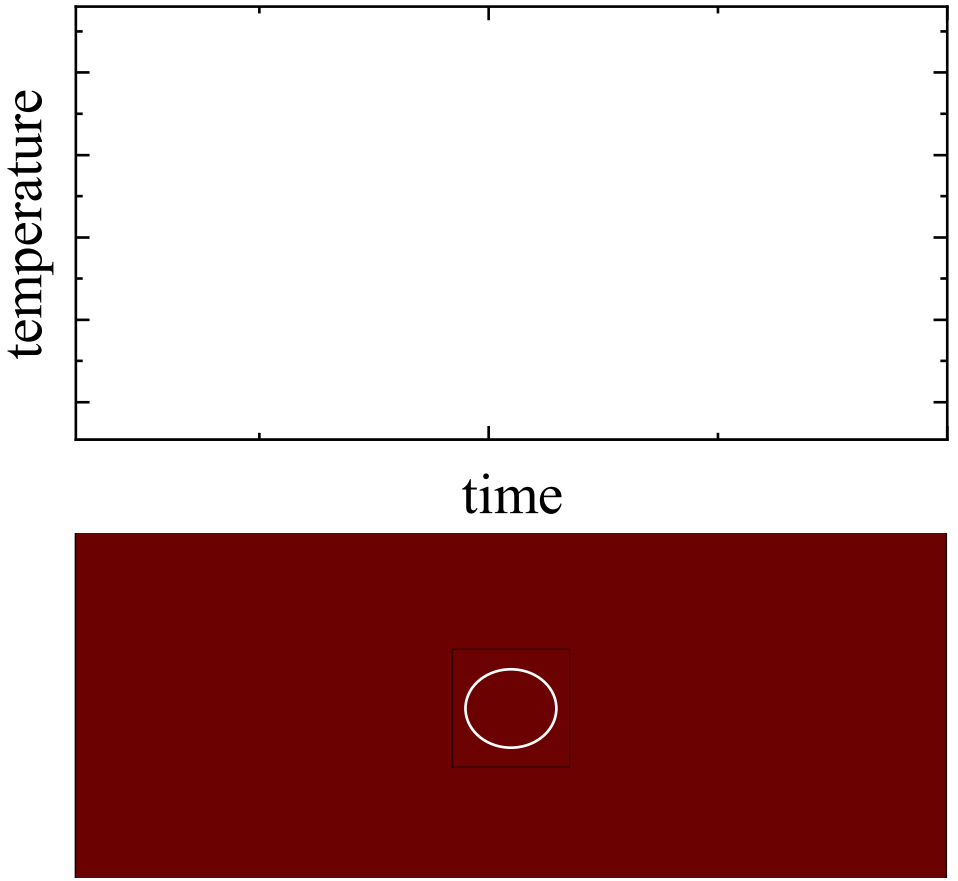
Numerical model





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