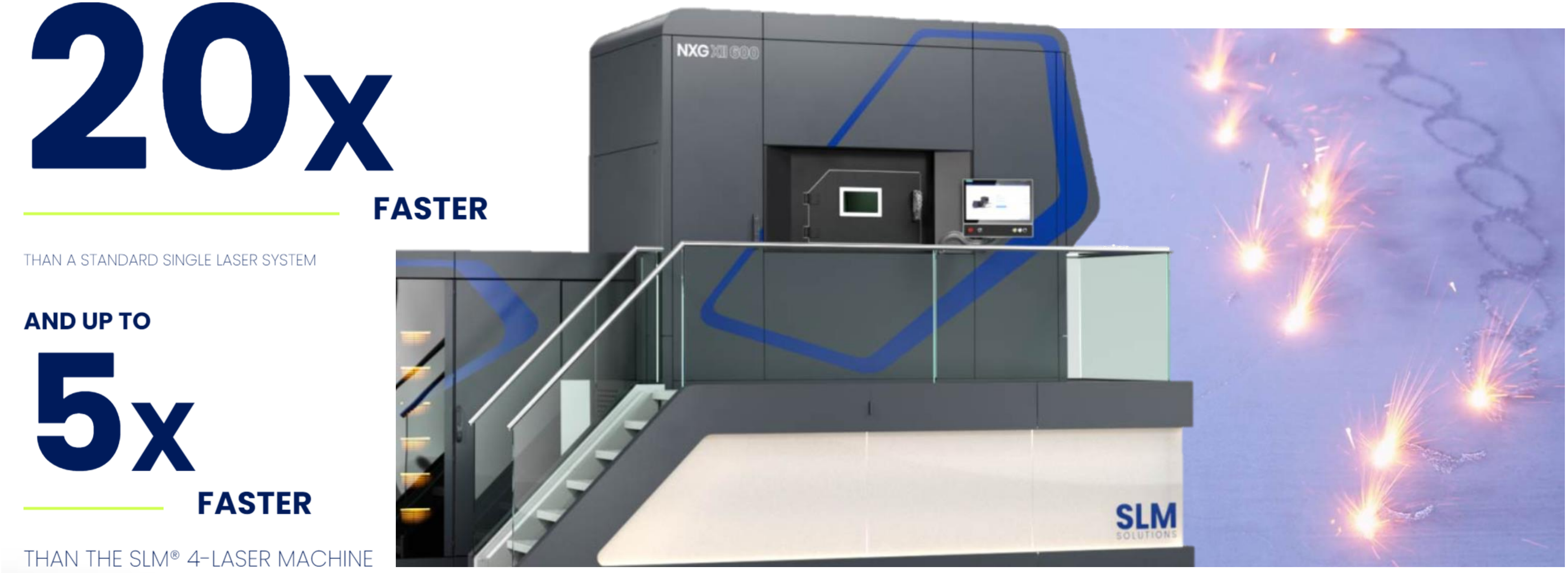
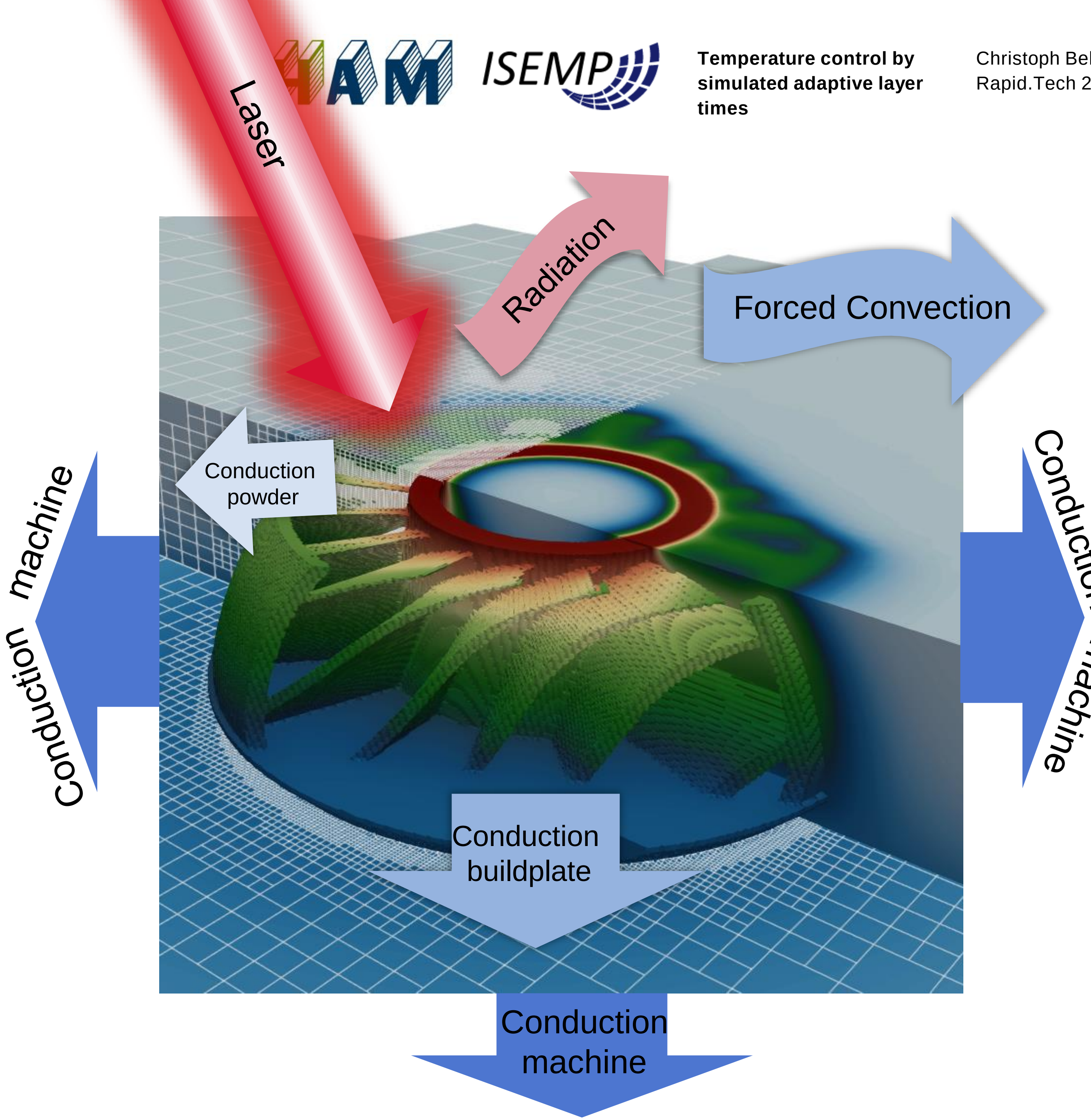
Temperature control by simulated adaptive layer times in powder bed fusion processes

Christoph Behrens · Niklas Ostermann · Jan T. Sehrt · Vasily Ploshikhin

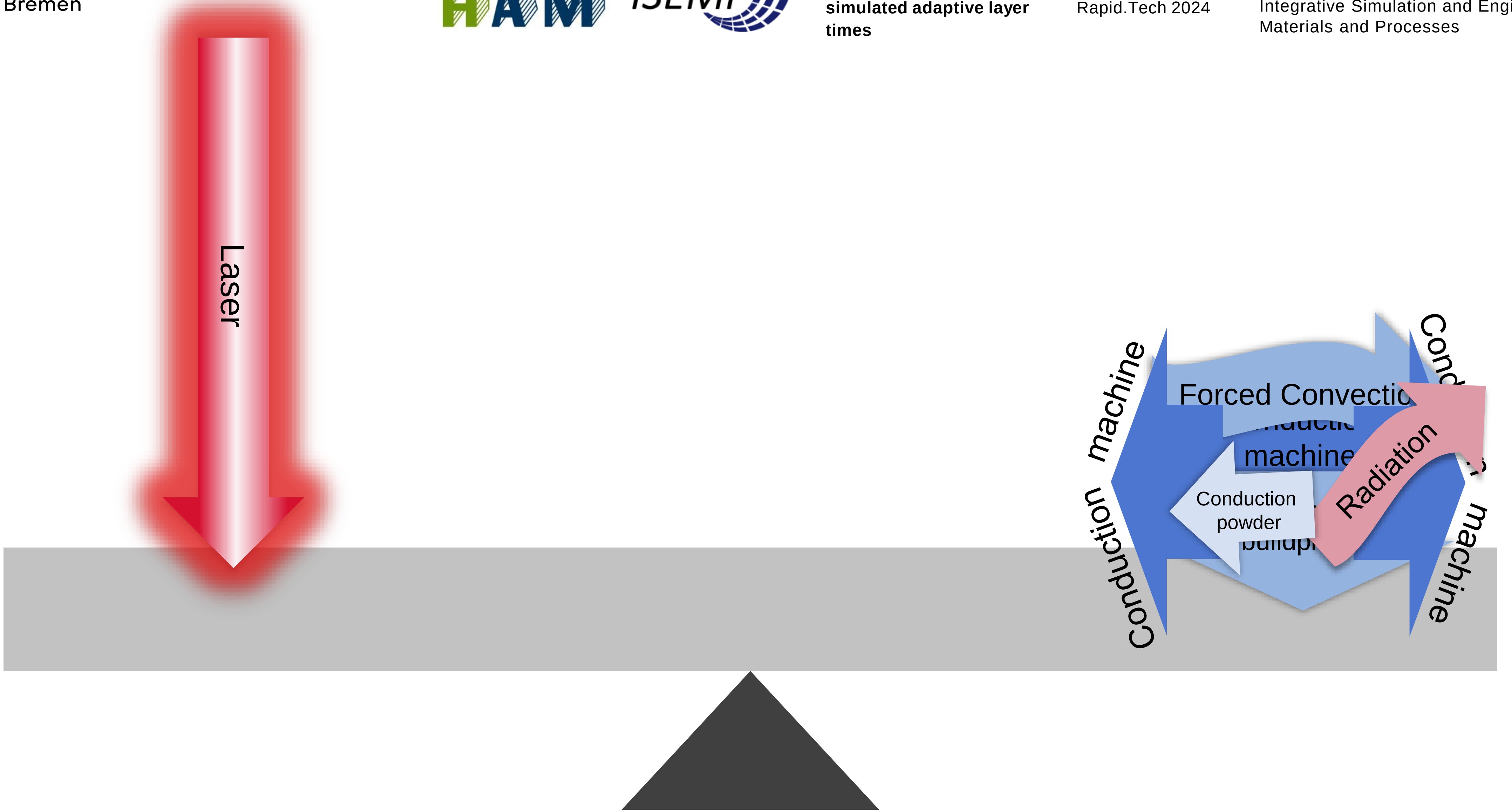


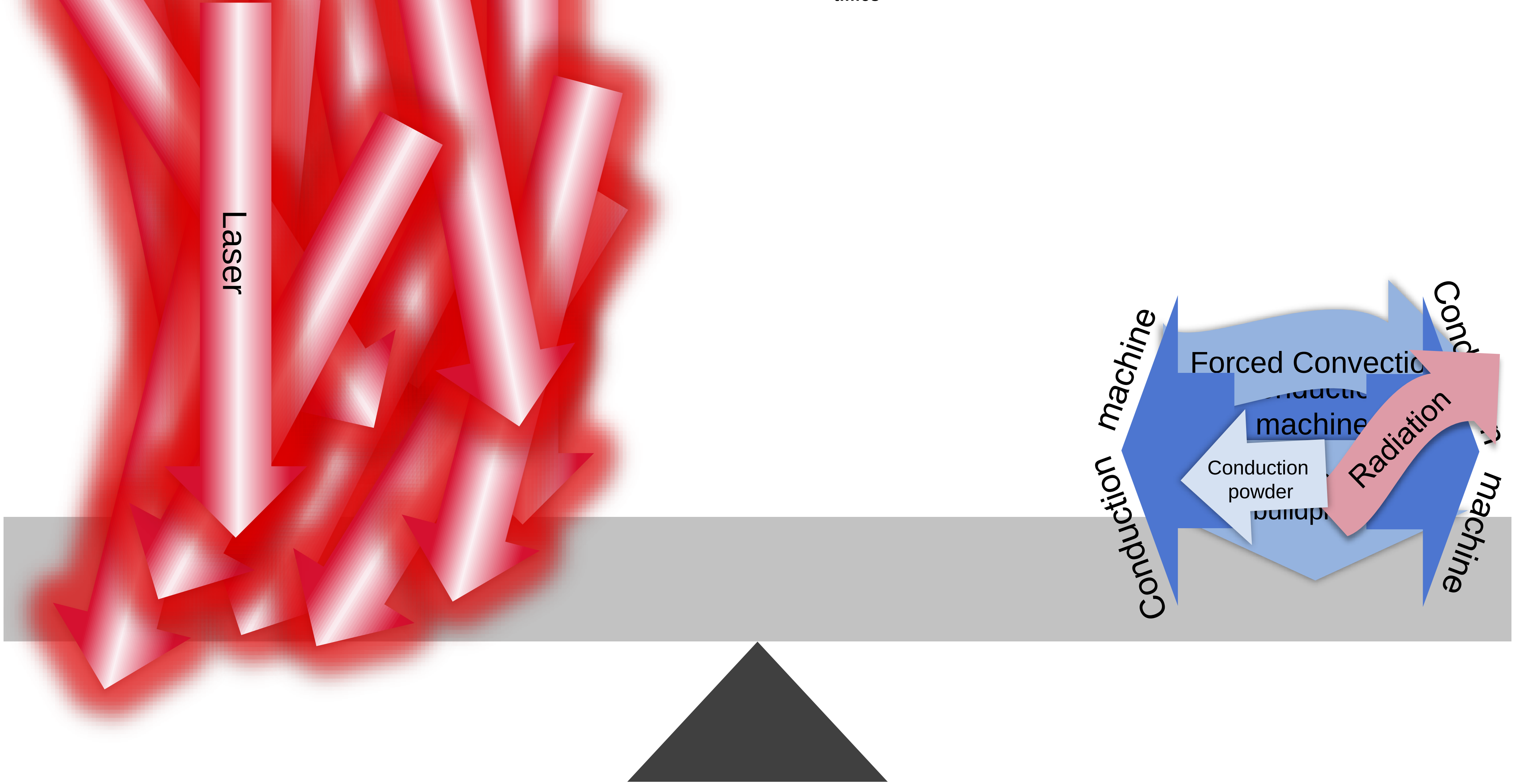
https://www.slm-pushing-the-limits.com/, last visited 4.11.2024