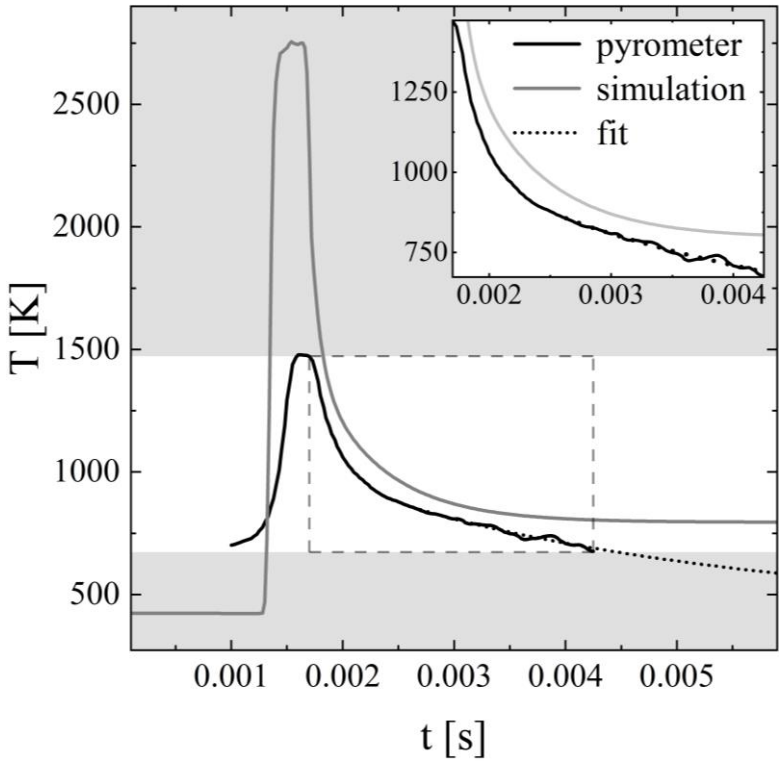
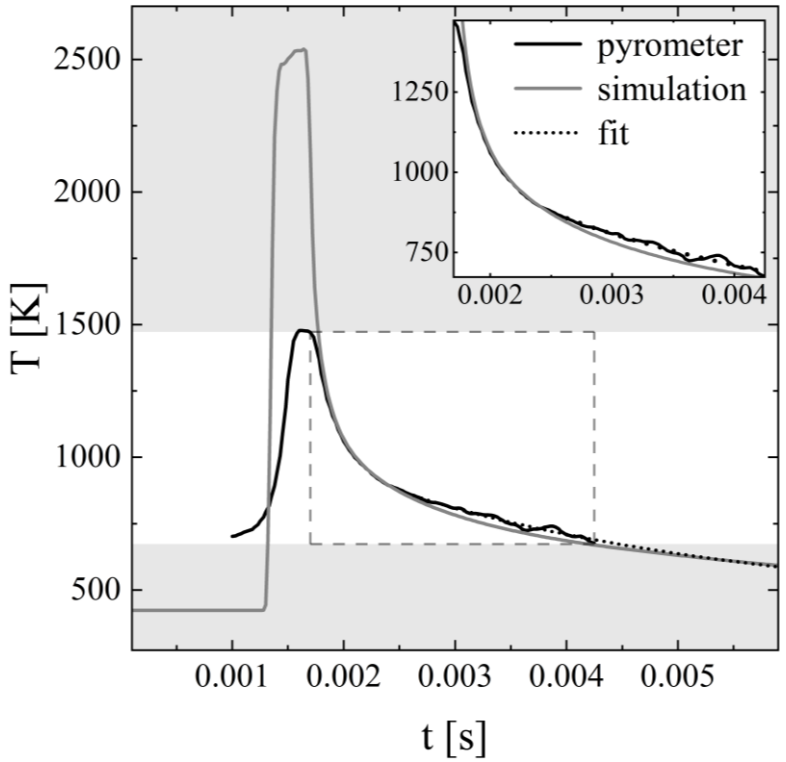
Calibration

adjusting calibration factors

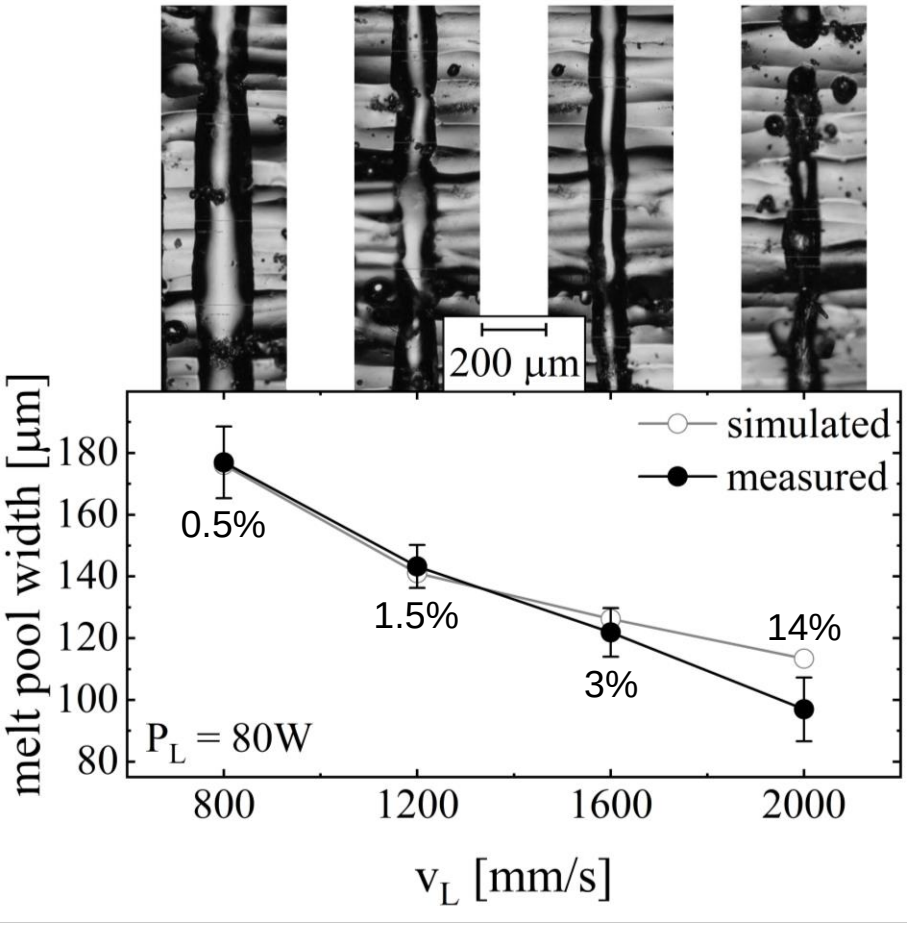
starting point

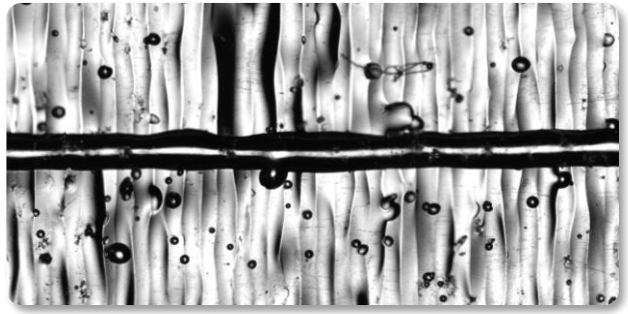


calibrated model



Validation


200 µm
simulated
measured
melt pool width [µm]
180
160
140
120
100
80
0.5%
1.5%
3%
14%
P_L = 80W
800
1200
1600
2000
v_L [mm/s]