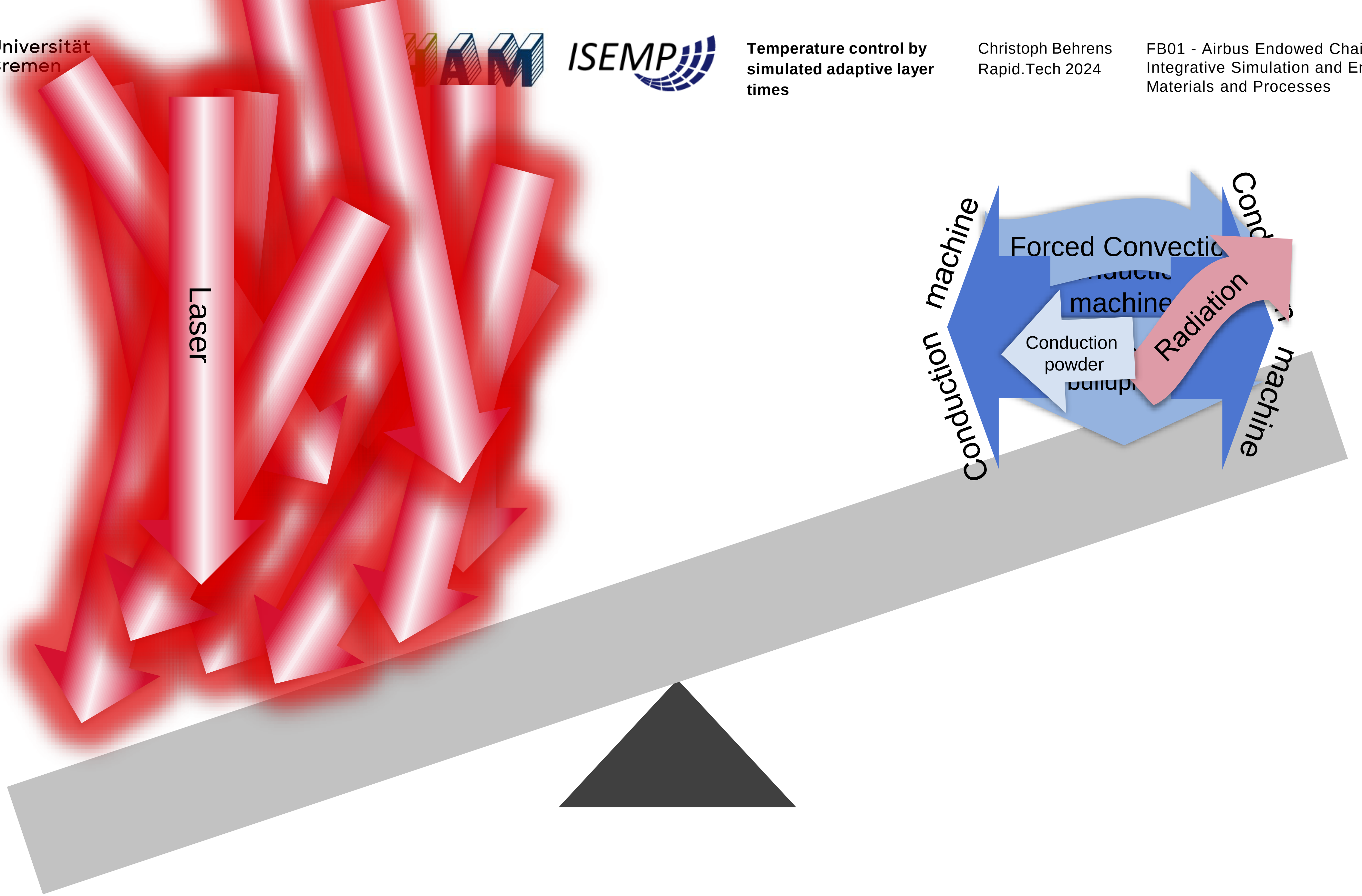

Laser
Radiation
Forced Convection
Conduction powder
Conduction machine
Conduction machine
Conduction buildplate
Conduction machine

Christoph Behrens
Rapid.Tech 2024

FB01 - Airbus Endowed Chair for Integrative Simulation and Engineering of Materials and Processes




Laser
machine
Conduction
Forced Convectio
machine
Conduction
powder
Radiation
machine


Laser
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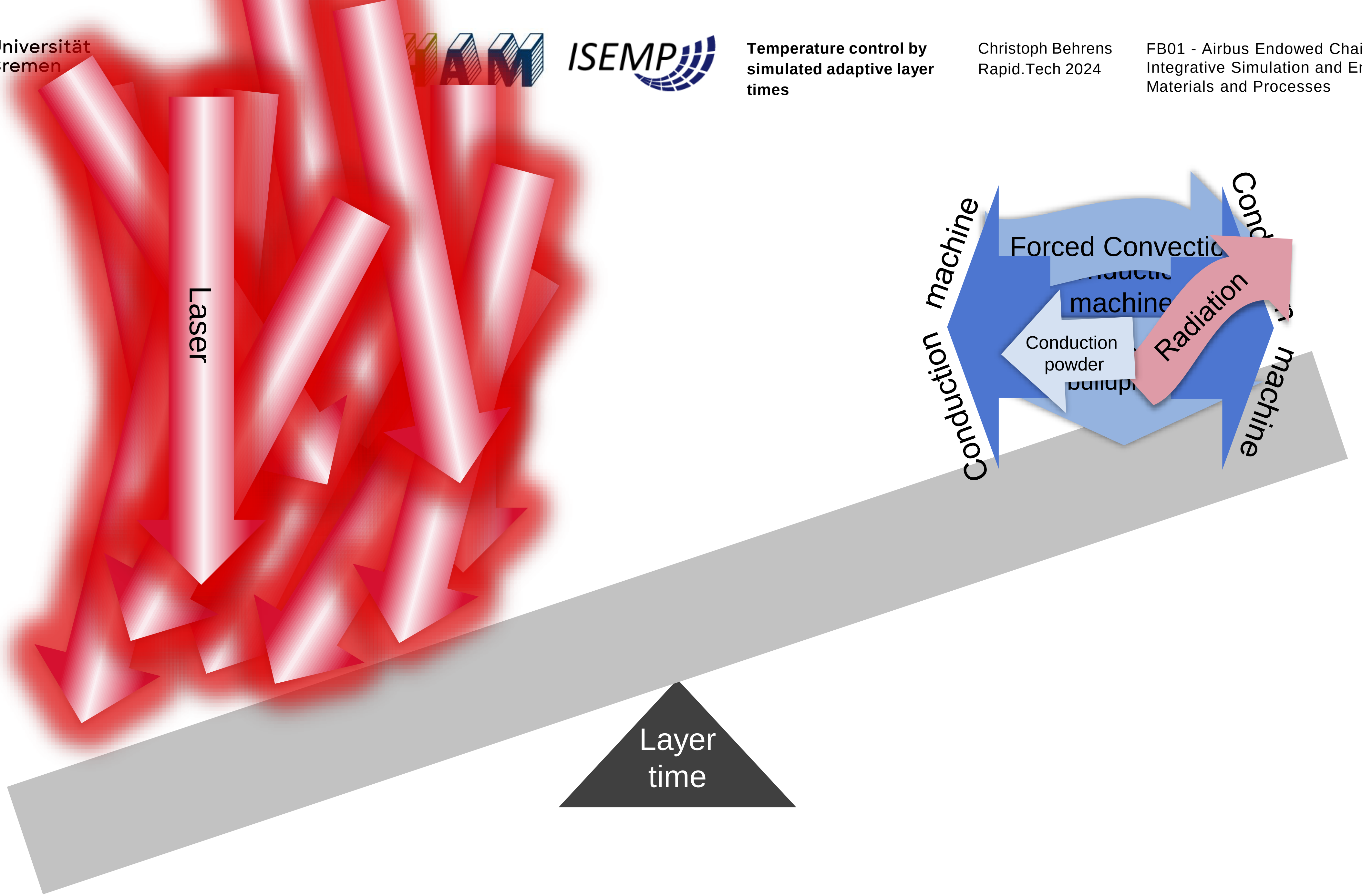
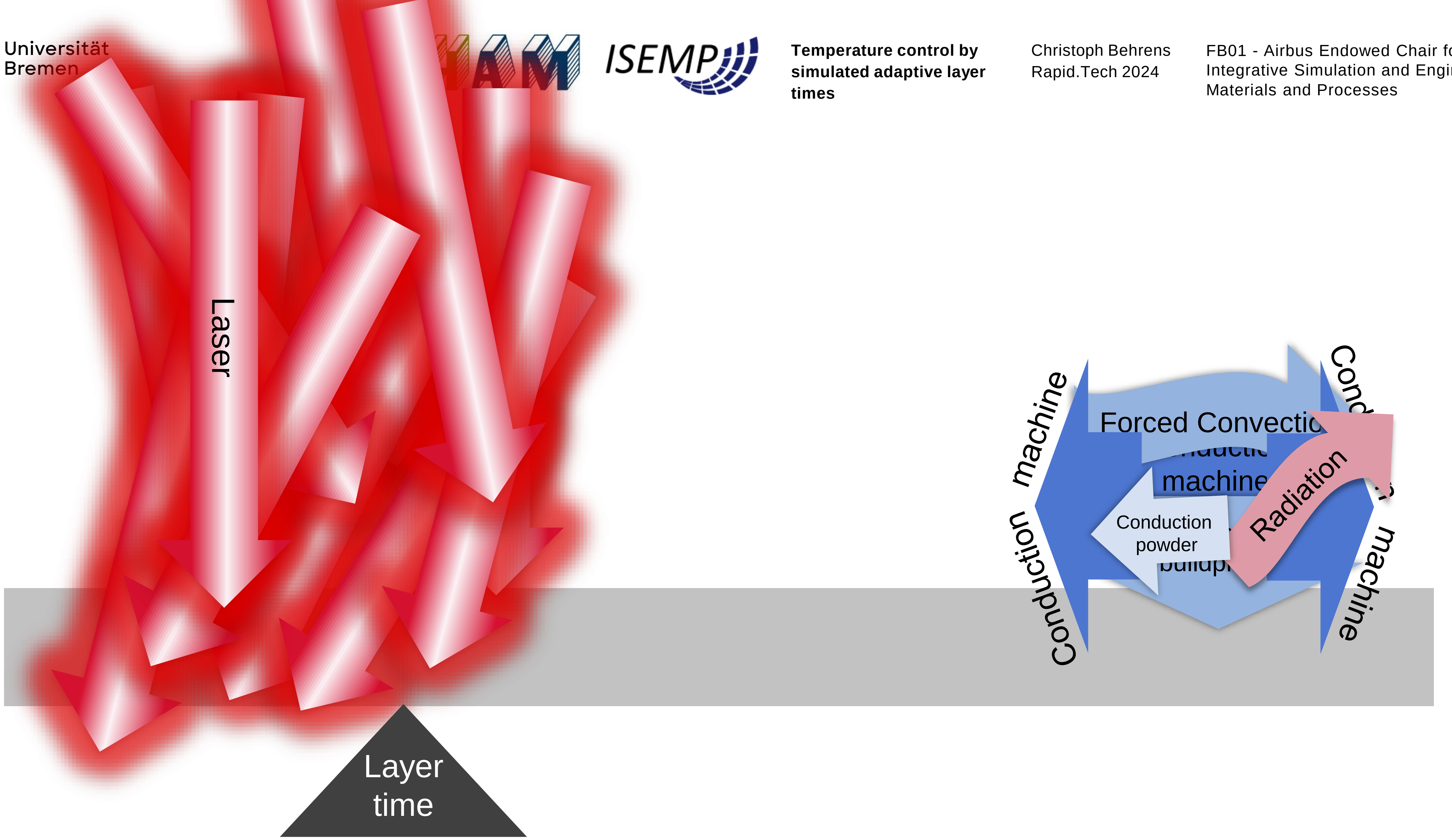
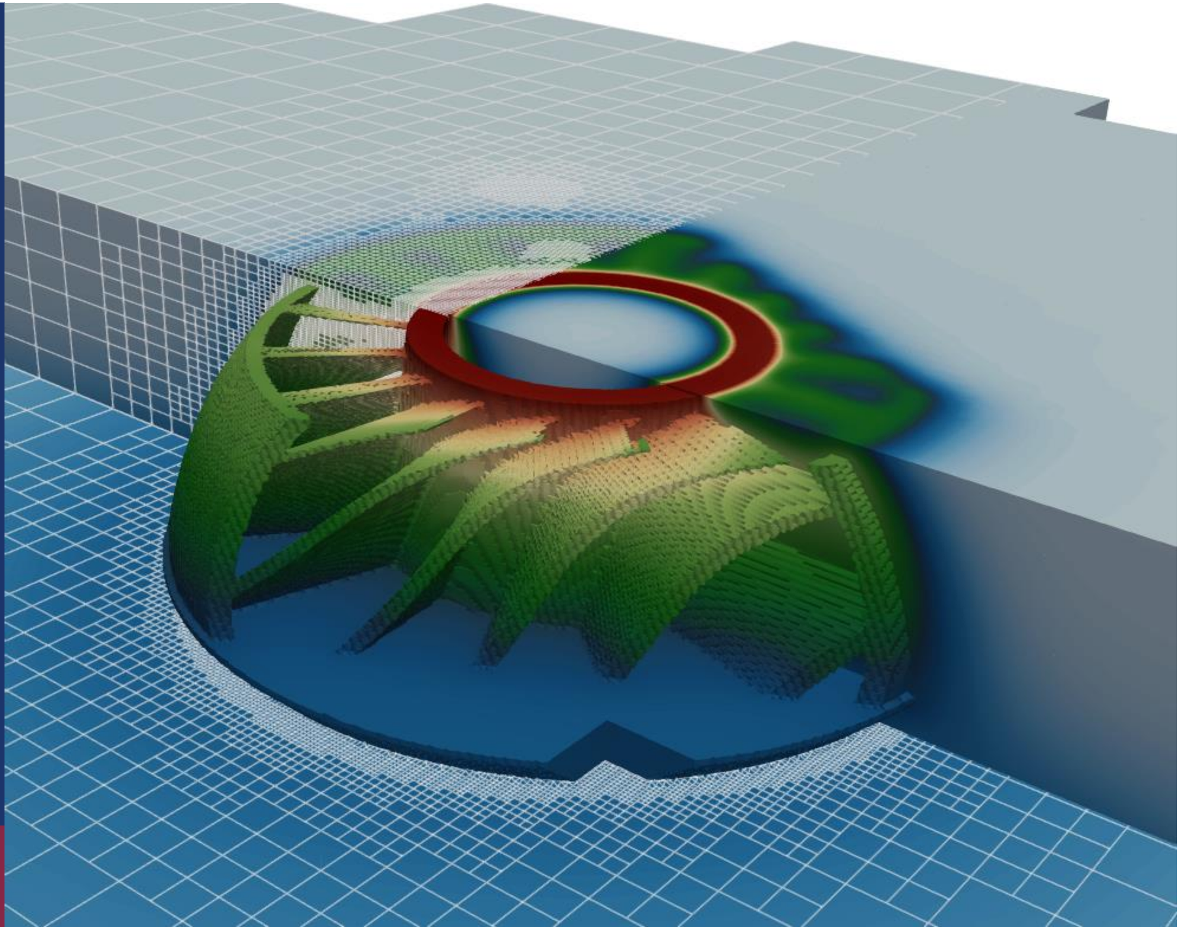

Laser
Forced Convection
machine
Conduction powder
Radiation
Conduction
machine
machine
Layer time

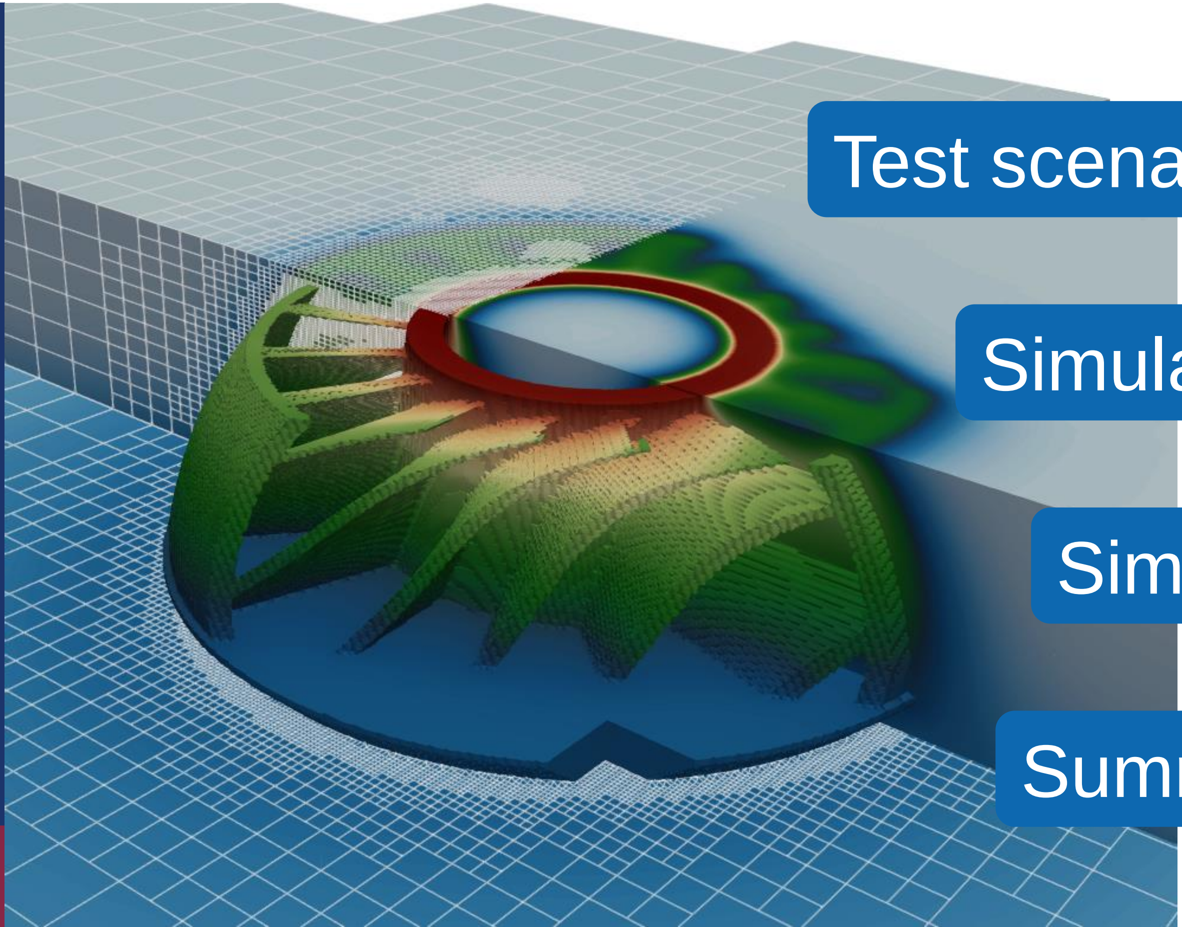

Laser
Layer time
Forced Convection
machine
Conduction powder
Radiation
machine
Conduction
machine

Calculate optimized layer times

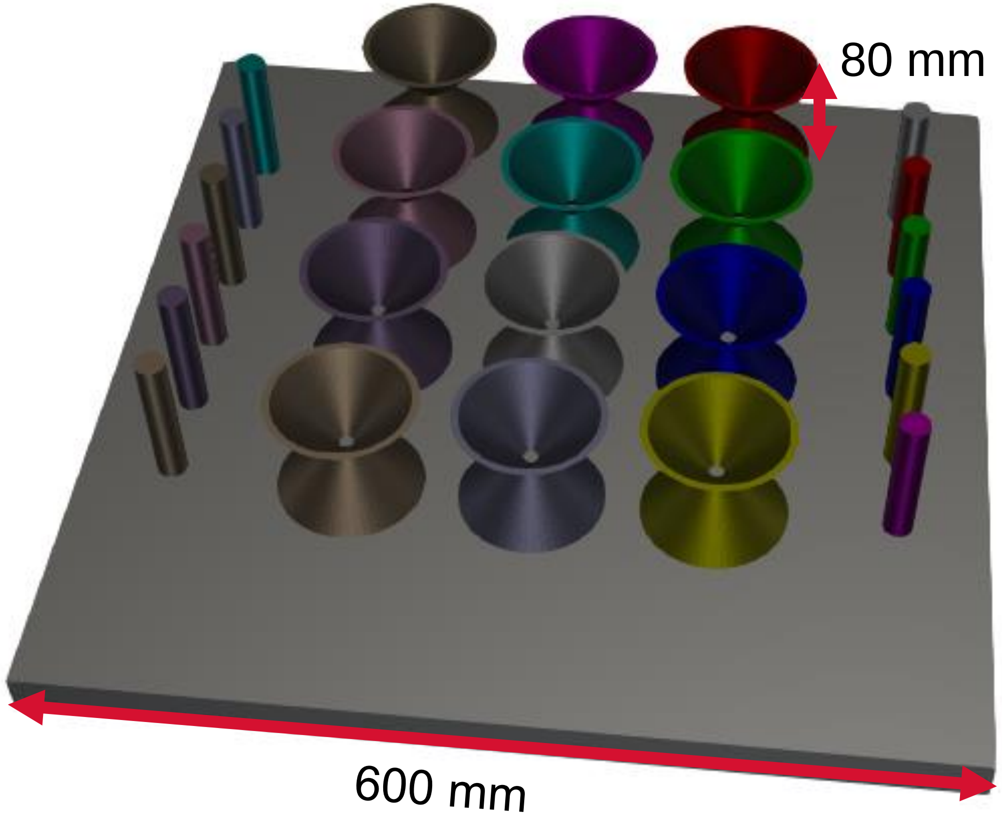


…and maximize the potential of multi-laser machines

Calculate optimized layer times



- Test scenario
- Simulation method
- Simulation-based waiting times
- Summary & Outlook



Test scenario

SLM NXG XII 600

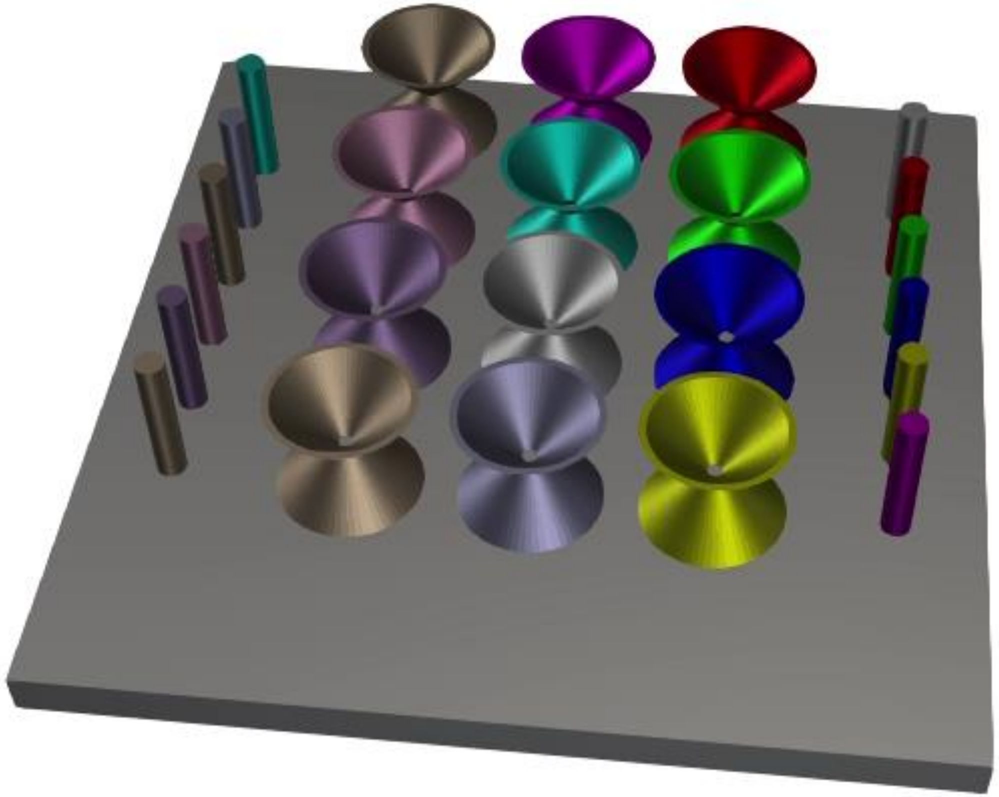
→ Parallel mode
→ Each laser: one double conus + offset specimen

Simulation

→ Practically one specimen pair is a single laser process
→ Inconel 718

Recoating time + offset specimen	15 s
Layer thickness	30 µm
Power	400 W
Speed	1200 mm/s
Hatch distance	90 µm

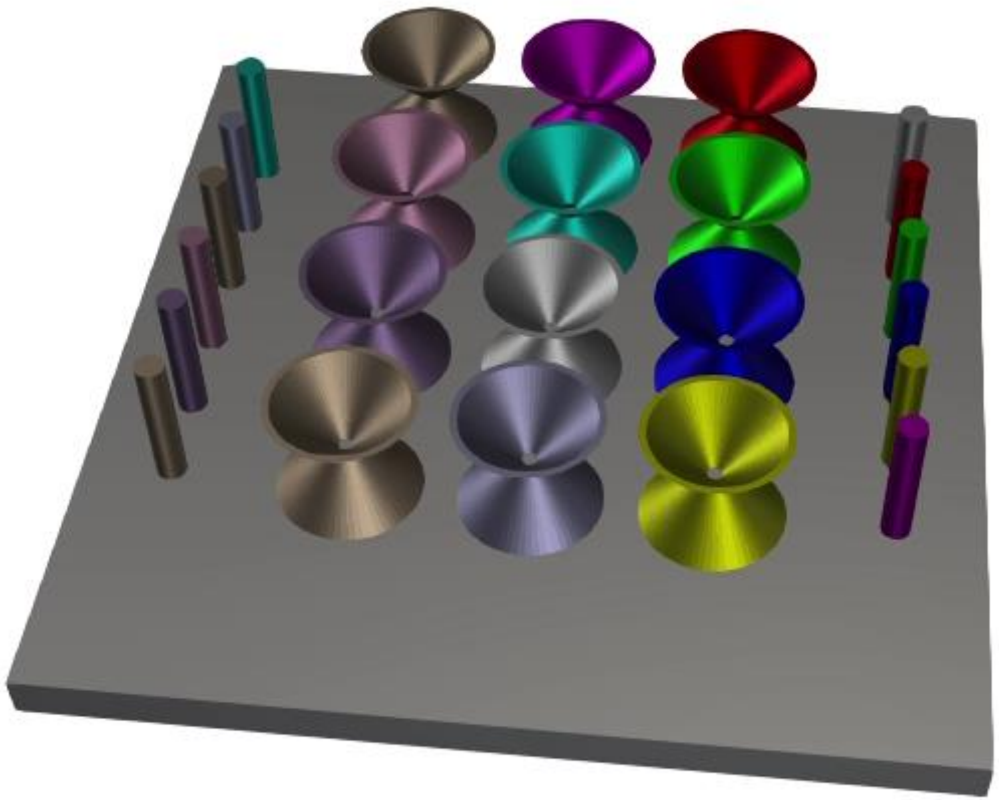
Y. Huo, C. Hong, H. Li, and P. Liu, *Materials Research*, vol. 23, 2020.



Simulation method

Thermal Macro Simulation

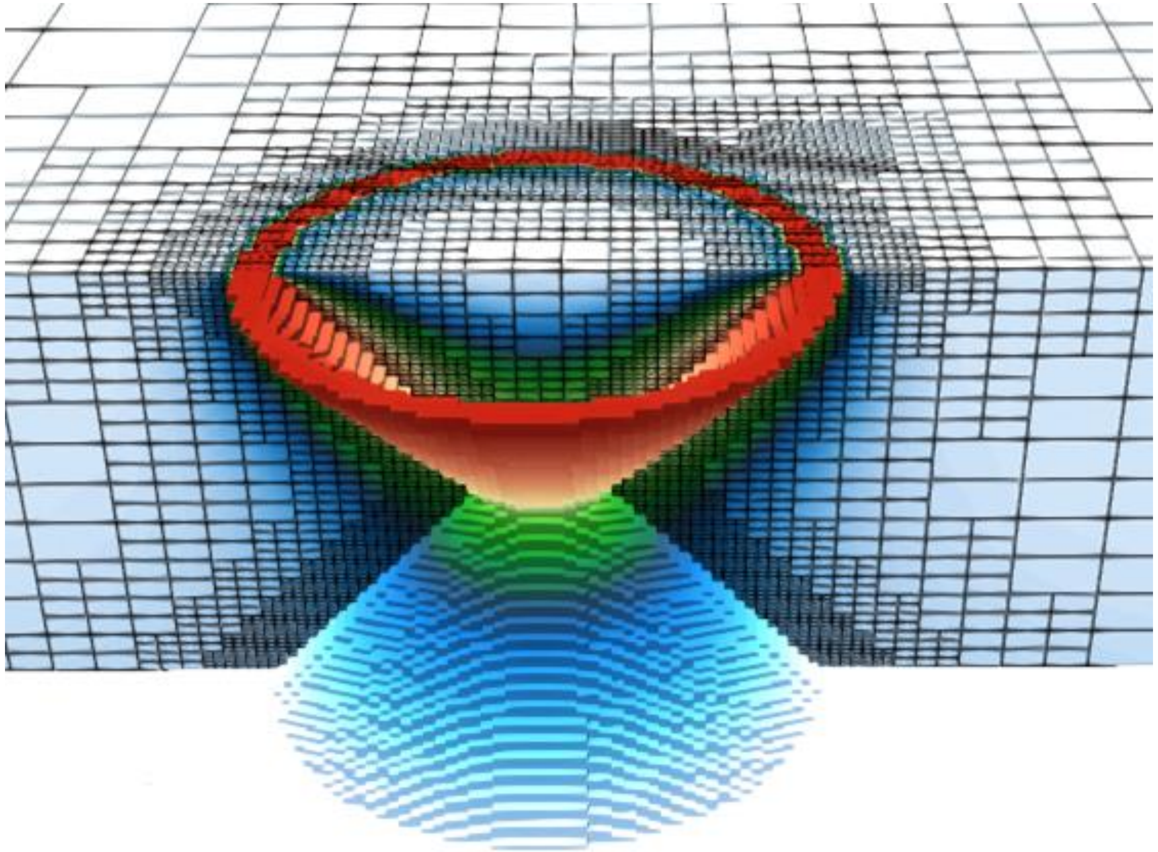
→ One double-conus
→ Offset specimen in recoater time