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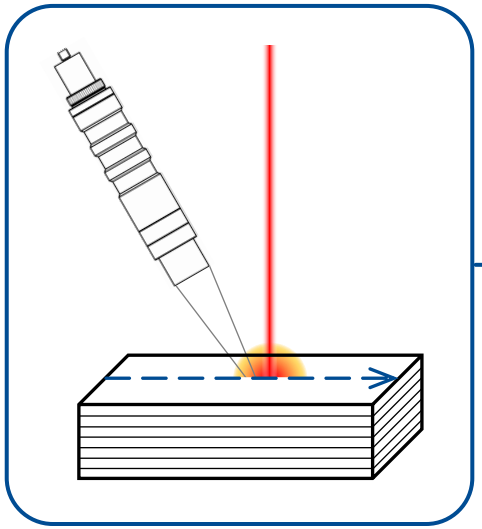
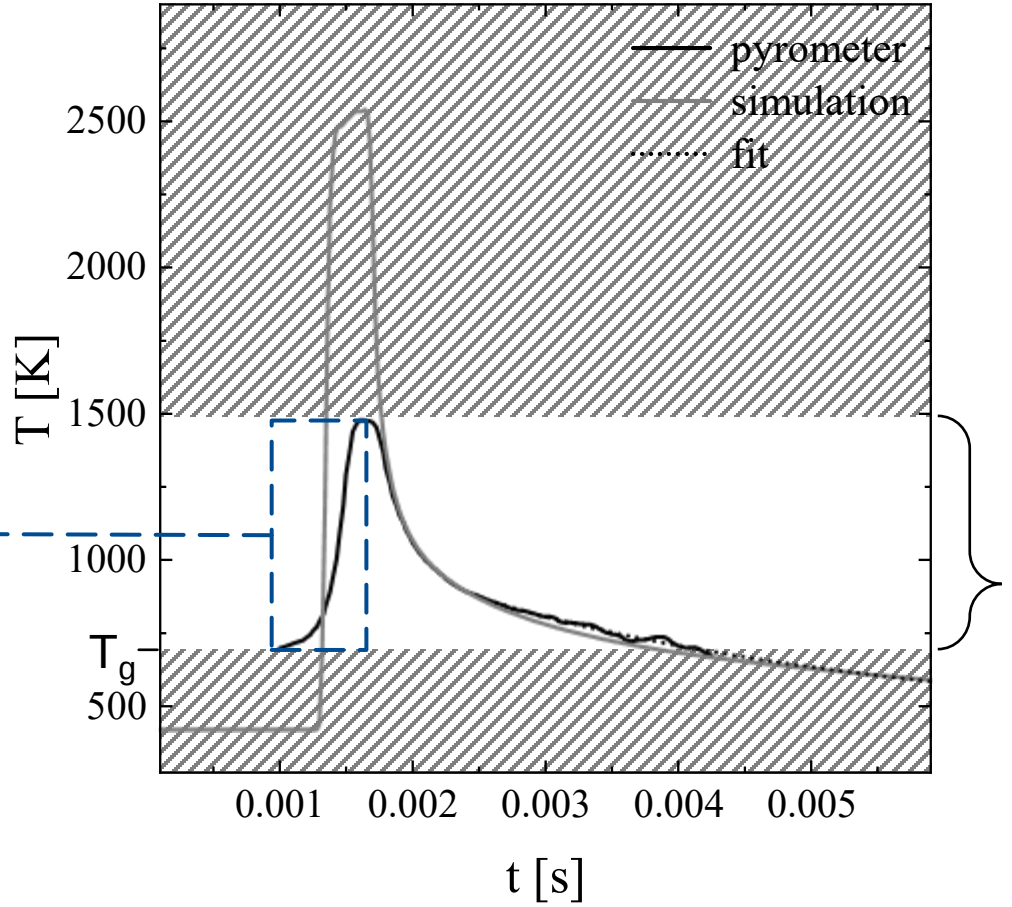
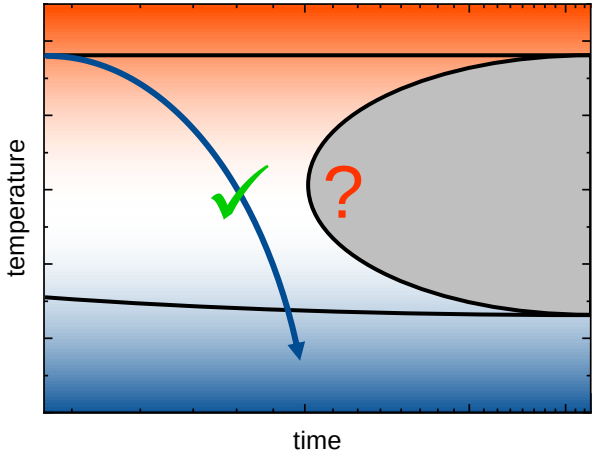
Discussion