Simulation method

Thermal Macro Simulation

→ One double-conus
→ Offset specimen in recoater time
→ Locally adaptive finite element mesh
→ Powder & Baseplate represented by coarse elements
→ Part fine enough to represent geometry
→ Calculate temperature distribution based on energy activation



Simulation method

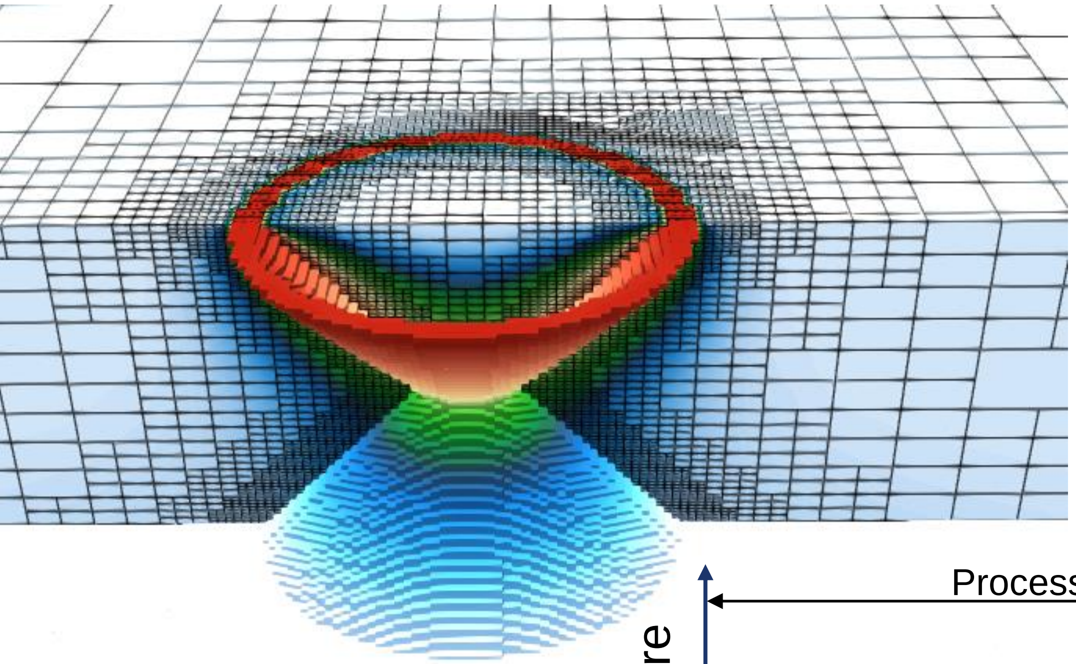
Thermal Macro Simulation

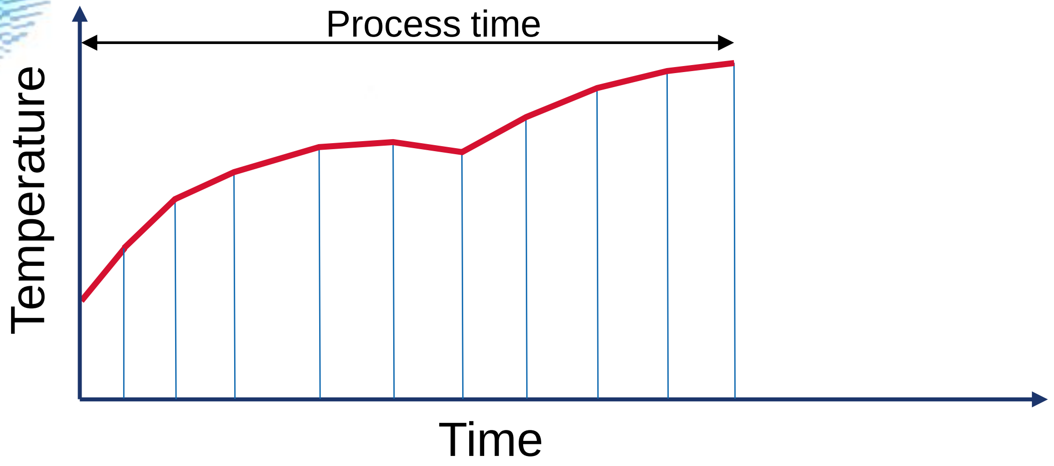
→ One double-conus
→ Offset specimen in recoater time
→ Locally adaptive finite element mesh
→ Powder & Baseplate represented by coarse elements
→ Part fine enough to represent geometry
→ Calculate temperature distribution based on energy activation
→ Layer-wise or batch-wise activation

Simulation method

Interpass layer time algorithm

→ Activate batches of 60 layers at once
→ Energy from CLI
→ Time from CLI + offset via input





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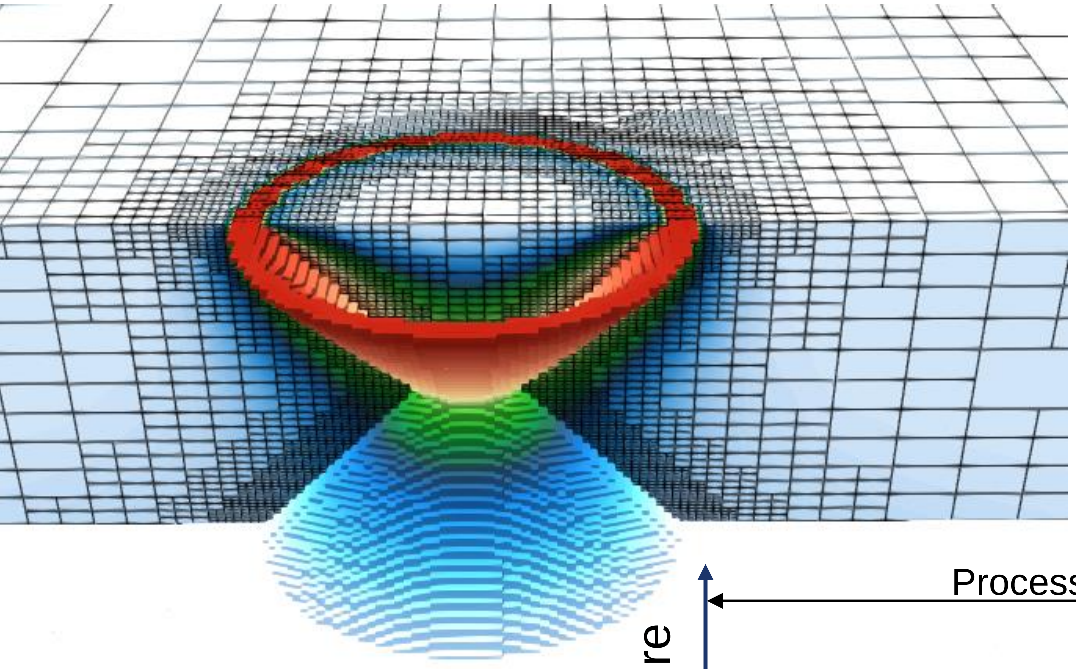

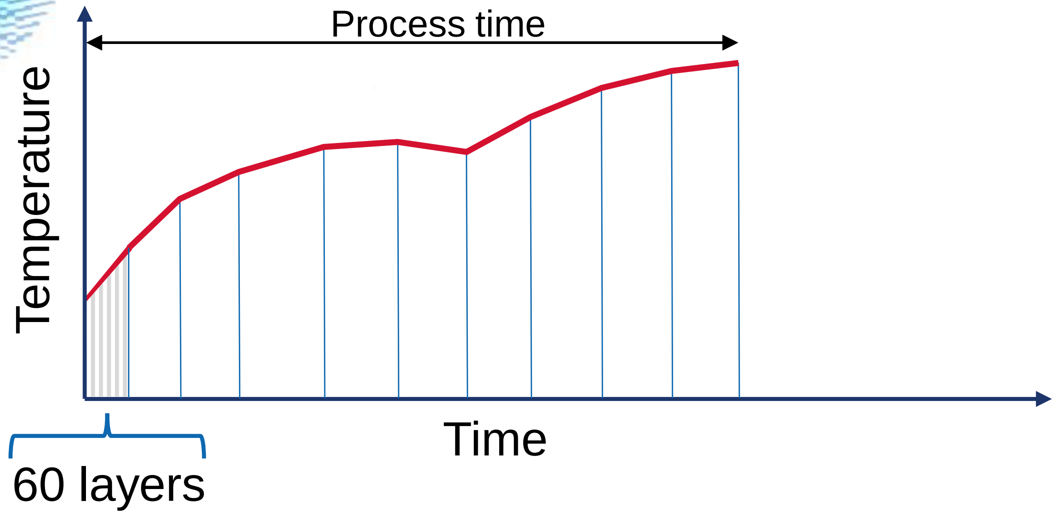

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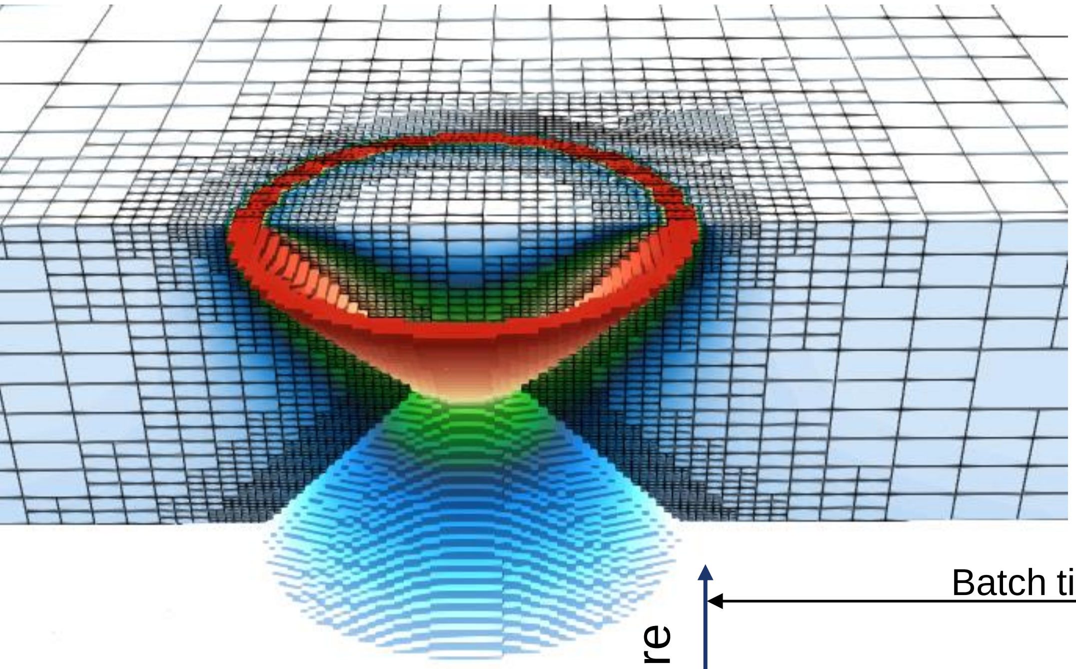

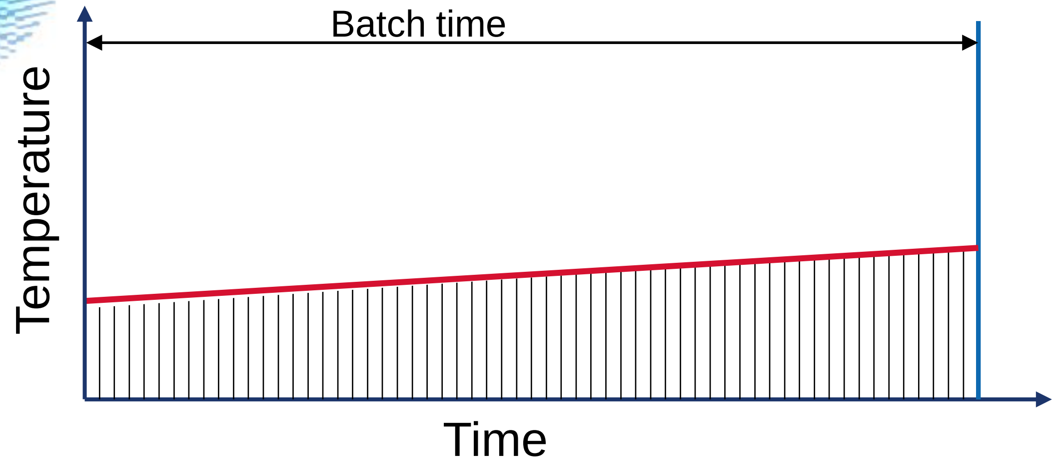

Simulation method

Interpass layer time algorithm

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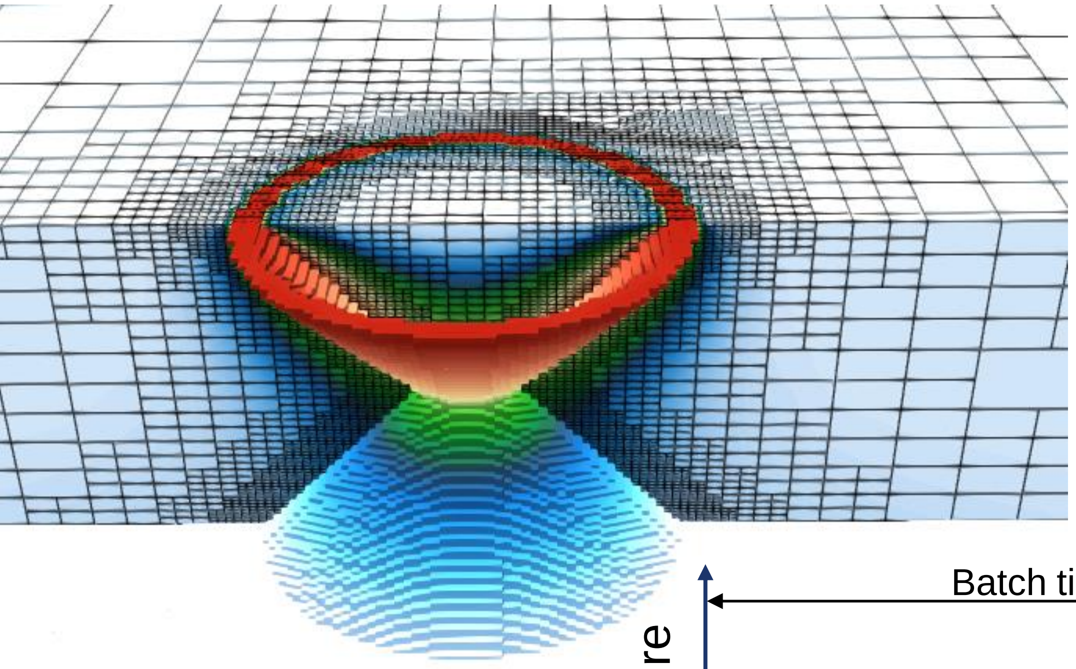

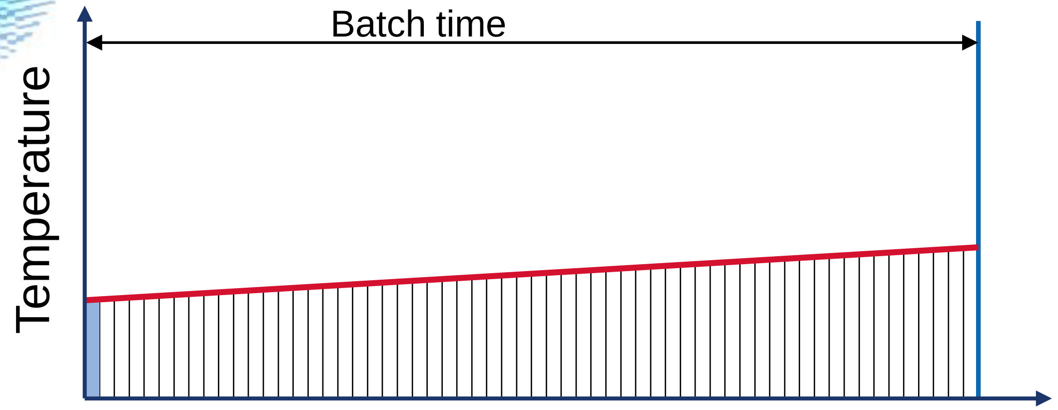

→ Interpass layer time algorithm applied in single layer

Simulation method

Interpass layer time algorithm

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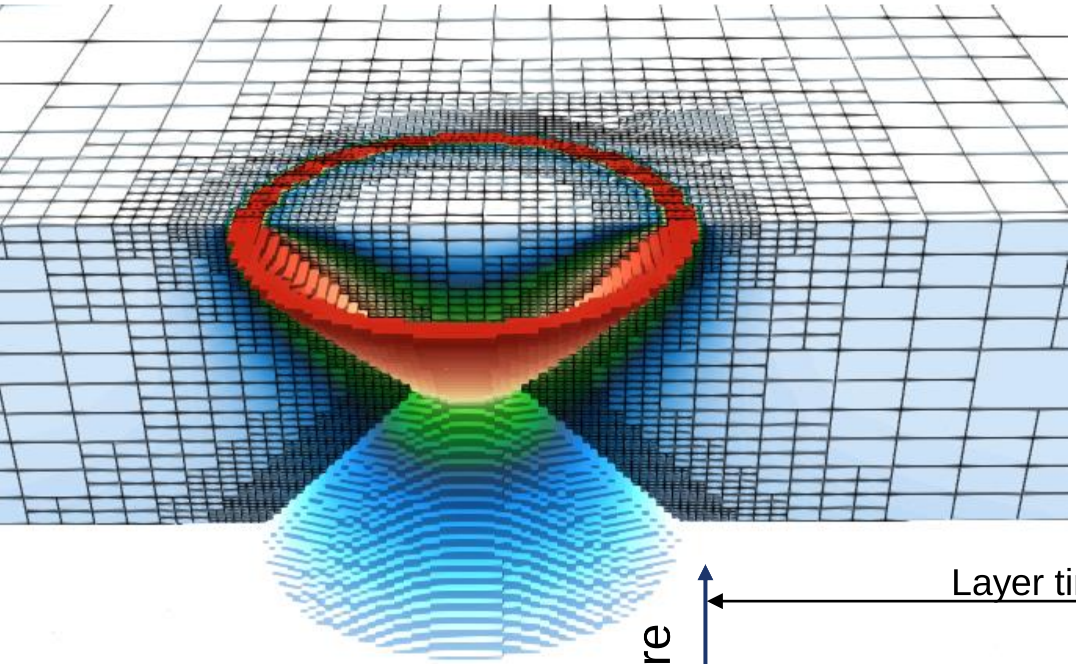

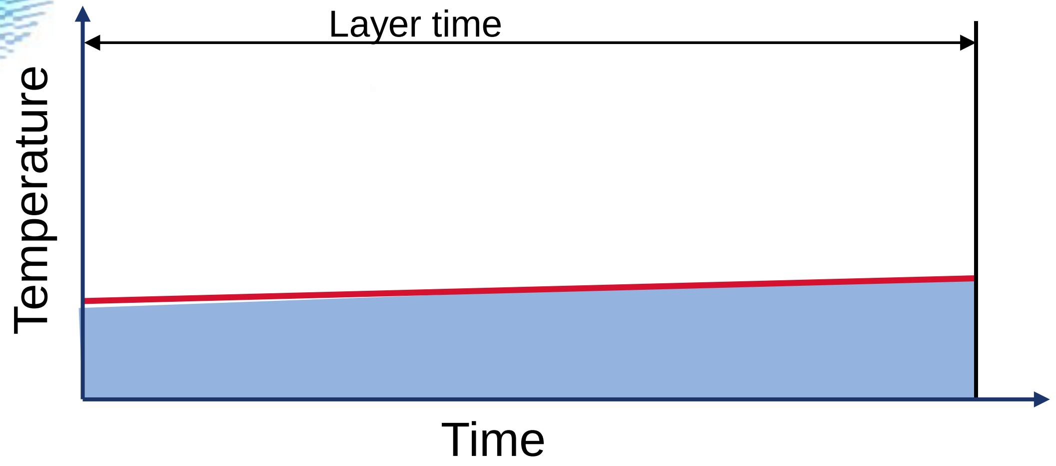

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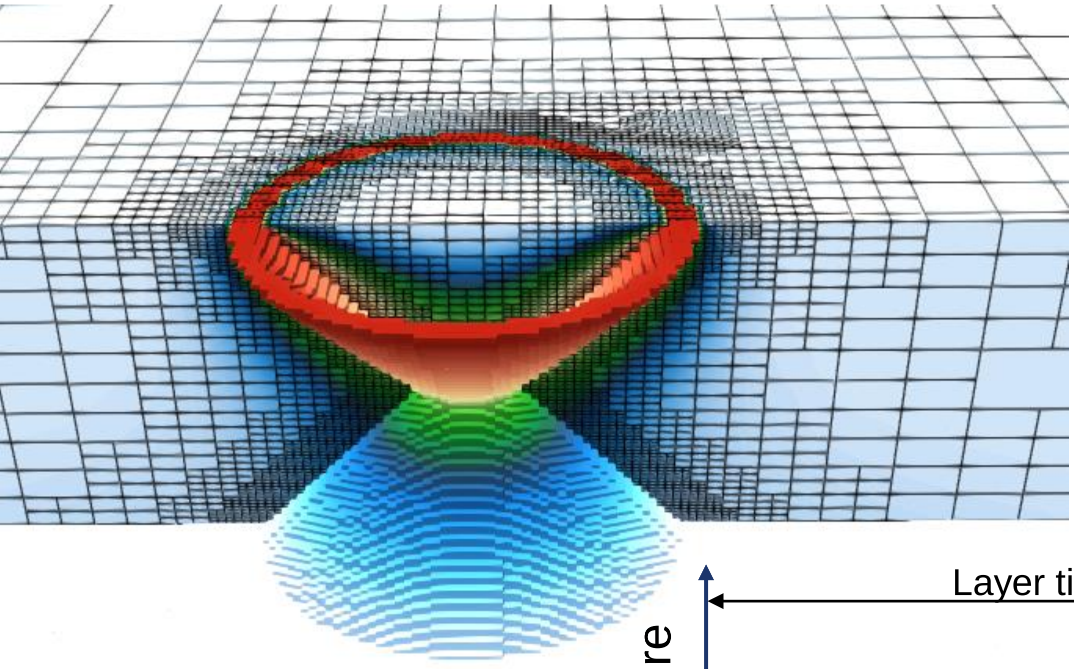

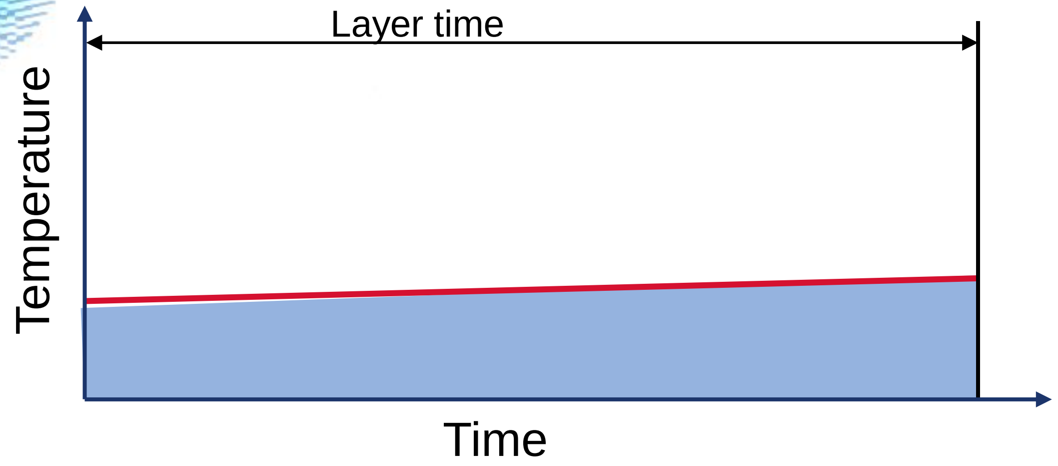

→ Interpass layer time algorithm applied in single layer

Simulation method

Interpass layer time algorithm

→ Thermal macro simulation: activate batches of 60 layers at once
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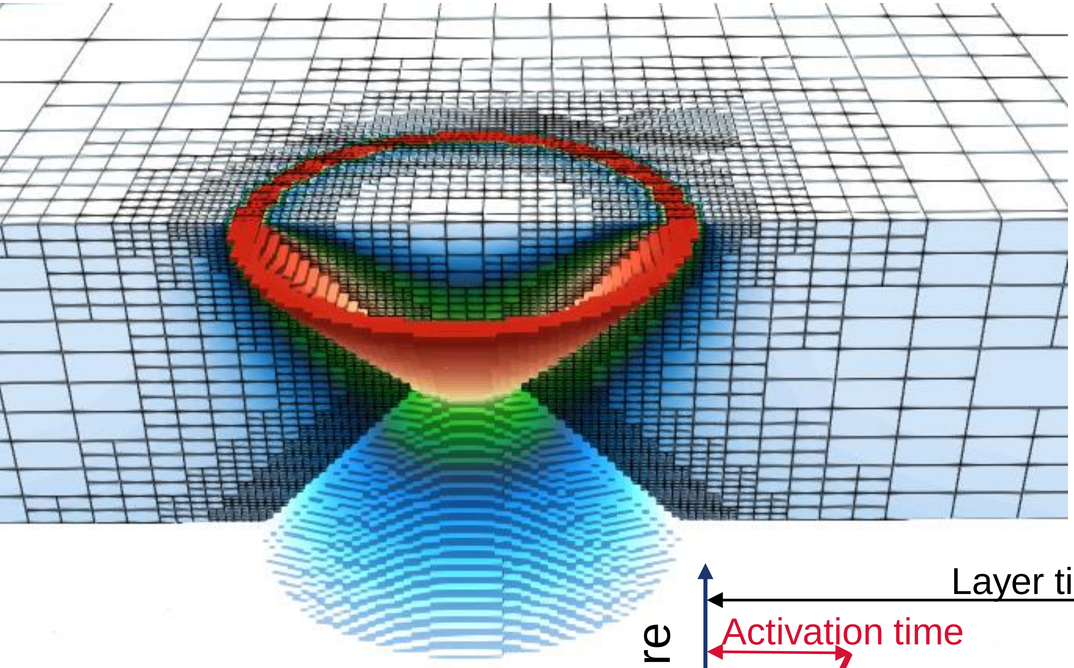
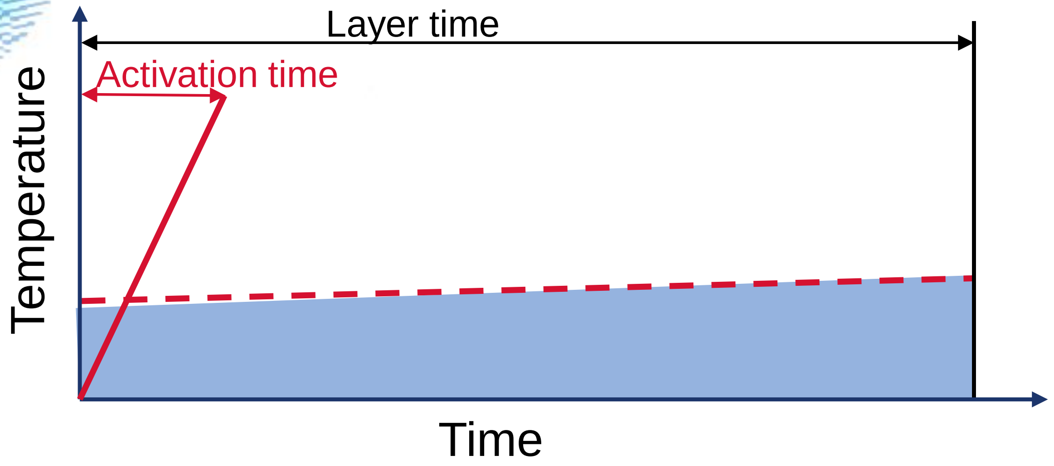