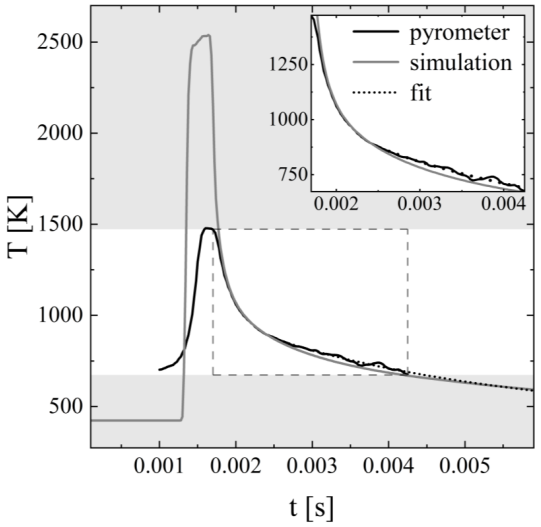


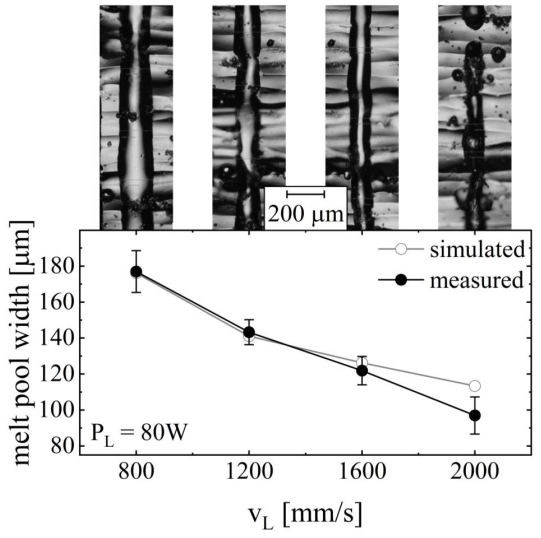
$R_{min} \sim 10^4$ K/s

Simulation: $R_{avg} \sim 3 \times 10^5$ K/s
Pyrometer: $R_{avg} \sim 2 \times 10^5$ K/s

Summary

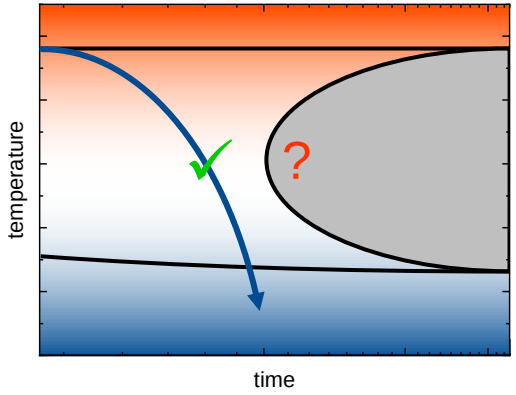
- Measured cooling profile matches simulation after calibration
  - Validation of heating rate ongoing
- Minimal cooling rates of ~ 10^4 K/s measured and simulated above glass transition temperature
  - ➢ exceeds nominal CCR of Vit101 → amorph
- Model can predict melt pool widths
  - Deviation of 0.5 to 3% for stable melt tracks

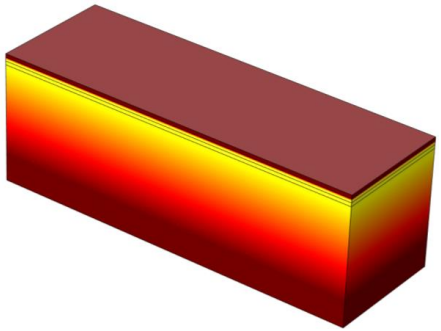


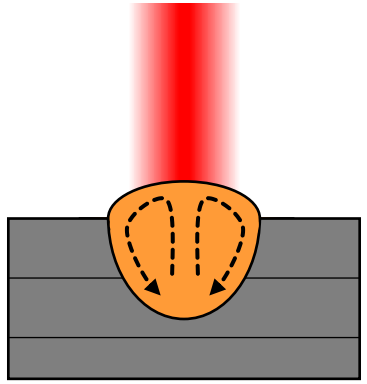


Outlook

- Validate temperatures exceeding current measuring range
- Determine TTT crystallization nose
- Implement fluid dynamics and crystallization effects
- Apply principle to multi vector model
  - Effect of overhang structures
  - Integrate scan strategies







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