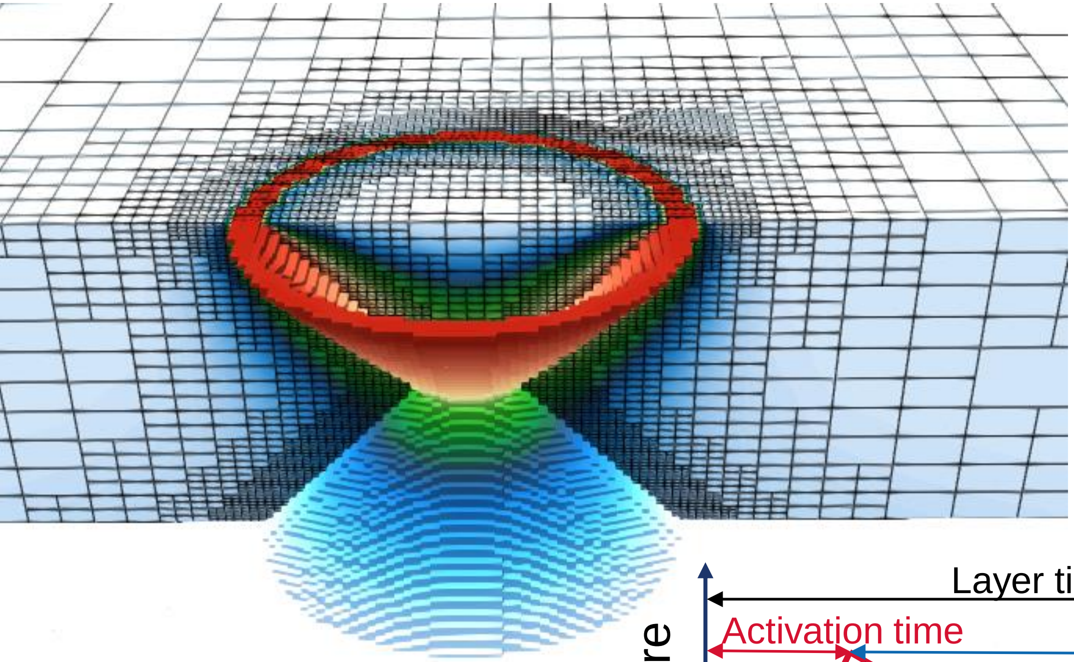


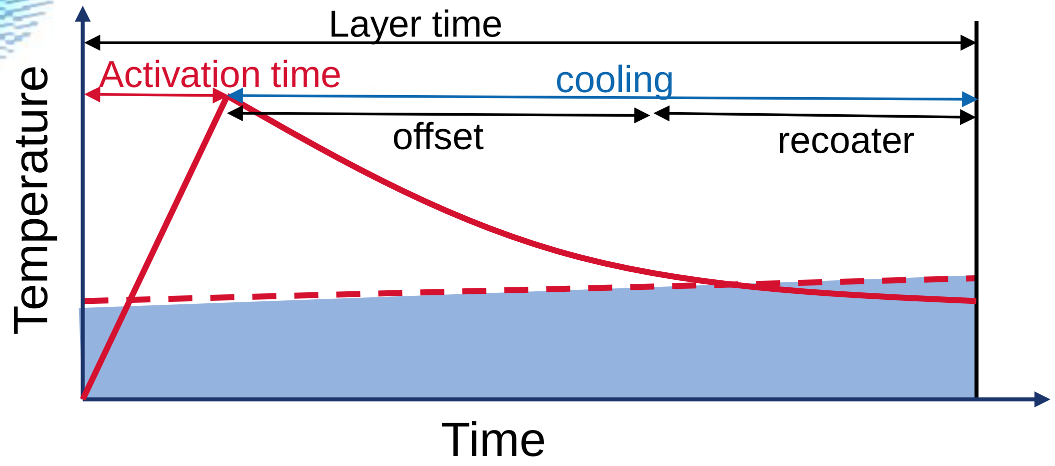
→ Interpass layer time algorithm applied in single layer
→ Activate Hatching

Simulation method

Interpass layer time algorithm

→ Thermal macro simulation: activate batches of 60 layers at once
→ Energy from CLI
→ Time from CLI + offset via input

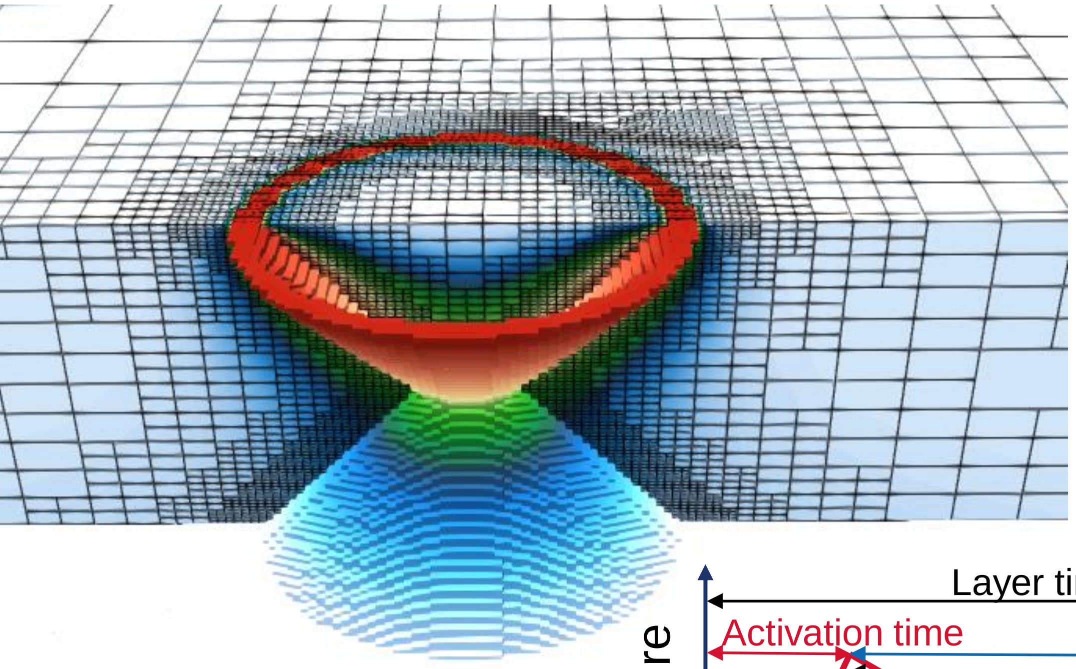




→ Interpass layer time algorithm applied in single layer
→ Activate Hatching, calculate cooling

Simulation method

Interpass layer time algorithm



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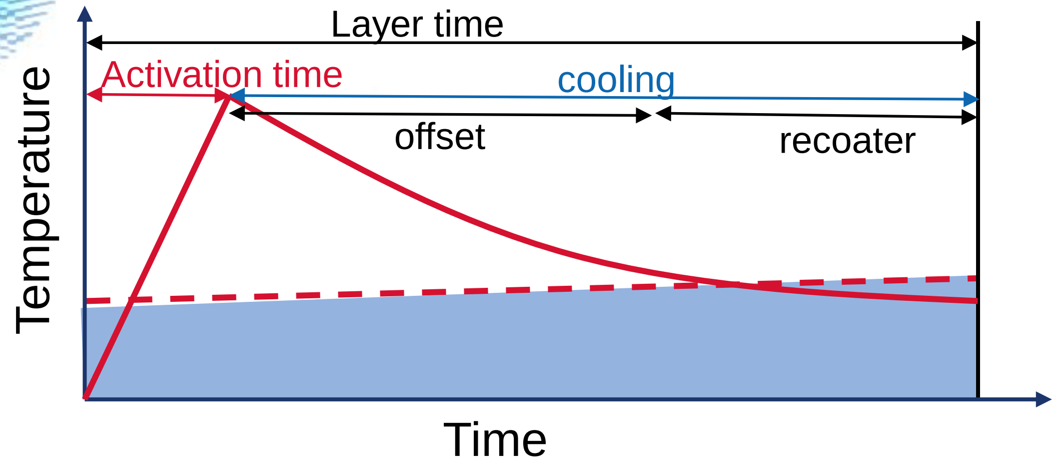

→ Interpass layer time algorithm applied in single layer
→ Activate Hatching, calculate cooling

Simulation method

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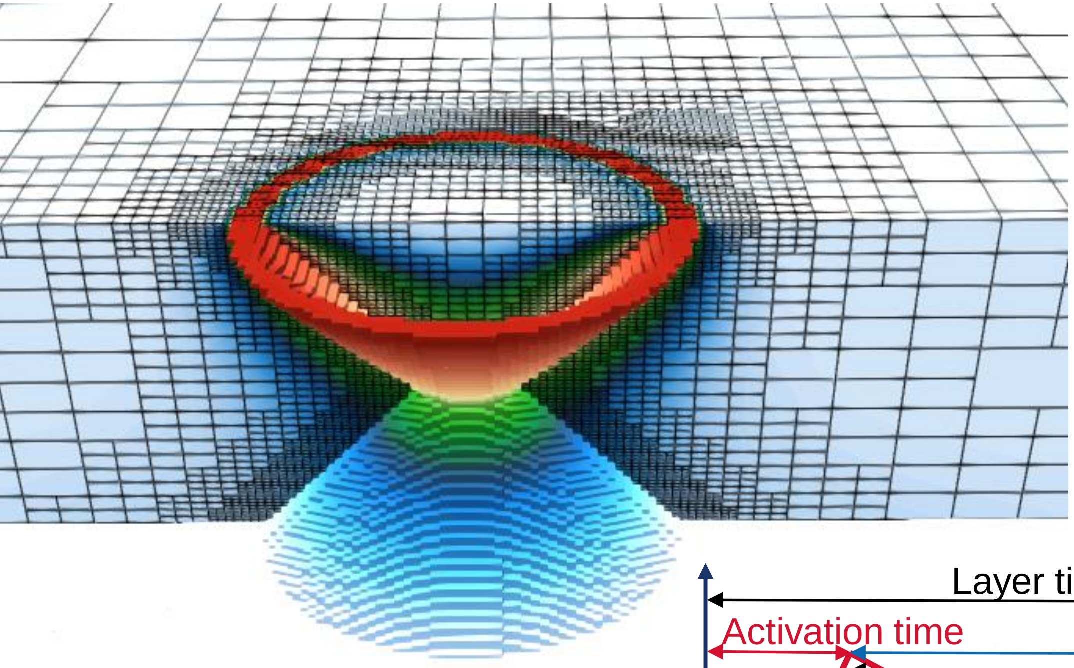
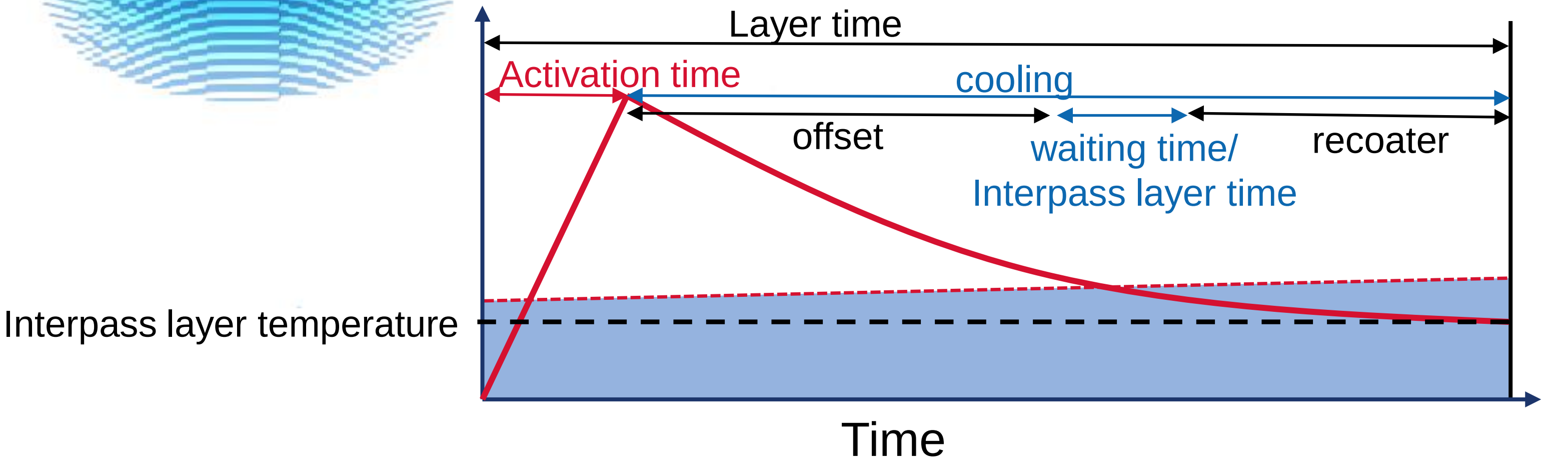


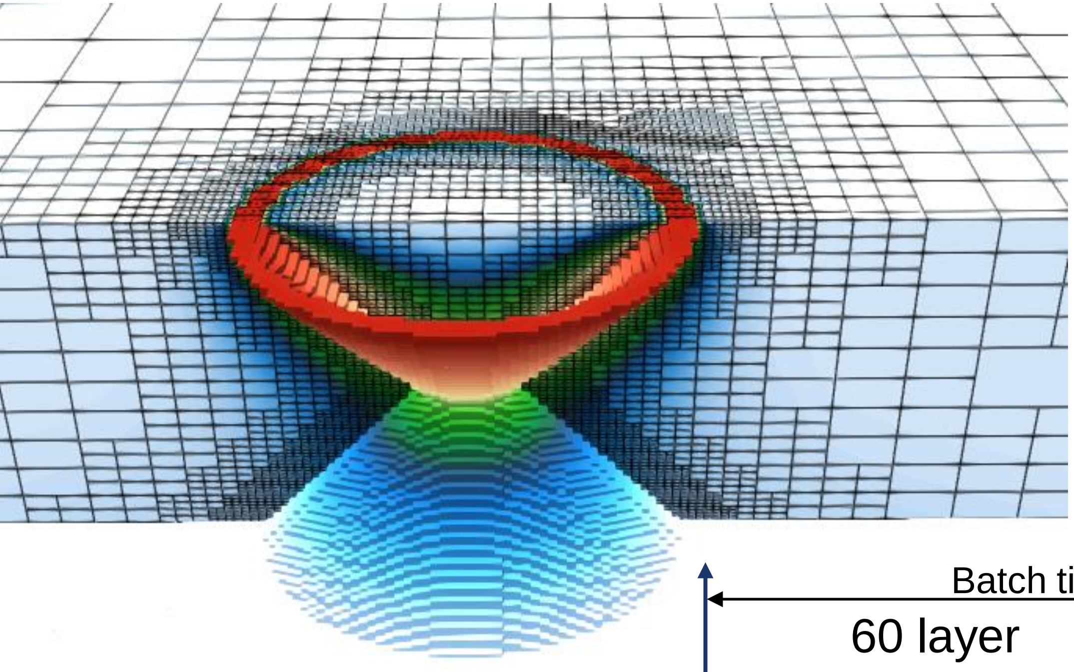


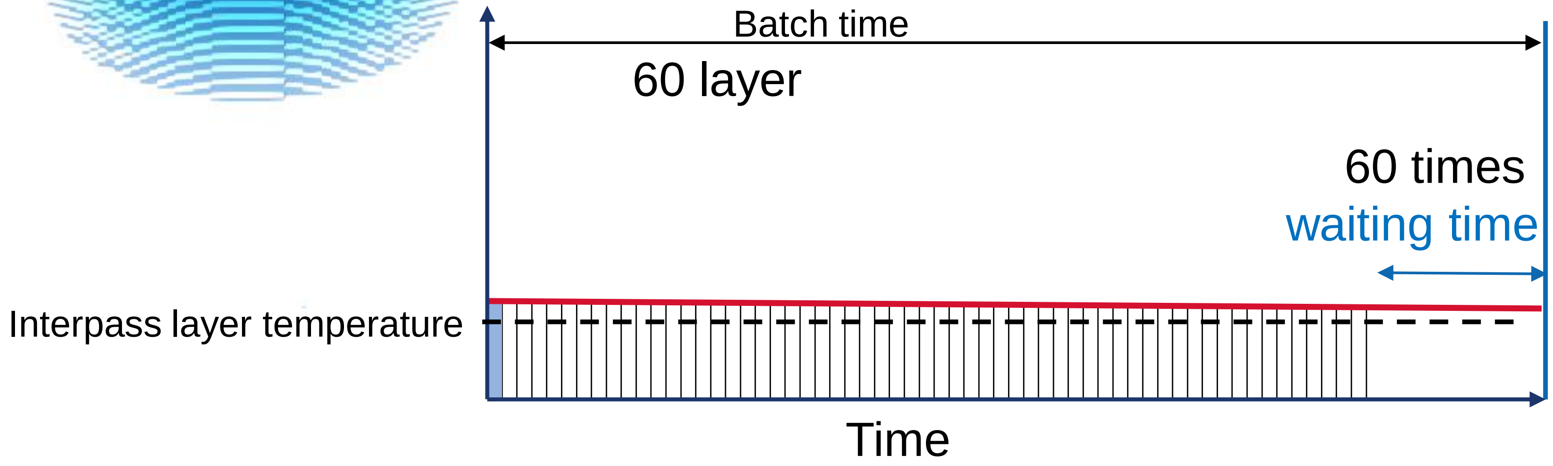
→ Interpass layer time algorithm applied in single layer
→ Activate Hatching, calculate cooling
→ Waiting time until interpass layer temperature is reached

Simulation method

Interpass layer time algorithm

→ Interpass layer time algorithm applied in single layer
→ Activate Hatching, calculate cooling
→ Waiting time until interpass layer temperature is reached



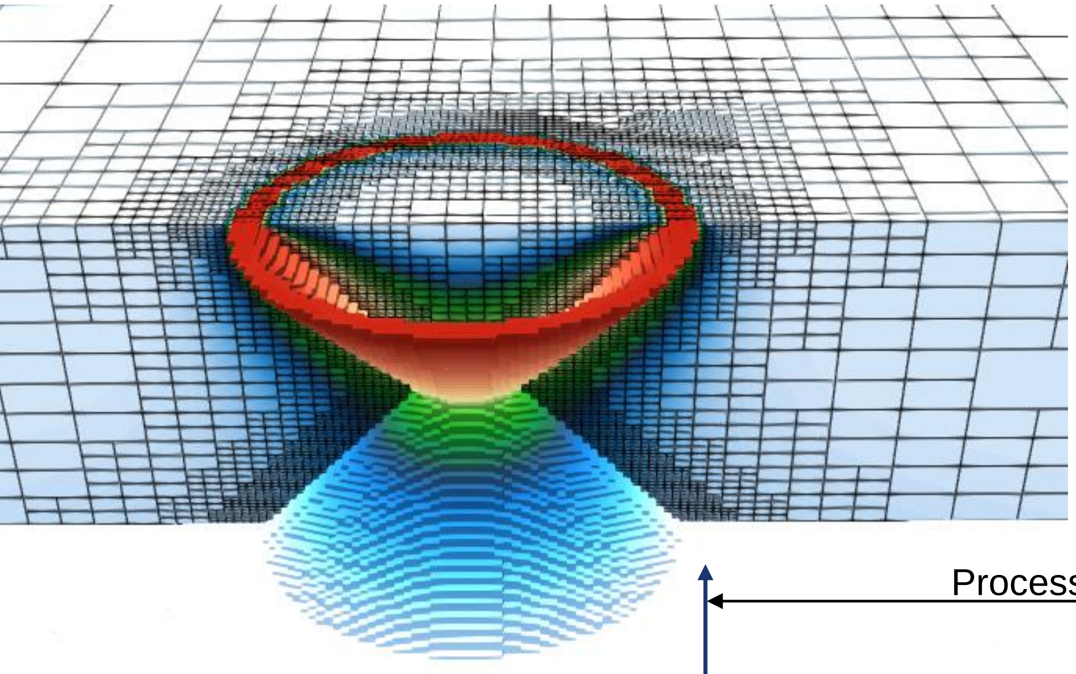


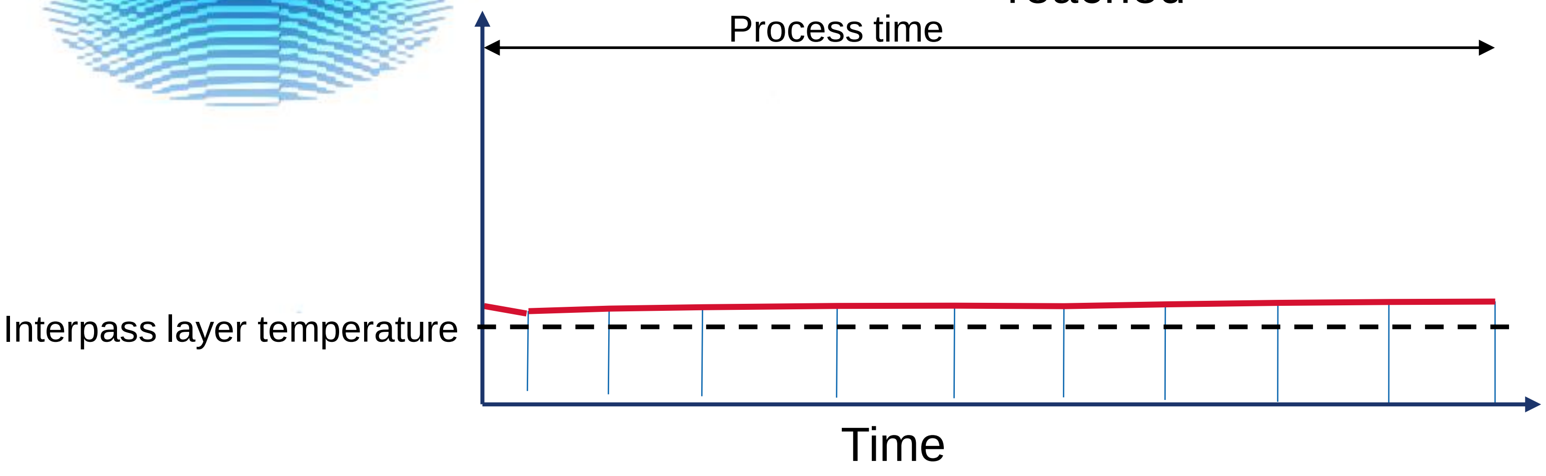
→ Apply waiting time to batch activation

Simulation method

Interpass layer time algorithm

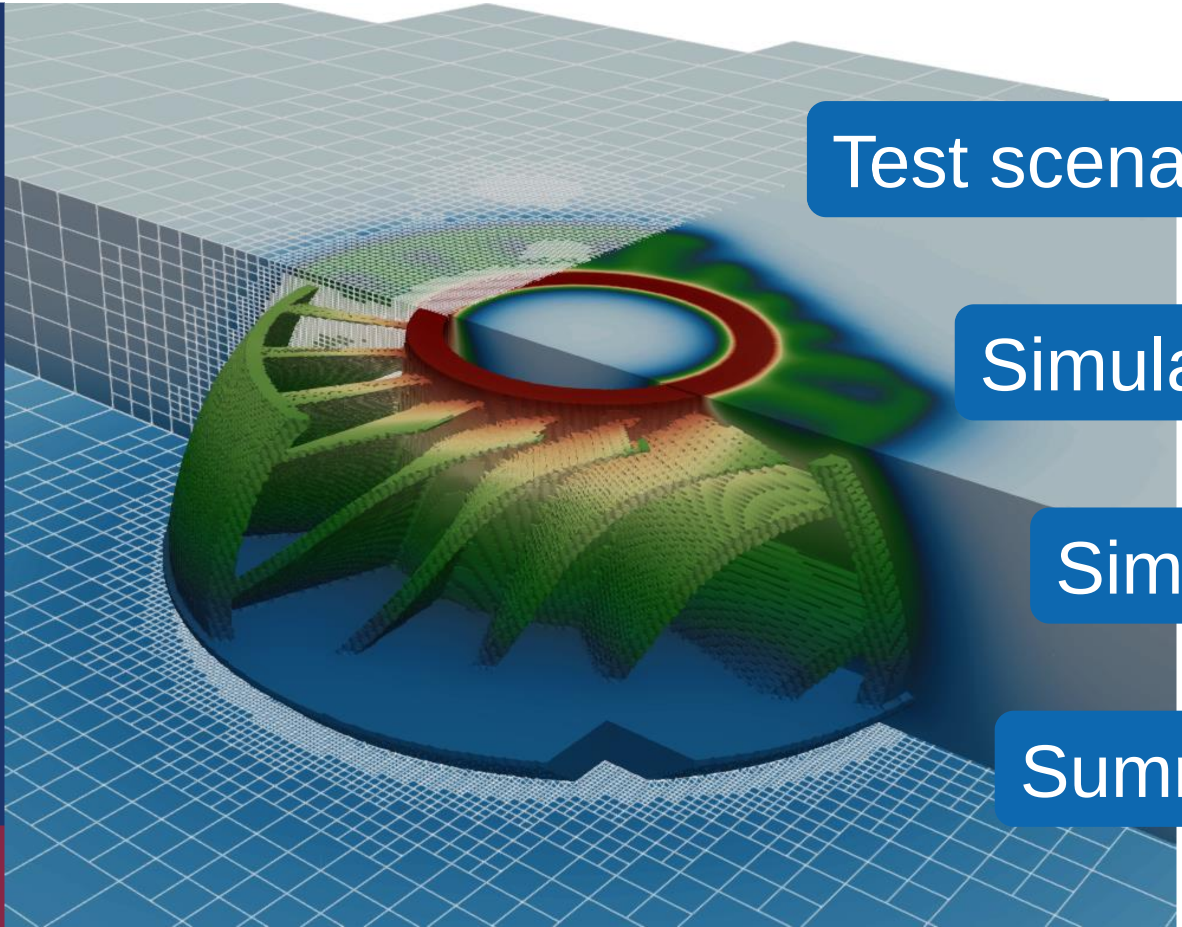
→ Interpass layer time algorithm applied in single layer
→ Activate Hatching, calculate cooling
→ Waiting time until interpass layer temperature is reached



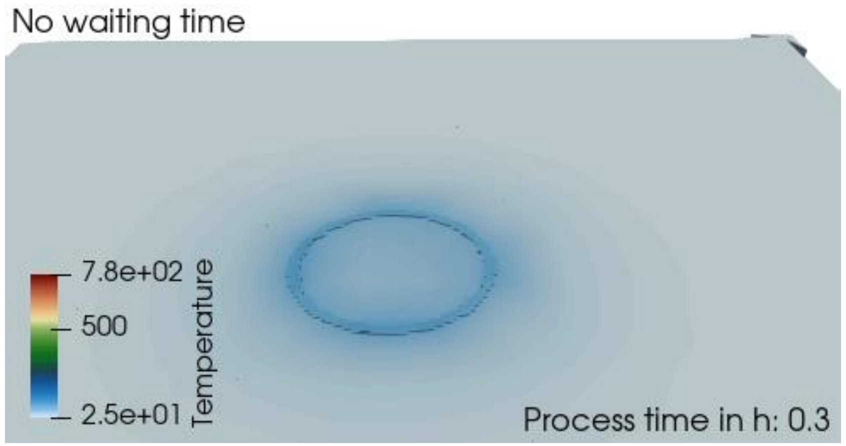


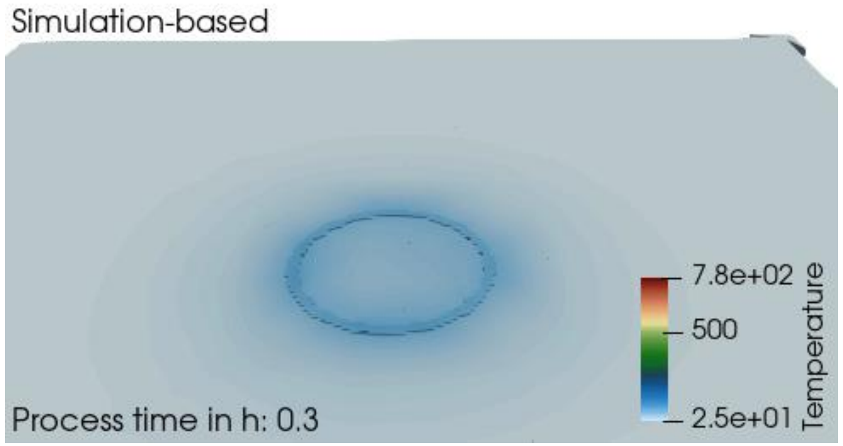
→ Apply waiting time to batch activation
→ Recalculate waiting time for each batch

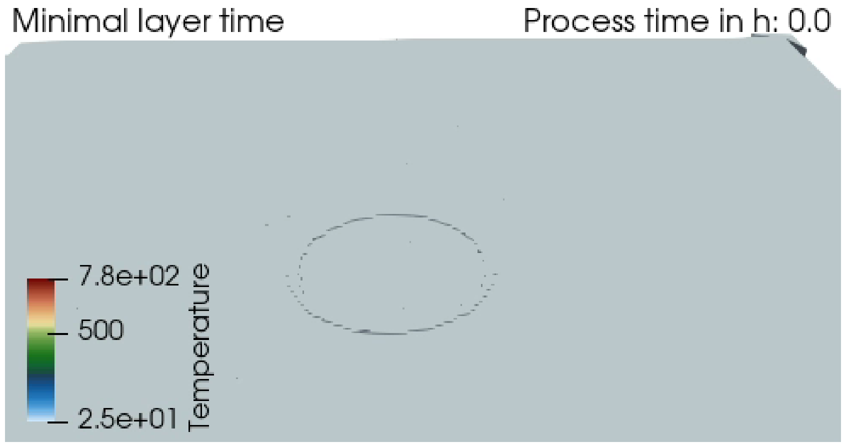
Calculate optimized layer times

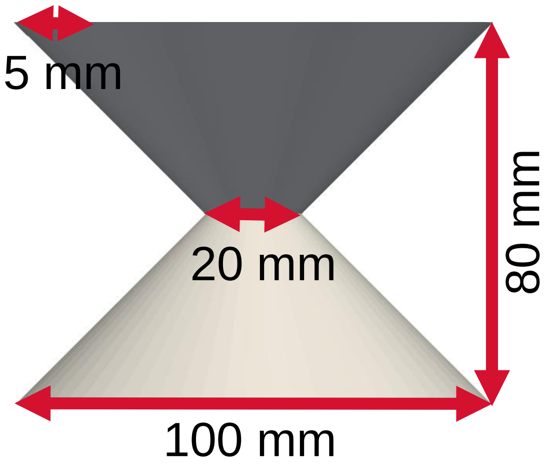


Simulation-based waiting times

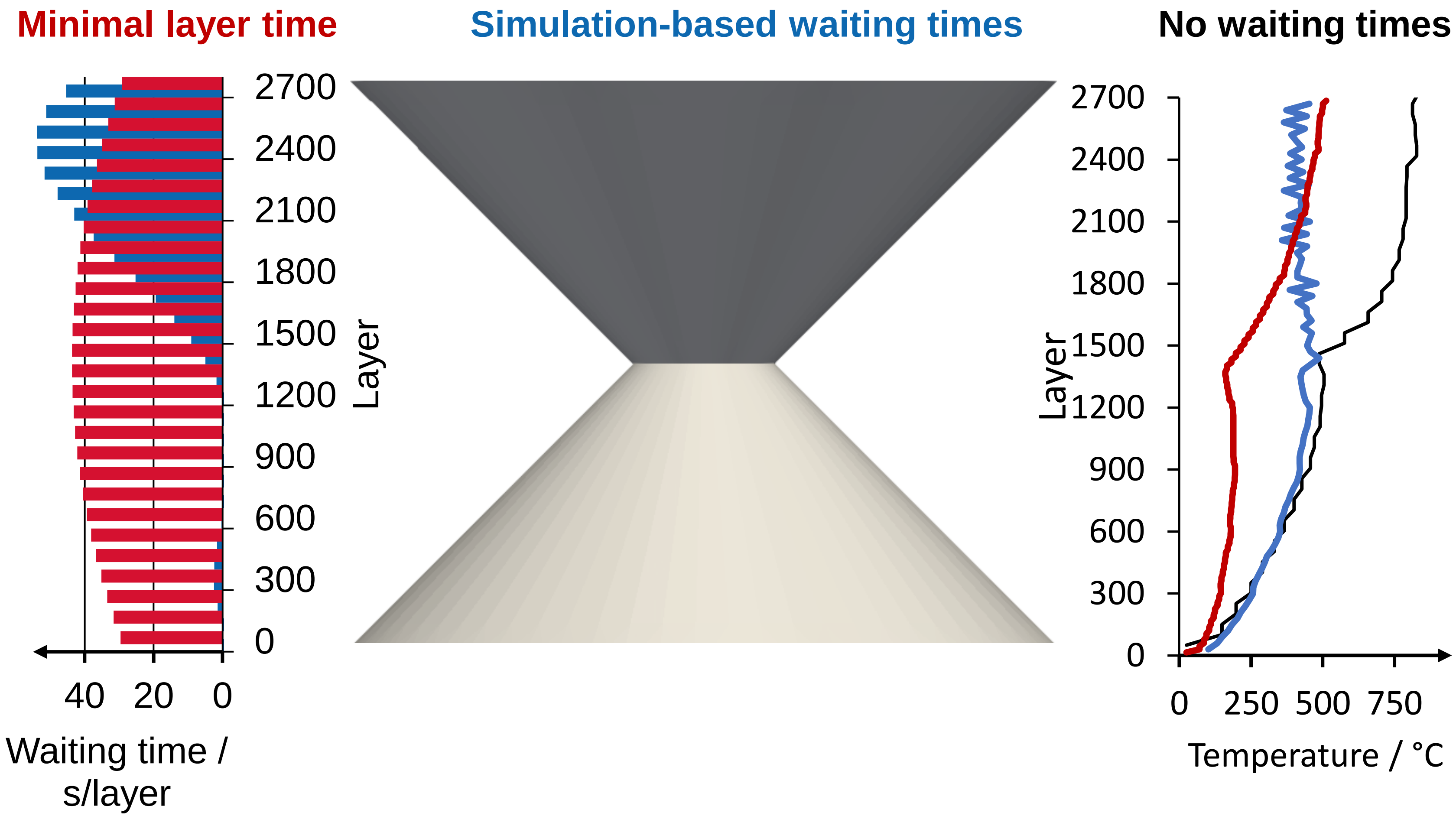






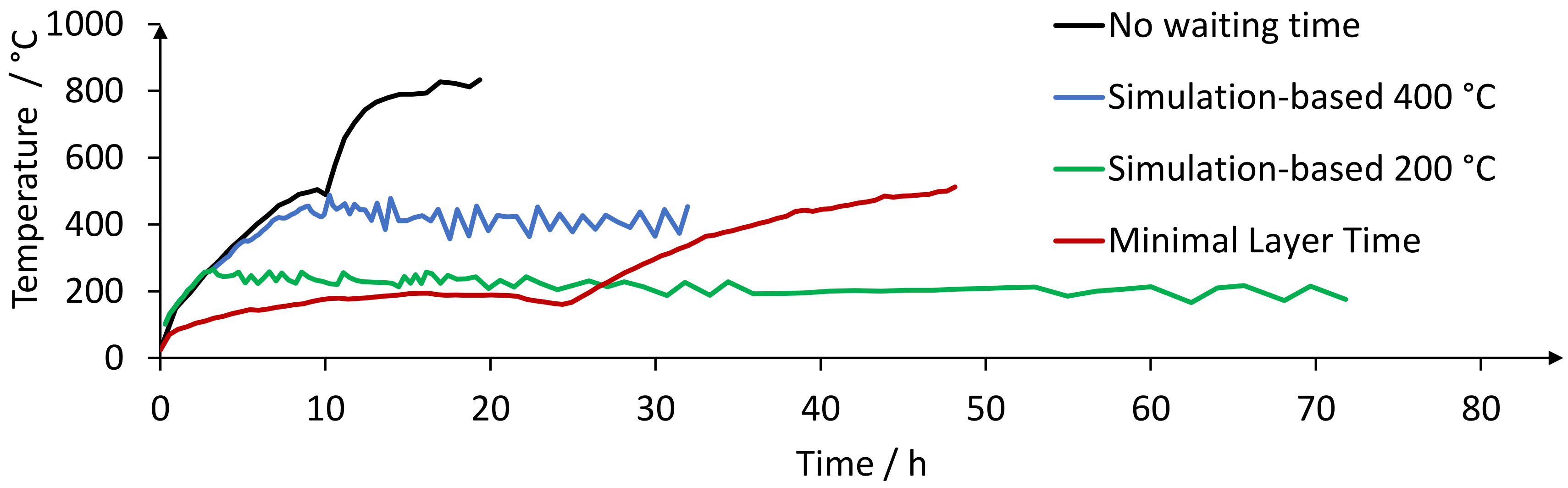


Simulation-based waiting times



BUT…

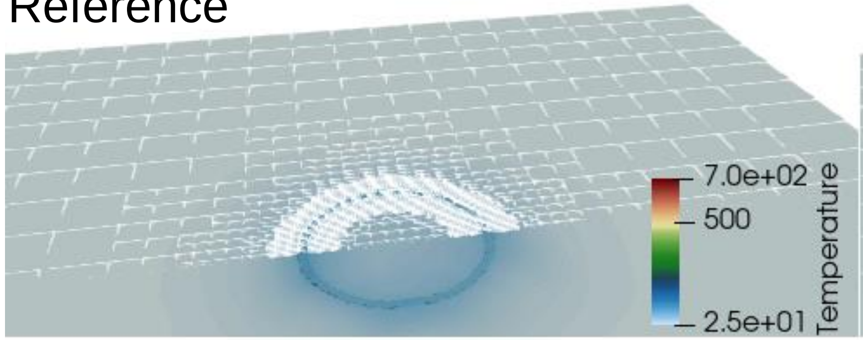
Waiting is not efficient



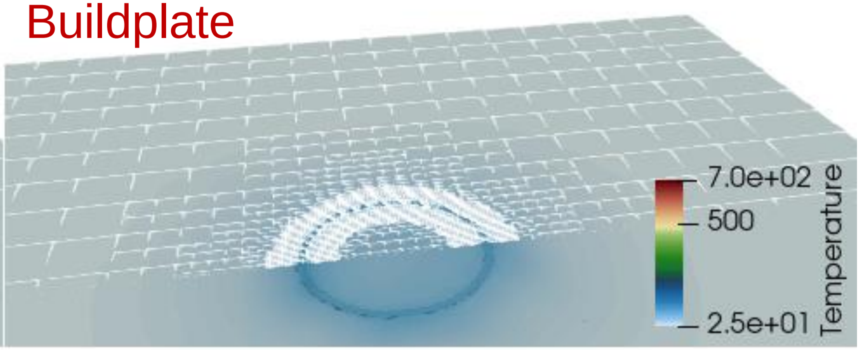
200 °C interpass layer temperature
→
375 % more process time for a “simple” geometry

Increased cooling coefficients

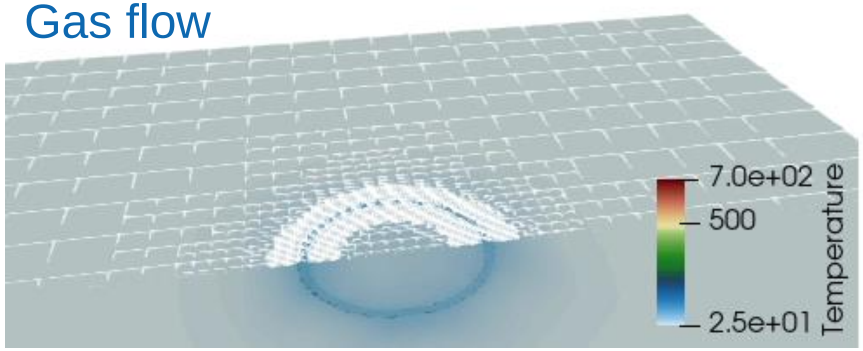
Reference

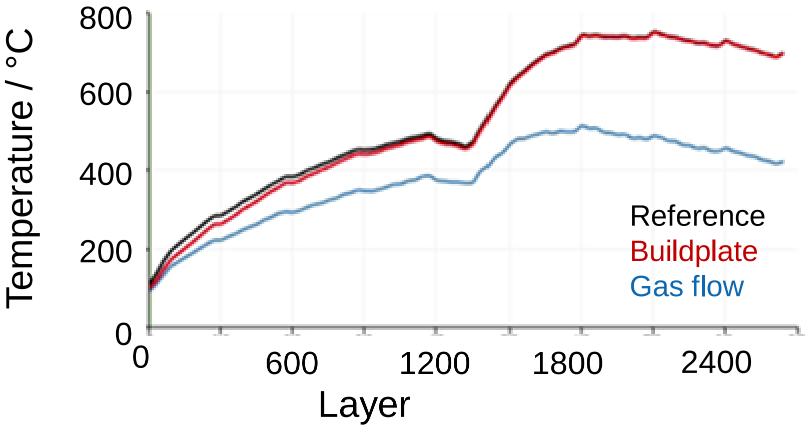


Buildplate

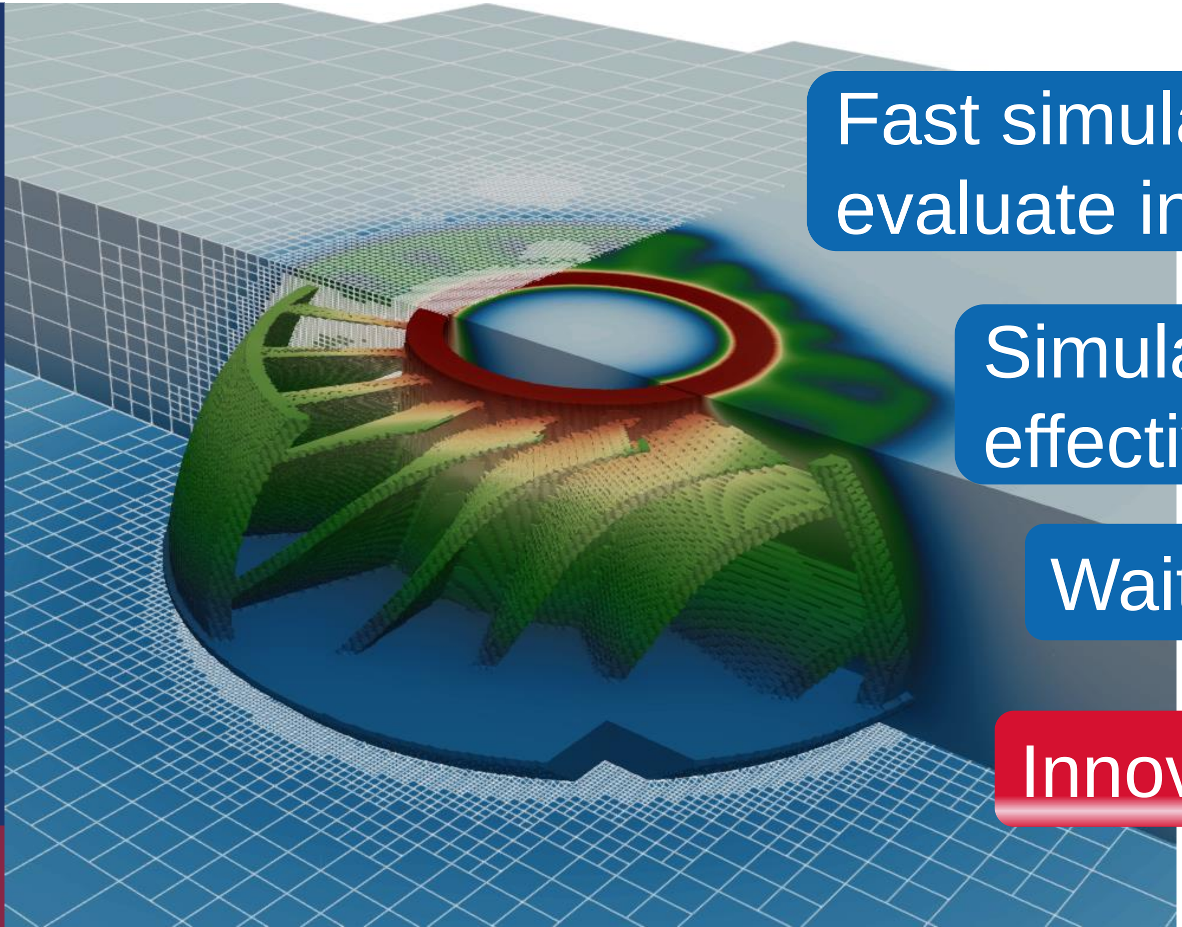


Gas flow





Calculate optimized layer times



Fast simulation to calculate and evaluate interlayer waiting times

Simulation-based waiting times more effective than minimal layer times

Waiting is not efficient

Innovations in cooling are necessary

Let’s empower metal 3D-printing technology together and get in contact

Christoph Behrens · Niklas Ostermann · Jan T. Sehrt · Vasily Ploshikhin

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Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag