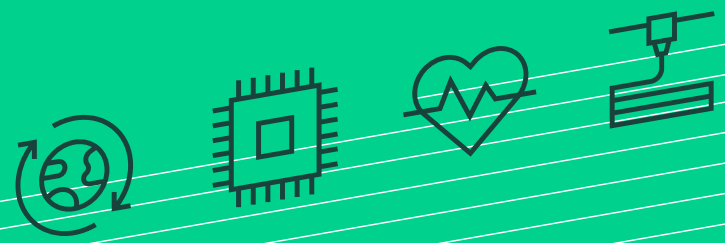
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CARDAM & Hi-Lase cooperation

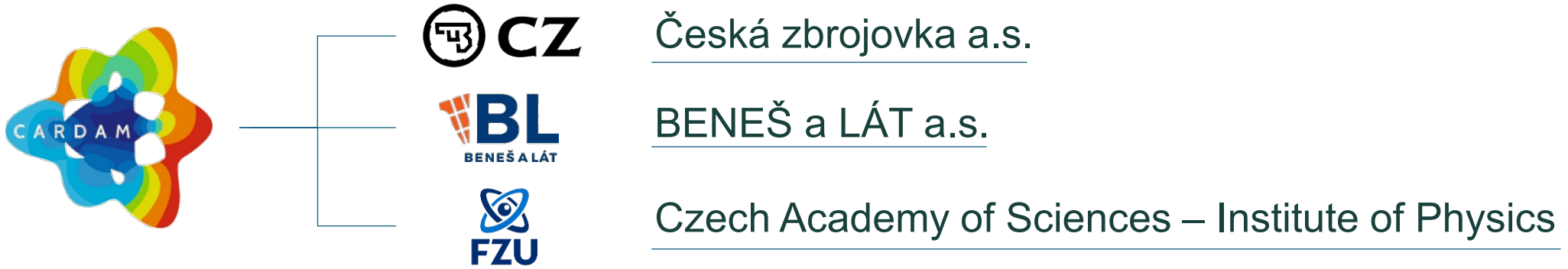
LASER-PRO MEETING | 30. 09.– 01.10.2026

Ondřej Kurkin

Excellent Laser Technologies
for the Sustainable Prosperity of Europe

Co-funded by
the European Union

Who we are



- CARDAM is a research and development workplace focused on product development, additive manufacturing and advanced mathematical calculations and simulations.
- We provide the complete process from product design through virtual verification to manufacturing with respect to costs and production technology.
- We use applied research and state-of-the-art technology to develop new, innovative products and raise the technological level of our customers.

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Who we are – BRAIN4INDUSTRY

We are a consortium of research institutes, leading scientific institutions, and technology companies that helps small and medium-sized enterprises incorporate innovative digital solutions and additive manufacturing systems into their processes, offering unmatched quality at low cost. At the same time, we enable scientific institutions to collaborate on new projects by leveraging their applied research and development. We place great emphasis on the sustainability of manufacturing processes, and our services cover the entire process chain.

FZU – Fyzikální ústav Akademie věd České republiky – Institute of Physics of the Czech Academy of Sciences

hilase

CARDAM – Center of Applied Research and Development for Additive Manufacturing

SIC – Central Bohemian Innovation Center

Institute of Thermomechanics – Czech Academy of Sciences

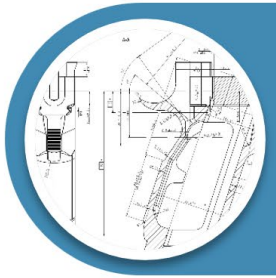
STAR – Research & Innovation cluster

We bridge the gap between innovative ideas and practical implementation, opening the door to a new era of manufacturing.

We are part of the European network of Digital Innovation Hubs (EDIH), which provides resources to develop services for small and medium-sized enterprises with the aim of accelerating the impact of digitalization, including financial assistance.

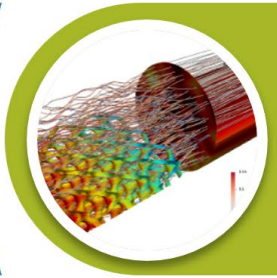
[laser pro Excellence Hub

Our services



CUSTOM DESIGN

Prototype development, cost optimization, product inovation



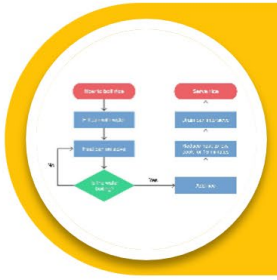
SIMULATIONS

Complex mathematical simulations with maximized number of influential factors



ADDITIVE MANUFACTURING

Variety of AM technologies, design for AM, feasibility studies, etc



PROCESS OPTIMIZATION & DIGITALIZATION

Process engineering, methodology creation, technology and digitalization strategy



TRAININGS

Trainings focused on most required topics

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Mathematical simulations

Verification of mechanical properties prior to actual production of parts. Thanks to simulations, we can reduce the number of development iterations.

STANDARD TASKS

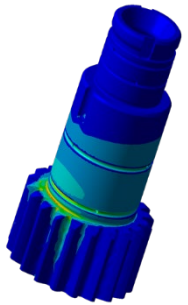
STRUCTURAL STRENGTH ANALYSES

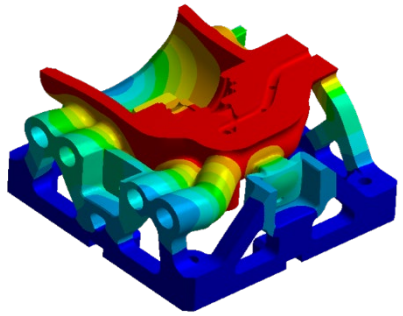
- STATIC/DYNAMIC
- IMPLICIT/EXPLICIT

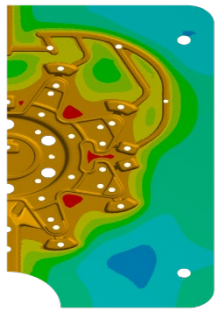
FATIGUE LIFE ANALYSES

THERMAL ANALYSIS

ANALYSIS OF NATURAL FREQUENCIES...





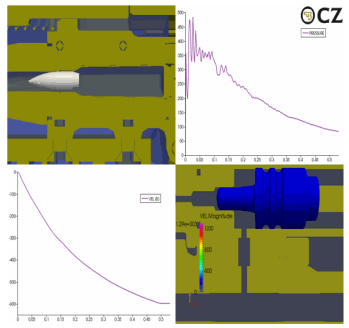


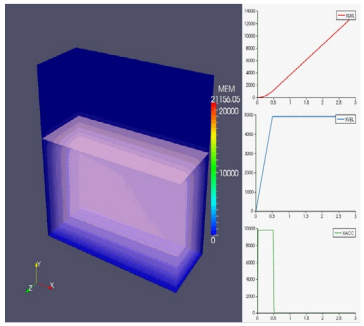
NON-STANDARD AND MULTIPHYSICAL TASKS

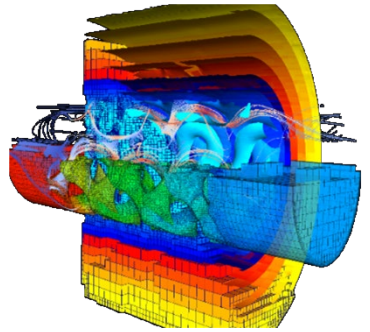
CALCULATION OF FLUID DYNAMICS

DYNAMICS OF MULTIPLE BODIES

NON-STANDARD TASKS

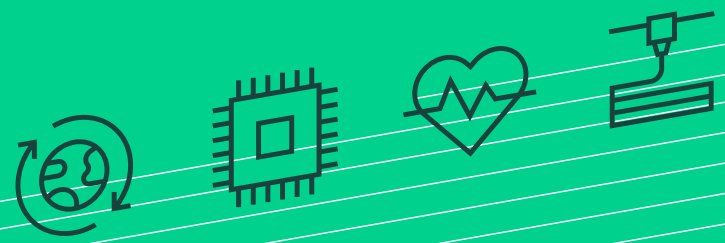






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Role of CARDAM in LASER-PRO project

Excellent Laser Technologies
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Objectives and Expectations

Objectives

- *Design of a cooling system using mathematical structures*
- *Verification of the mechanical properties of the cooling system using the finite element method*
- *Verification of cooling efficiency using finite volume simulations*
- *Topological optimization of components*

Expectations

- *Application of our procedures and methodologies*
- *Application of our own topological optimization algorithm*
- *New experiences in an international consortium*
- *Establishing new contacts*

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Role in the project

WP3: TASK 3.4. Utilisation of 3D printing technologies for thermal and mechanical stability of lasers

The task deals with the enhancement of **mechanical and thermal performance** of specific laser components, primarily beam dumps and cold plates, dedicated to remove locally generated heat inside the laser.

These components typically need, all while **providing effective heat management and thermal stability.**

A comprehensive set of simulations will be employed, including static load simulations, to maximise mechanical strength while minimising weight.

Composite materials will be used to reduce thermal expansion. **Heat exchange, cooling flood flow analyses, and topological optimisation** will be applied to prepare a design for the heat management of laser components.

These efforts will be complemented by **additive manufacturing methods, particularly 3D printing of metals through Selective Laser Sintering.** The 3D printed components are expected to be lighter, stronger, environmentally friendly (due to material savings), and feature improved thermal management. This includes enhanced heat dissipation for components and a well-balanced thermal environment for laser housings. The findings could be easily transferred to other industries.

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Our team in the project

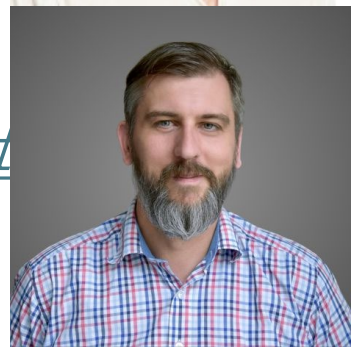
- *Martin Okénka, Designer, martin.okenka@cardam-solution.cz*



- *Pavel Gruber, Mathematical specialist, pavel.gruber@cardam-*



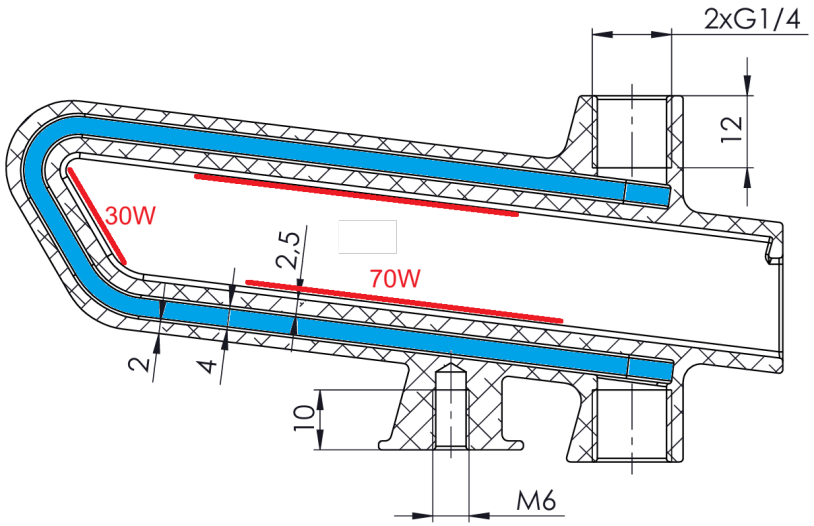
- *Antonín Miller, Projekt manager, antonin.miller@cardam-solut*
- *Ondřej Kurkin, ondrej.kurkin@cardam-solution.cz*

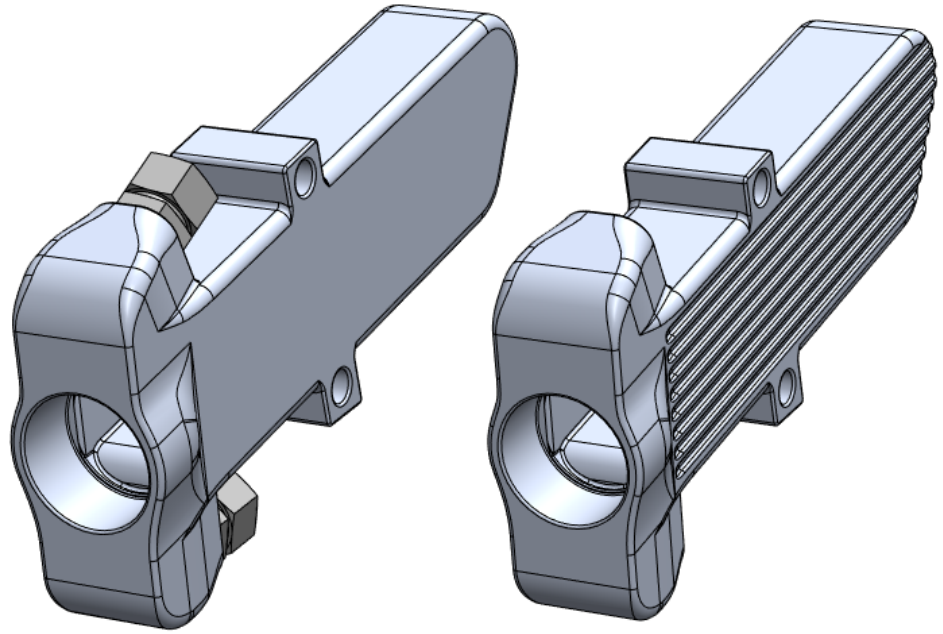


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Laser beam dump

Laser beam dump with an internal mathematical TMPS (Triply Periodic Minimal Surfaces) structure – second prototype developed and manufactured – *now it testing.*

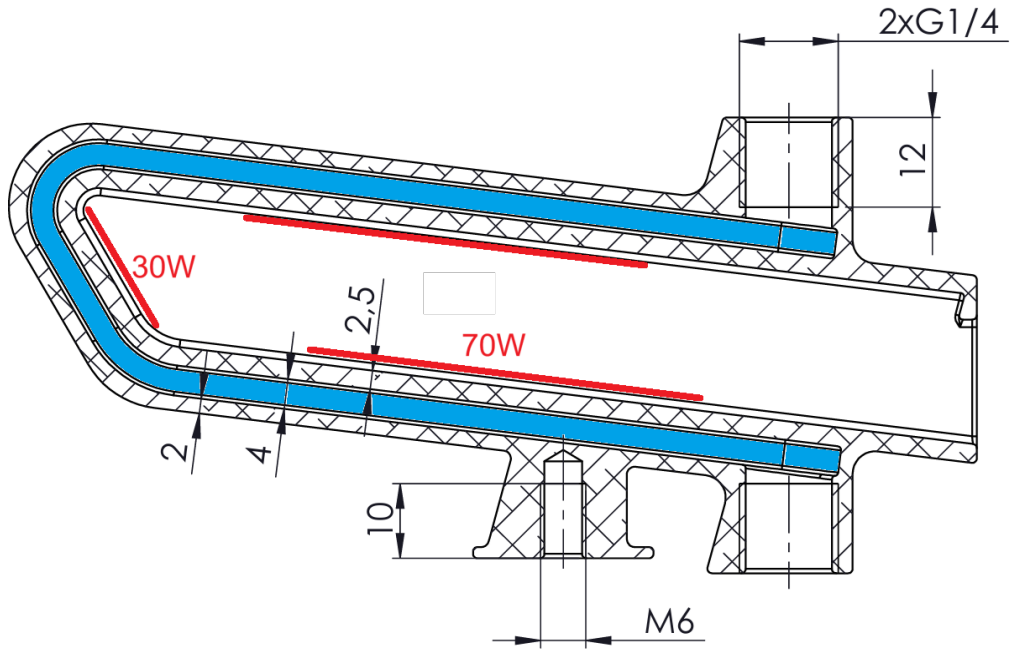




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Laser beam dump

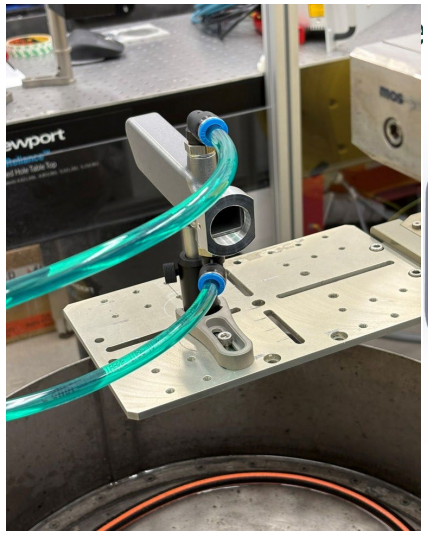
- **Water- cooled laser beam-dump** The 3D print technology is limited to roughly 1mm wall thickness and 1mm gaps, and the voids are filled with metal powder which need to be removed. For this reason, a snake pattern water cooling channel will work better than the gyroid pattern for manufacture. The laser power to be dissipated can be helpful for the 3D pattern design to know where to concentrate the pattern.

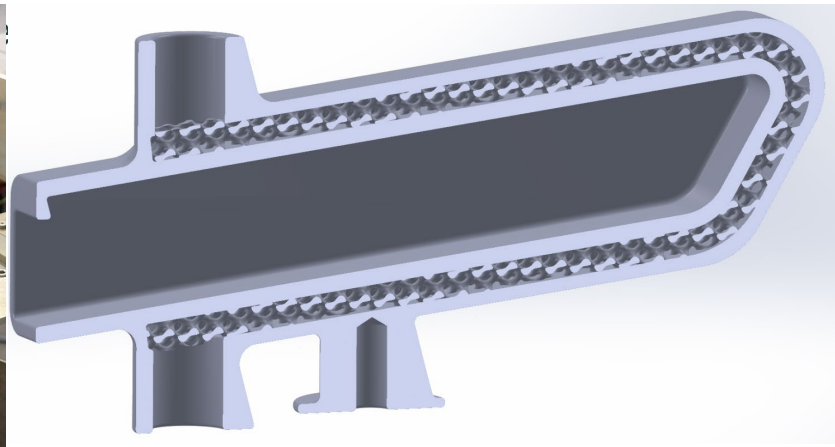


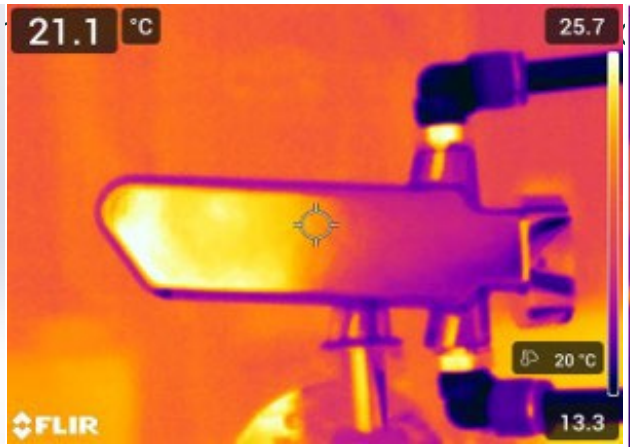
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Laser beam dump – First prototype

- First prototype of next generation laser beam dump was developed by HiLASE and CARDAM.
- Internal mathematical structure with optimized shape and density was employed for efficient heat transfer from the absorber body to the cooling system.
- The beam dump is 3D printed from Al alloy.
- First prototype was succesfully tested in two experimental campaigns.
  - Withstanding 10 000 laser shots (1 joule energy, 1064 nm wavelength, 2 mm beam diameter).
  - Withstanding gradually increasing laser power from 200 up to 2,000 W with no excessive heating



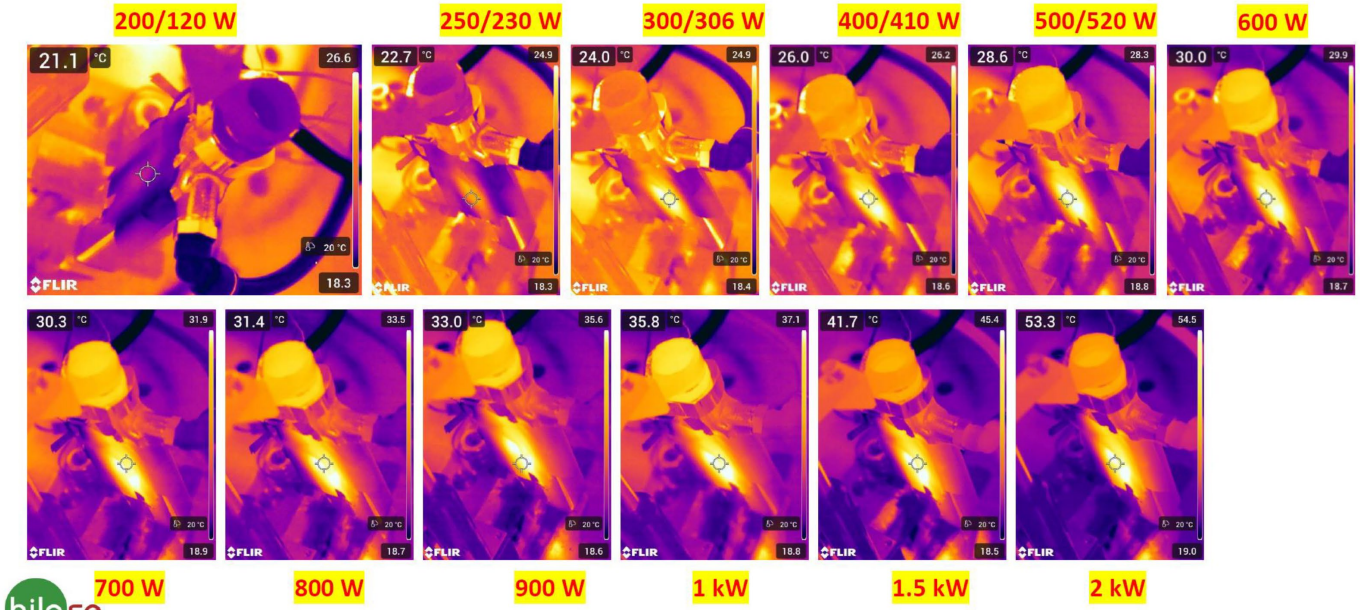


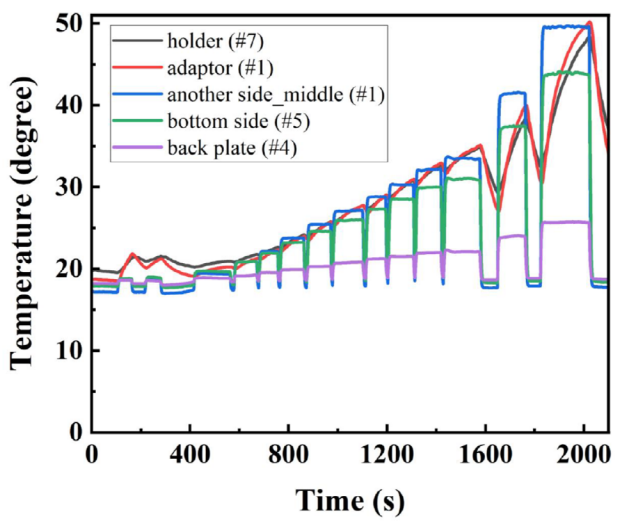


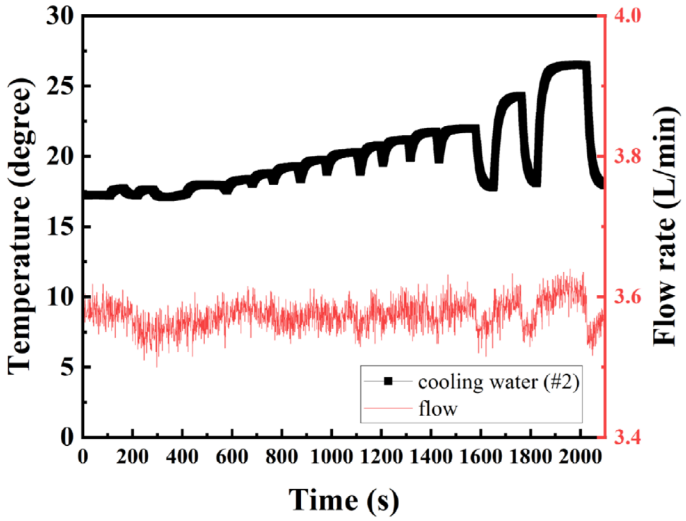


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Laser beam dump – First prototype testing





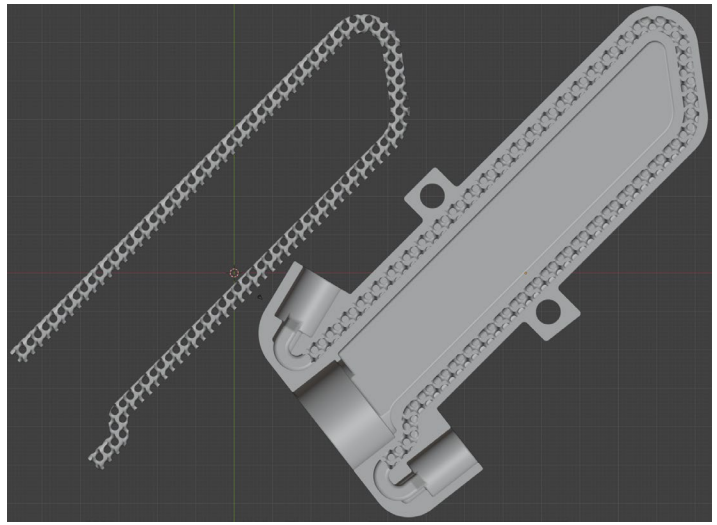




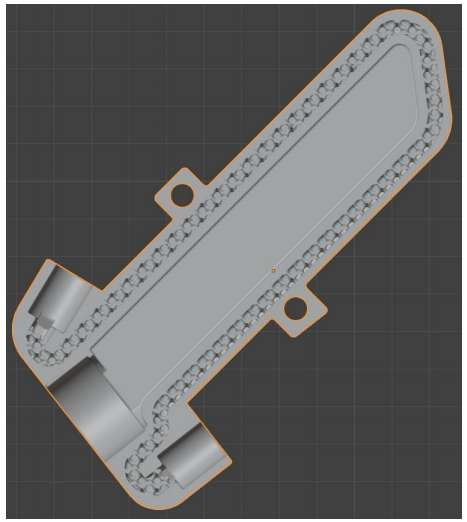
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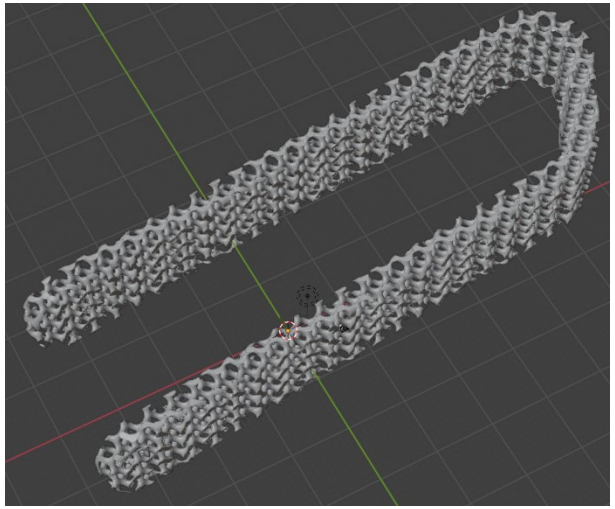
Laser beam dump – Second prototype

- *Optimised geometry:*



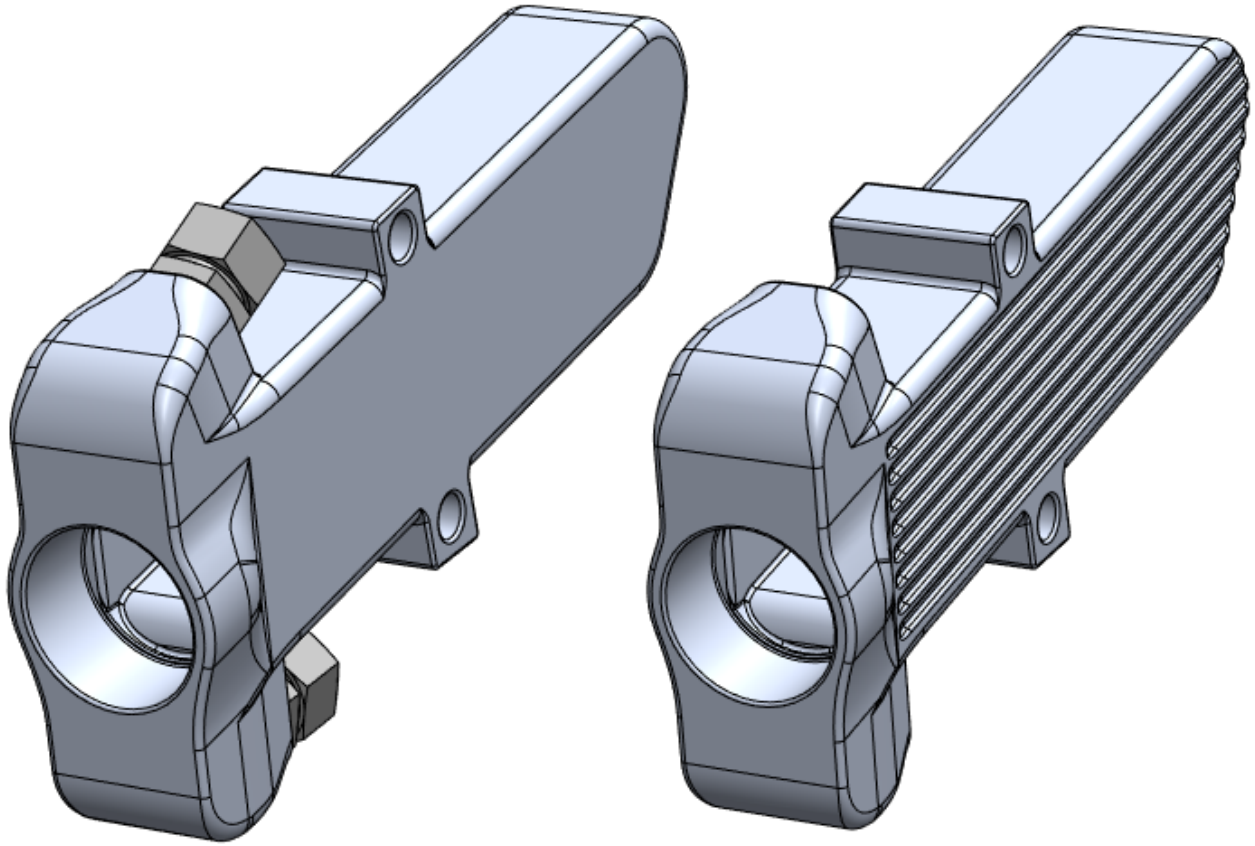
Optimised geometry for production





Laser beam dump

- *A second prototype of the next-generation **3D-printed laser beam dump** with an optimized internal TPMS structure was developed, manufactured, now in testing.*



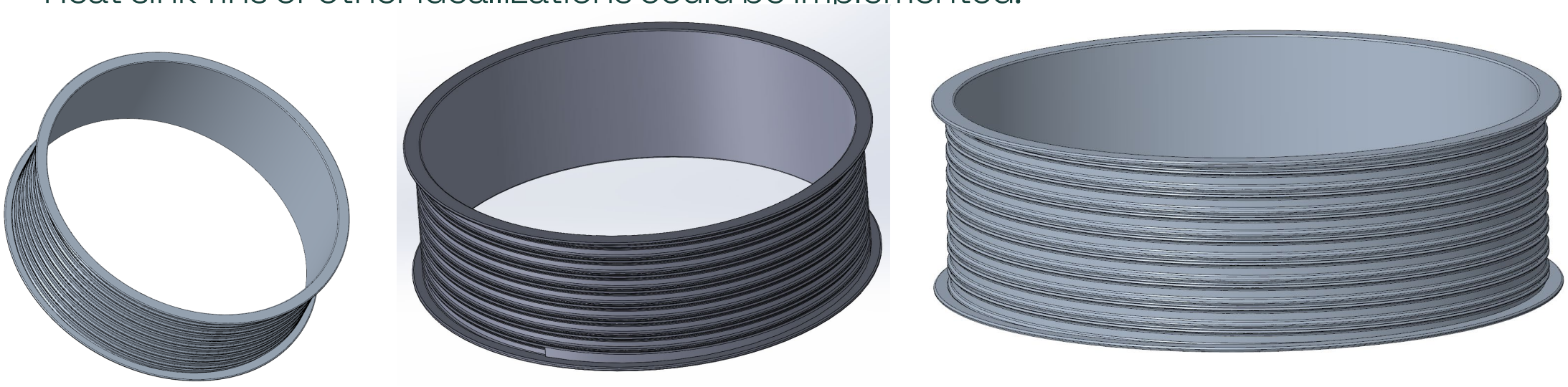
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Water-/air-cooled optical fiber stack

Water-/air-cooled optical fiber stack – *in development* – cooling structure (for both active an passive cooling) optimization stage

Air-cooled fiber cooling stack

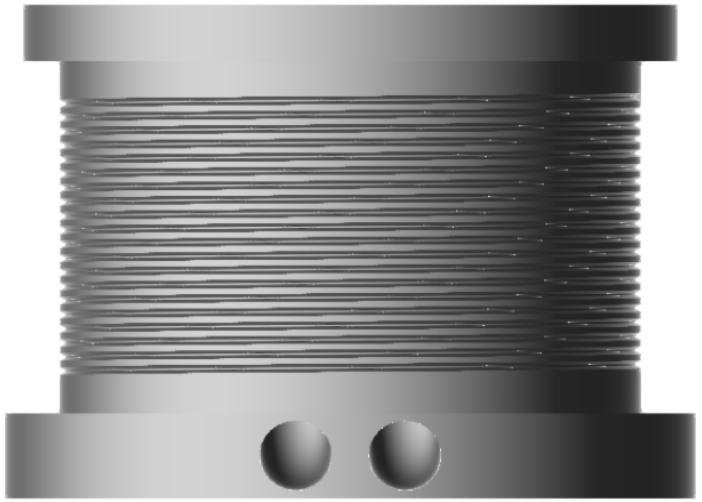
The intention of this design is to have a fibre optic cable coiled around this ring which will help air cool the fibre optic wire. Hilase described that it should be as light weight as possible. I suggested perhaps the ring could be used as a heat sink rather than just a wire organizer. Heat sink fins or other ideallizations could be implemented.



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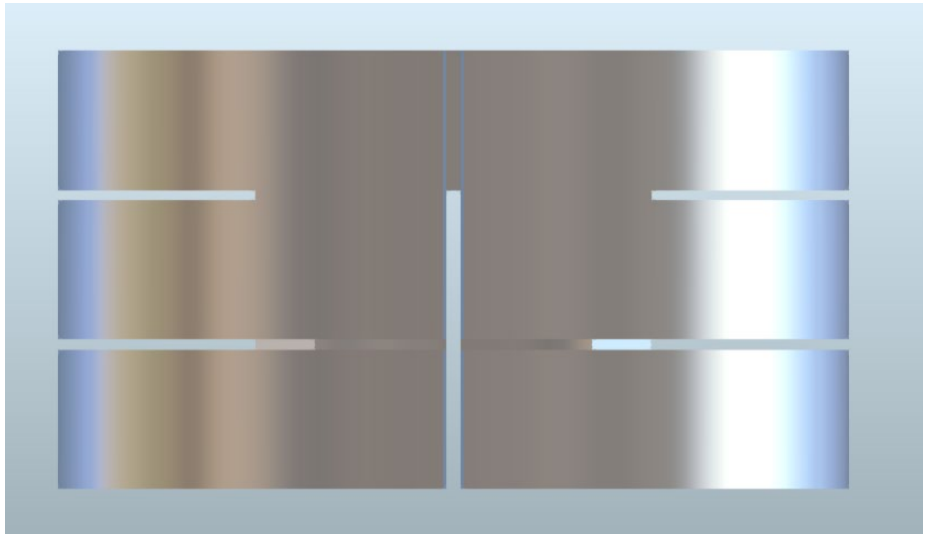
Water-/air-cooled optical fiber st

Optimized Cylinder with water cooling channels is designed for thermal management is designed

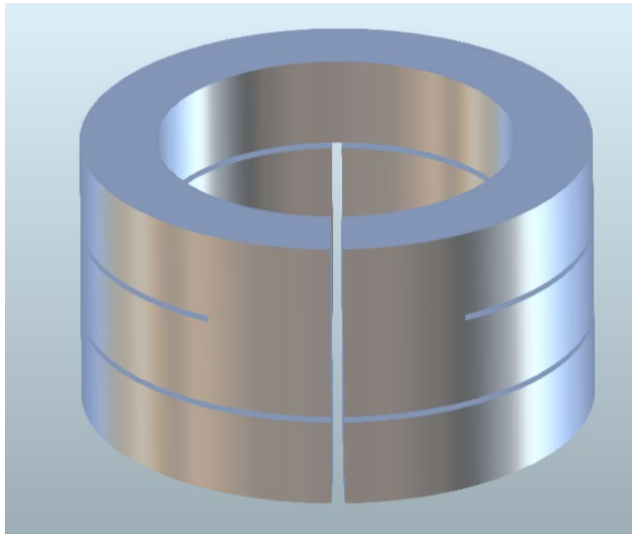




Cylinder (Sectional View)



Water Path (Front View)

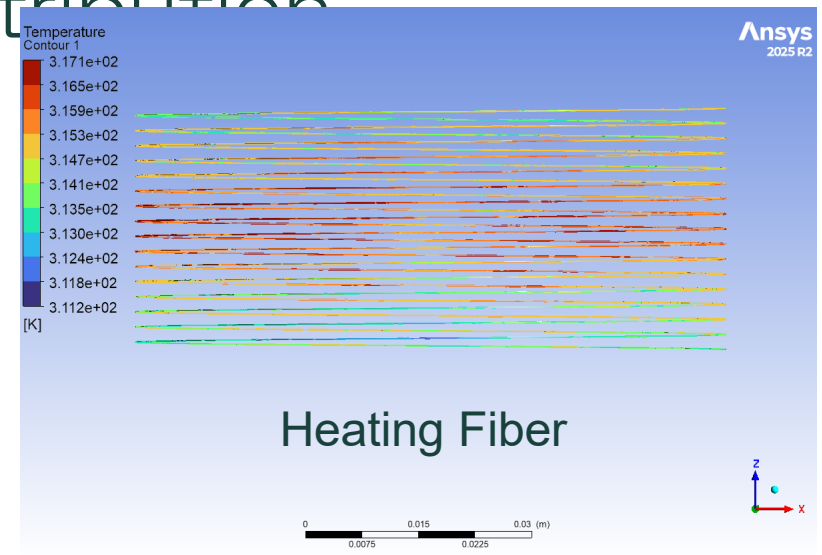


Water Path (Isometric View)

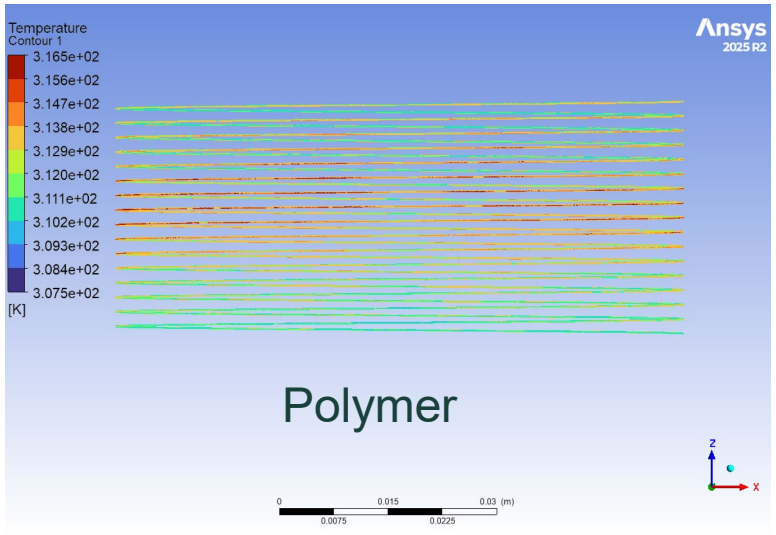
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Water-/air-cooled optical fiber stack - Temperature Distribution

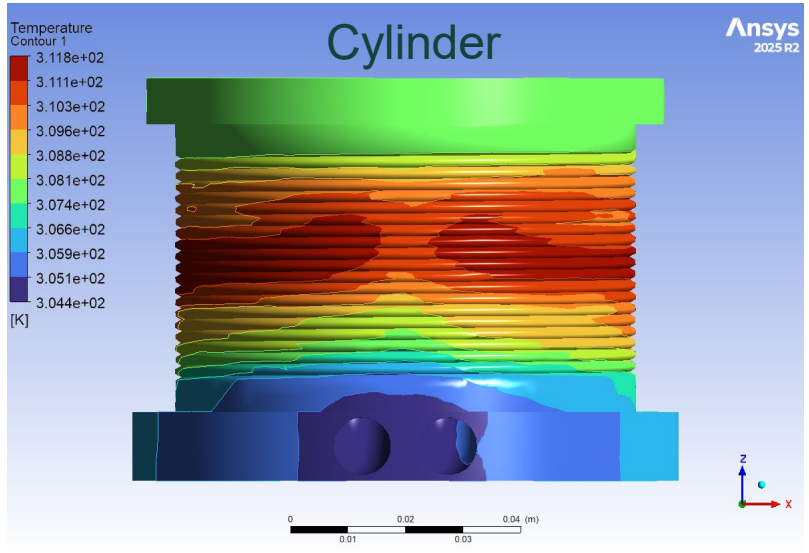
Max 317.1 K



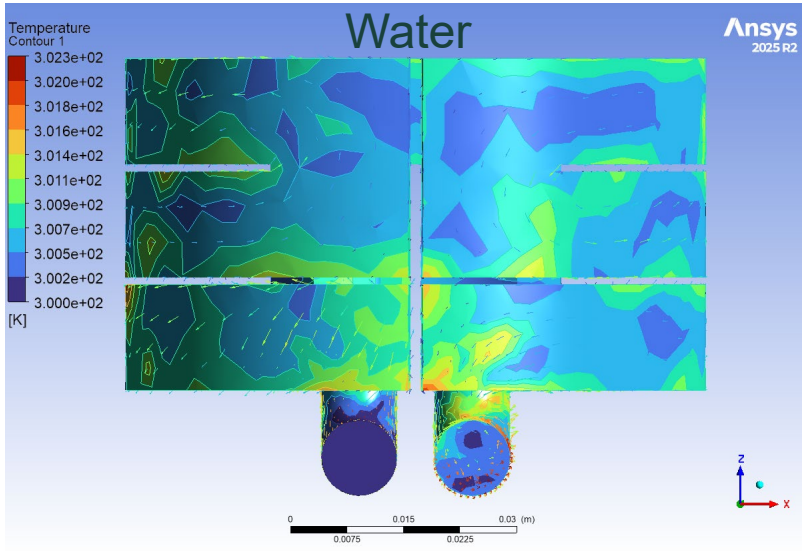
Max 316.5 K



Max 311.8 K



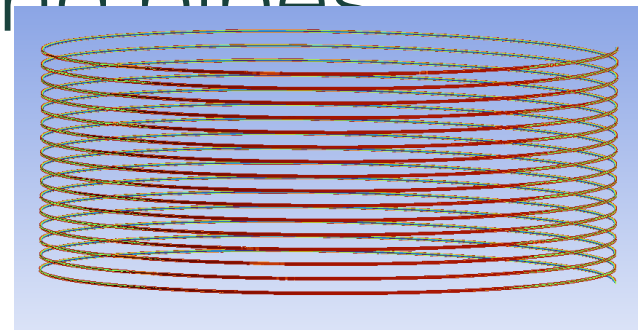
Max 302.3 K



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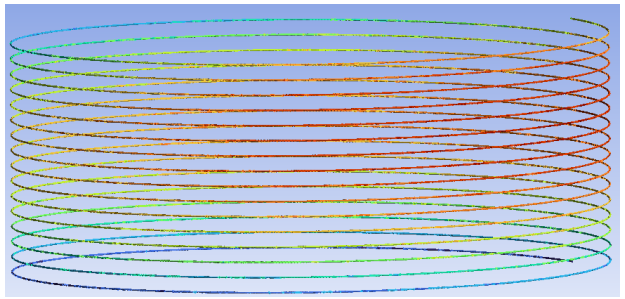
Water-/air-cooled optical fiber stack - with Cooling pipes

Max
324.9 K



Heating Fiber

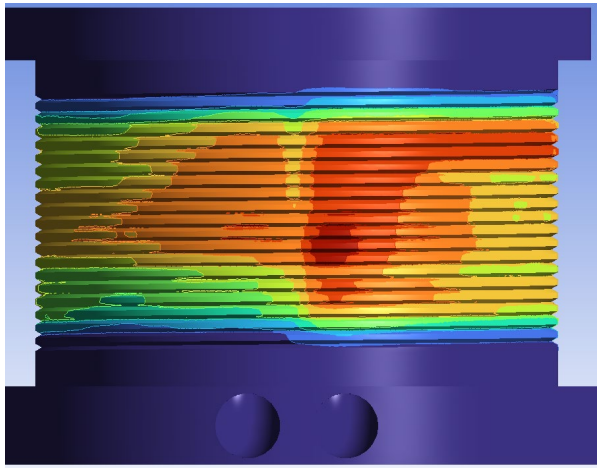
Max
324.3 K



Polymer

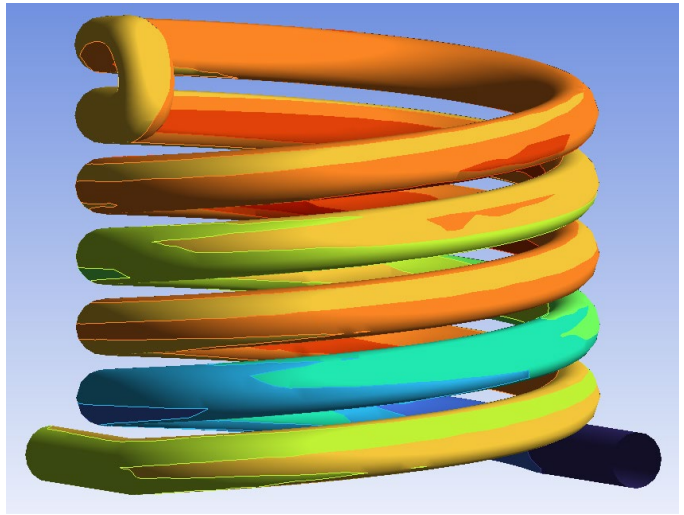
Cylinder

Max
316.8
K



Water

Max
303.6 K



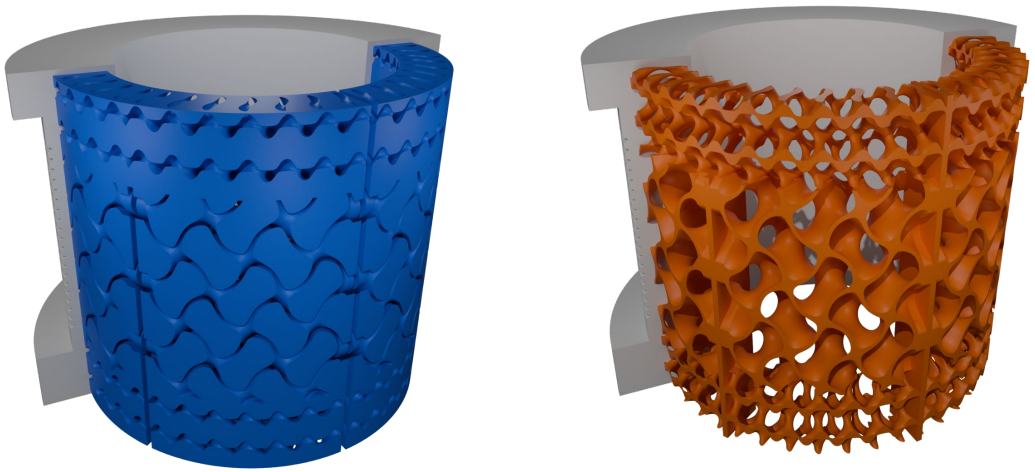
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Water-/air-cooled optical fiber stack

Progress: from a simply clipped Cartesian gyroid to a radial, flow-guided t-gyroid structure

A Porous inter-pass transition

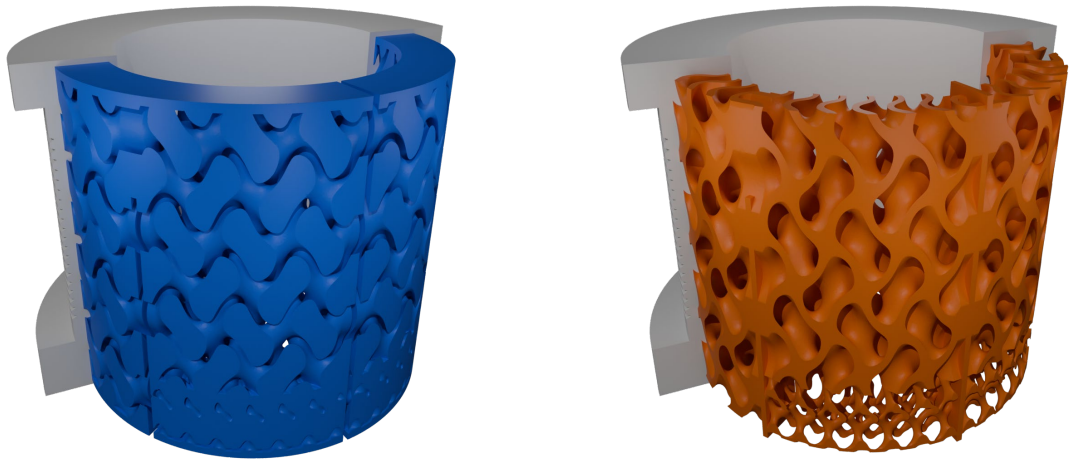
Low-density gyroid regions open redistribution zones at baffle ends.



fluid *solid*

B Connected t-gyroid transition

Main t-gyroid passages continue across local baffle breaks.



fluid *solid*

Design review:

- unwrapped surface rolled into cylinder → zig-zag multi-pass flow
- gyroid → t-gyroid interpolation avoids strut blockage
- phase-aligned clipping maximizes open flow area

Next verification: flow balance between passes, pressure drop and thermal uniformity.

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Thermally stable baseplate for a fiber laser oscillator

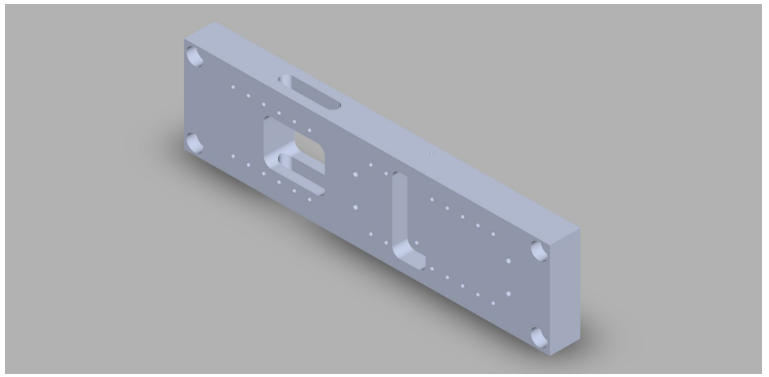
Thermally stable baseplate for a fiber laser oscillator – *in development* – adaptive structure (to minimize thermal deformations) optimization stage

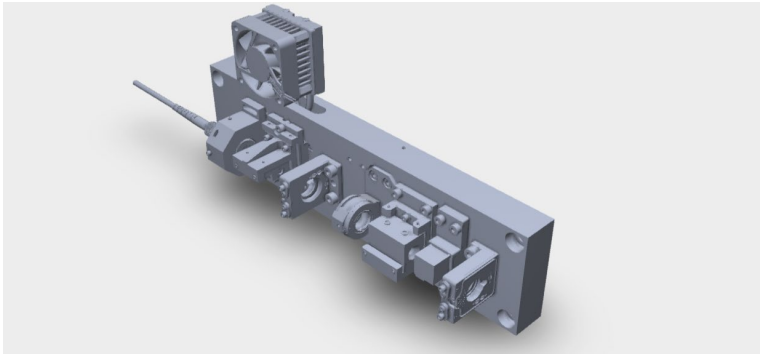


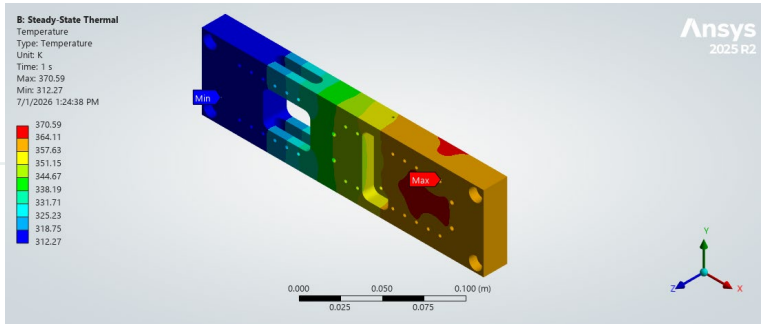
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T3.4 – Thermally stable baseplate for a fiber laser oscillator

- **Task / Problem Statement**
- The oscillator base, currently made of aluminium, is to be redesigned using **Fe29Ni17Co alloy**. Heat generated by the foil heater beneath the cavity causes thermal expansion and deformation of the base. The objective is to **minimize the thermally induced expansion of the oscillator base.**
- **Planned Approach**
- The internal **gyroid structure will be optimized iteratively using coupled thermal and structural simulations.** Local gyroid density will be varied to influence heat transfer, stiffness and the resulting thermo-mechanical response. **Sensitivity analysis** will be used to identify the regions where changes in the structure have the greatest effect on thermal expansion, while





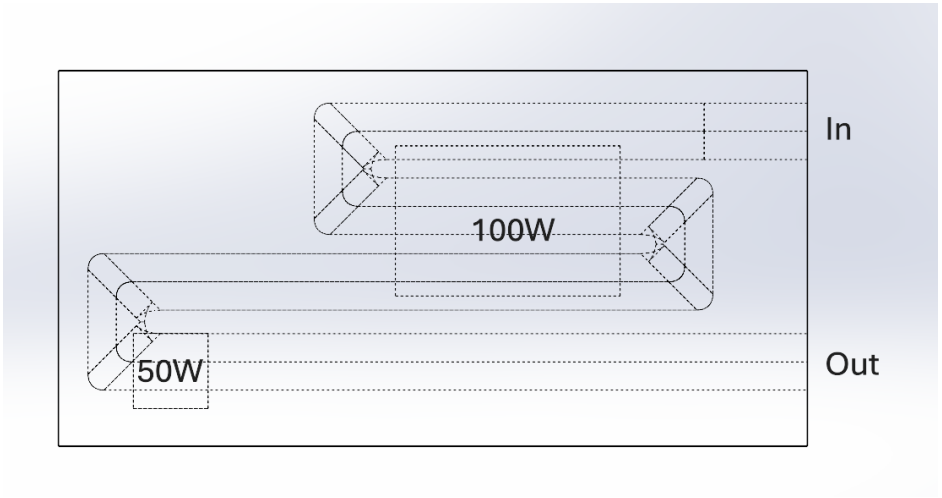


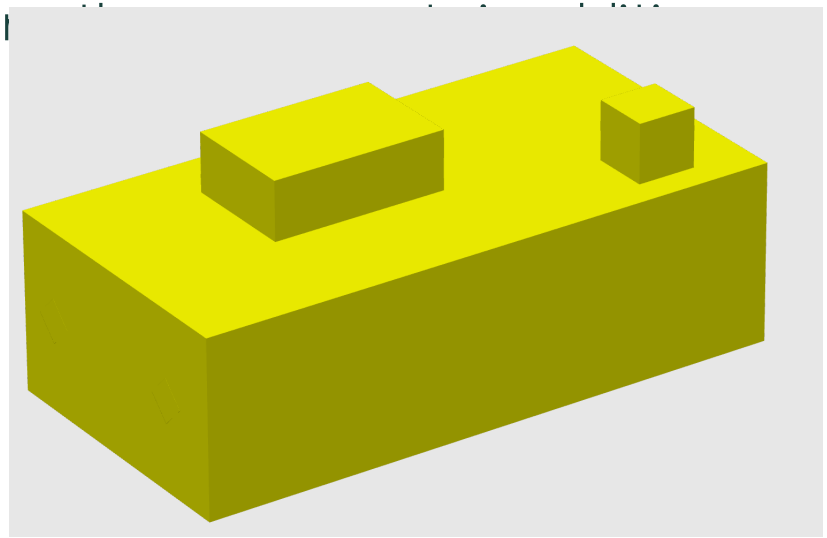
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Water-cooled cooling plate for a laser module

Water-cooled cooling plate for a laser module – *in development* – mechanical redesign completed; parallel optimization of the cooling structure (TPMS vs. a more conventional channel system) to be carried out

- Mathematical analysis of a heatsink design intended for laser systems.
- The heatsink is made from AlSi10Mg alloy and features two heat sources on its top surface—one at 100 W and another at 50 W. The system is cooled using water.
- Our main objective is to determine the optimal internal structure for efficient thermal management, with the intention of manufacturi





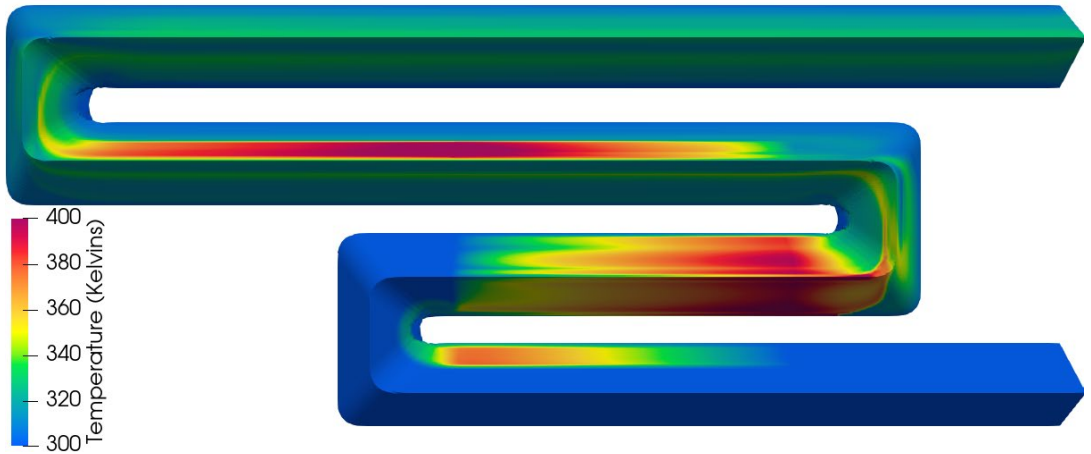
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Water-cooled cooling plate for a laser module – First concept

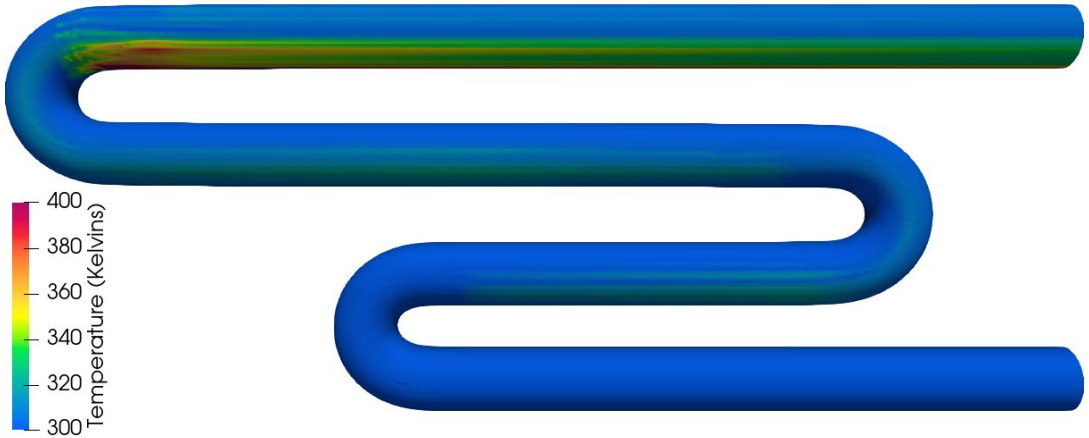
- Inlet temperature 300 K, pressure drop 12 Pa
- Two heat sources are placed—a 100 W source roughly in the center, and a 50 W source roughly at the top left (mirror-reversed from the original specification)
- Three variants simulated:
  - original FTMC concept
  - modified original concept – rounded cooling fluid path, cooling channel diameter approx. 5.8 mm – roughly corresponds to the original square design
  - use of a gyroid structure throughout the entire volume of the cooler
- Simulated:
  - wall temperature on the heat source side
  - pressure across the cross-section

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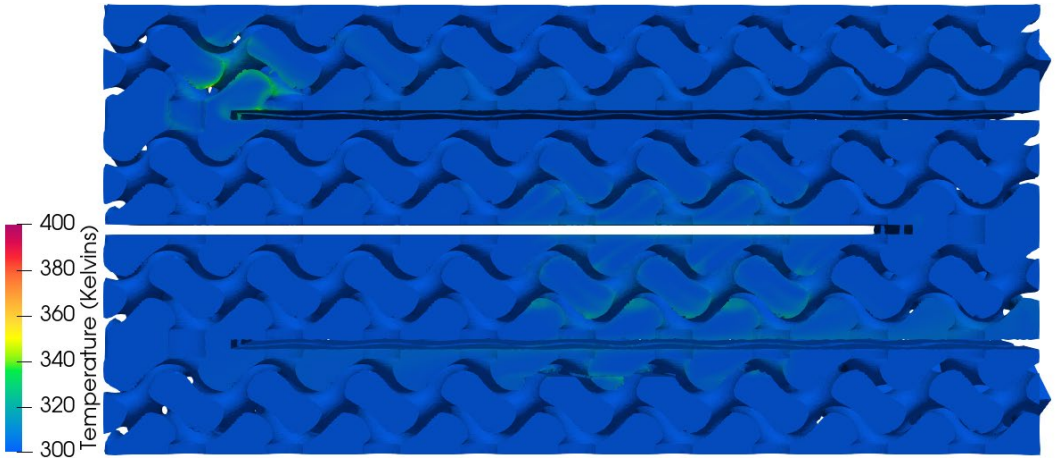
Result - wall temperature on the heat source side



- Heat dissipation is least effective
- A large number of ”hot” spots
- Maximum temperatures of 400 K



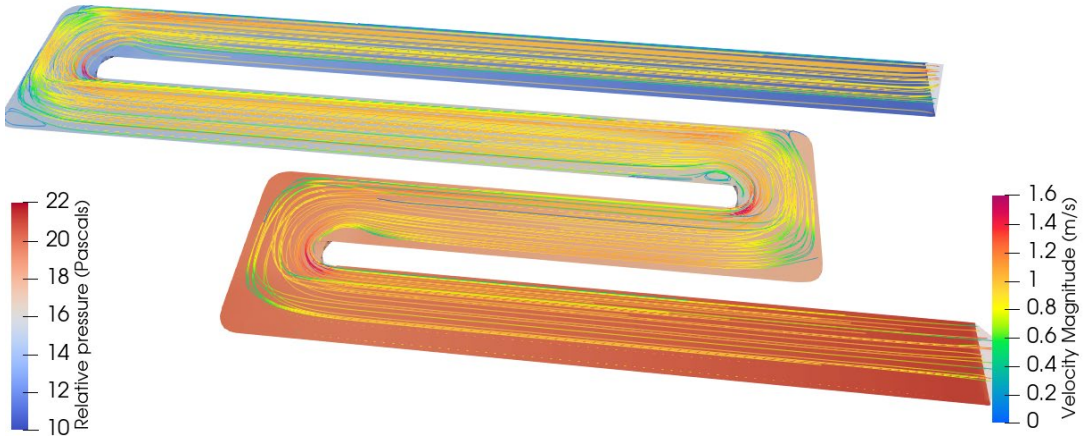
- Heat dissipation is more efficient, and heat is dissipated more effectively
- There are still noticeable areas with higher temperatures



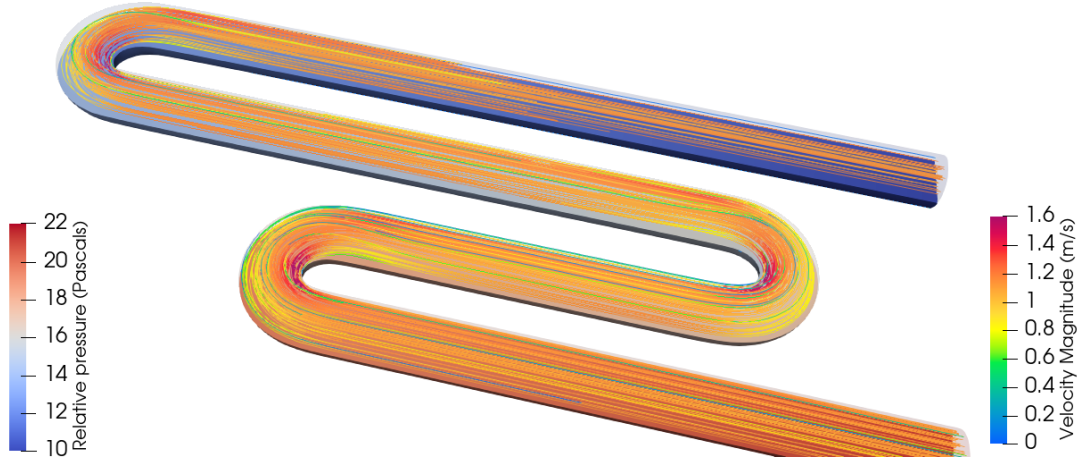
- Heat dissipation occurs at a slower rate
- It utilizes a larger surface area for heat transfer
- No significant heat buildup to high temperatures is observed
- Maximum temperatures are around 340 K

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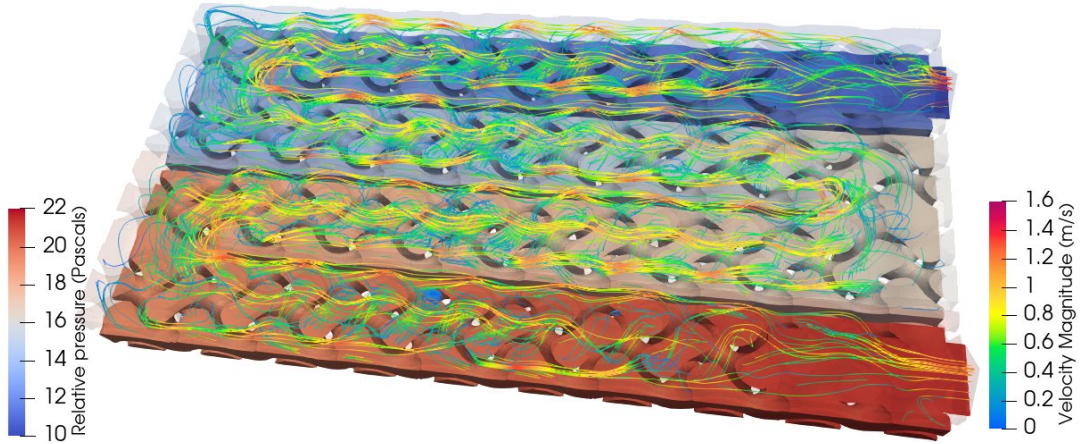
Result - pressure across the cross-section and flow



- lower flow rate – 1.6 L/min (0.95 m/s)
- turbulence occurs due to the ”angular” shape



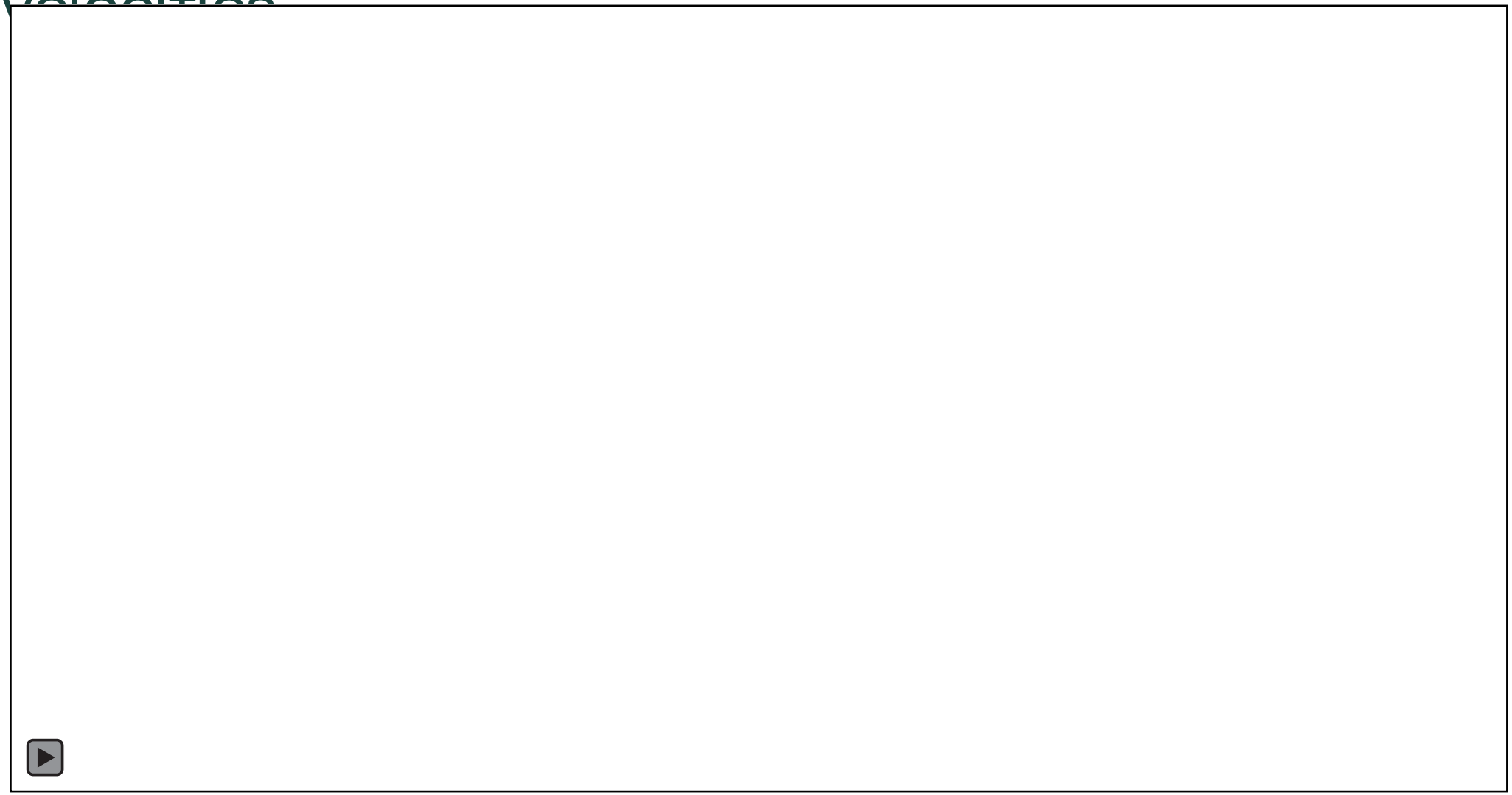
- flow rate: 1.9 L/min (1.09 m/s)
- the rounded shape eliminates turbulence
- the flow is smoother



- flow rate 1.9 L/min (1.09 m/s)
- partially turbulent, but covers a significantly larger area
- more uniform heat removal

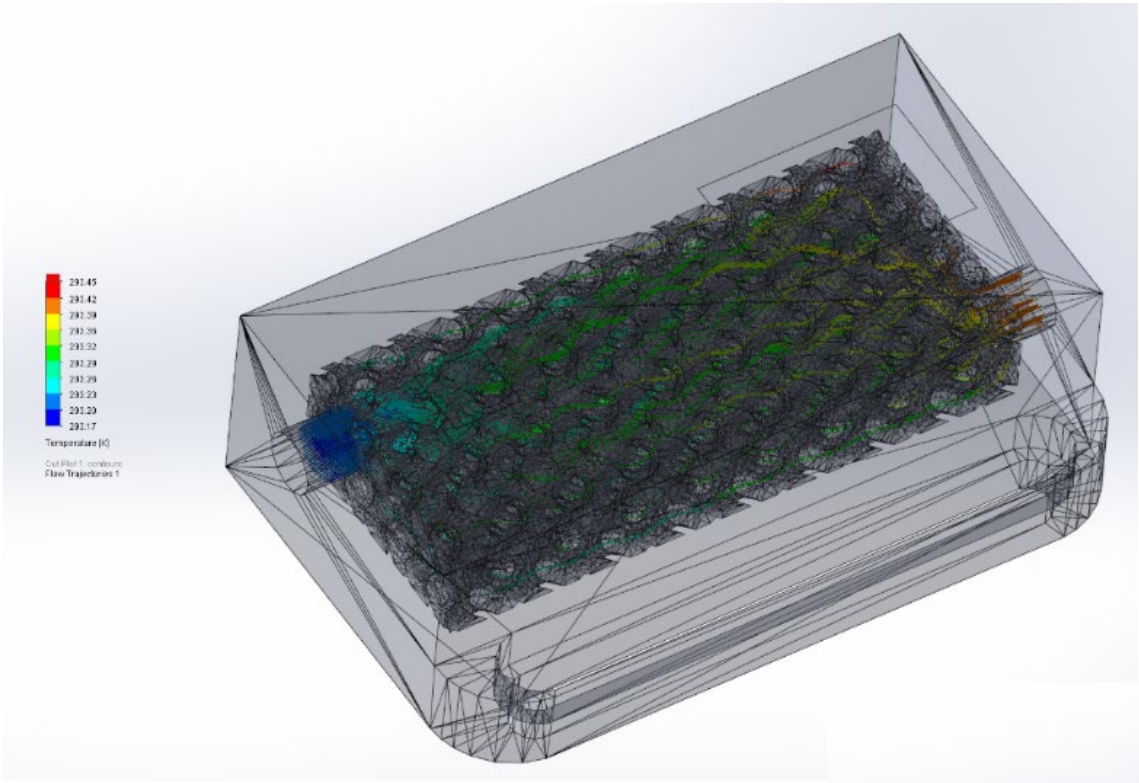
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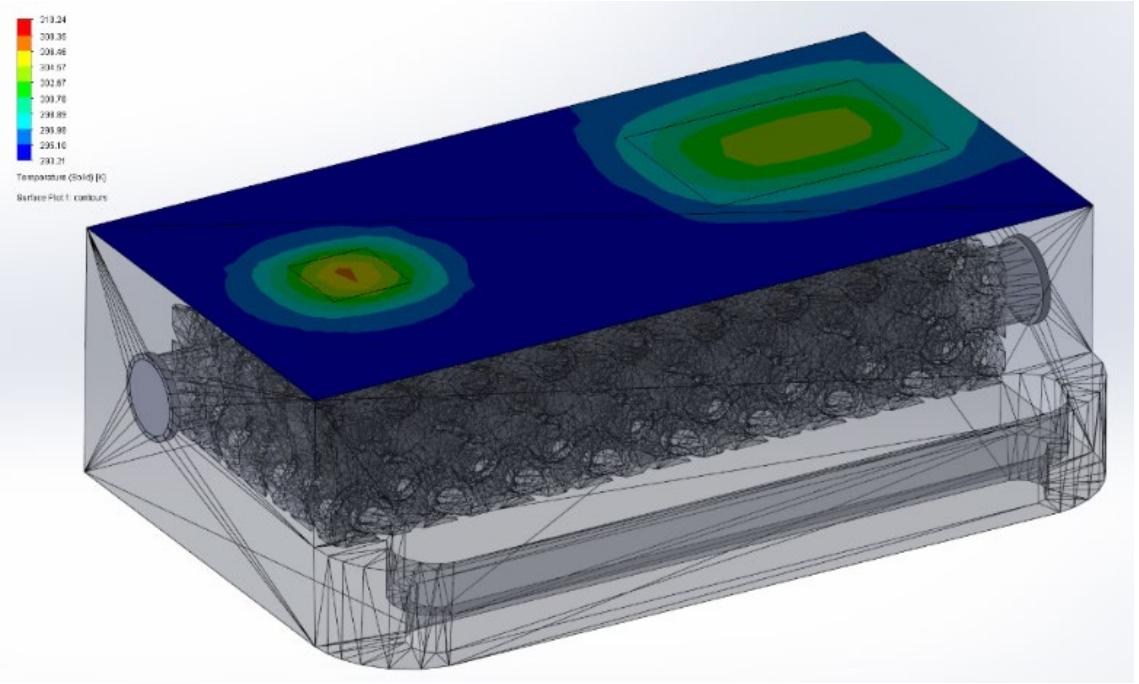
Result - pressure across the cross-section and flow velocities

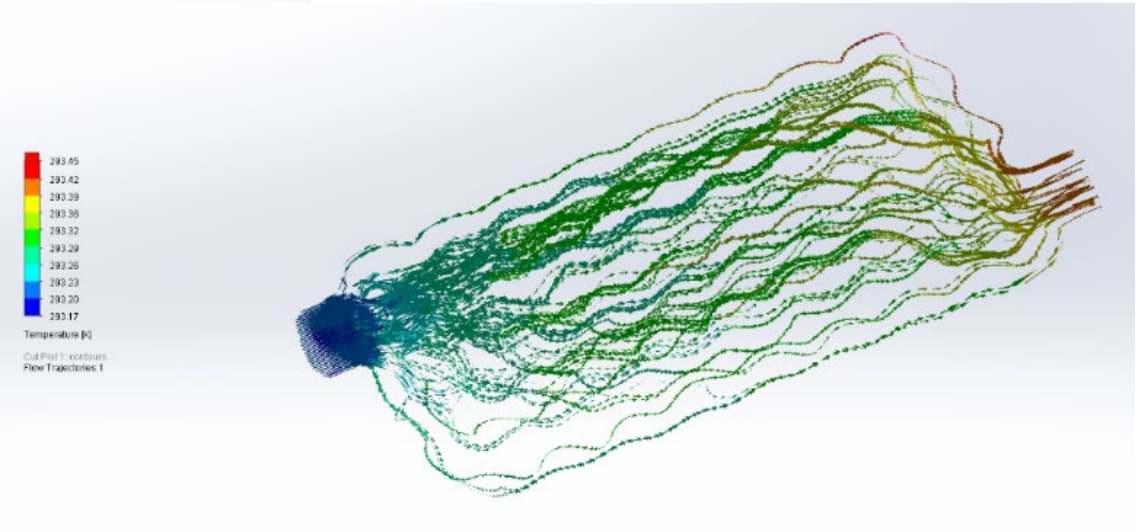


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First concept - conclusion







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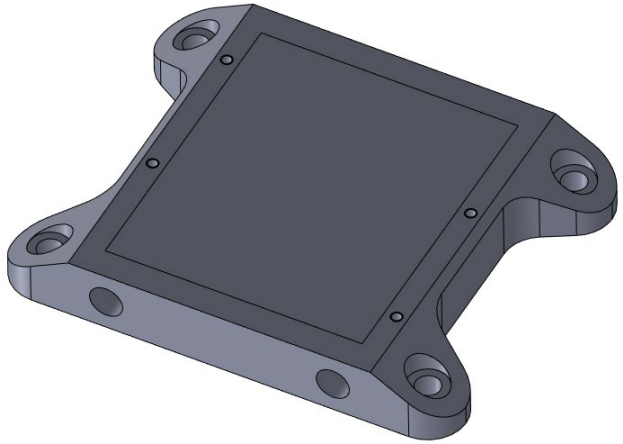
First concept - conclusion

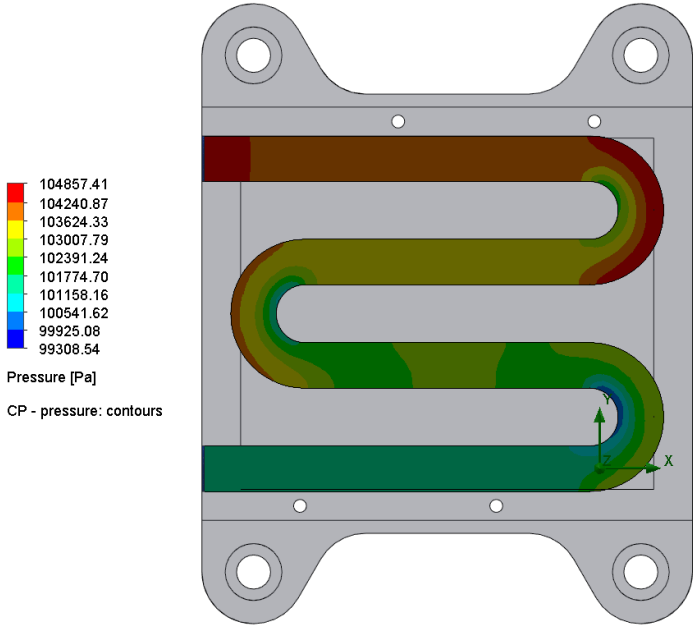
- Based on the simulations performed, the original design is the least suitable—high ”hot spot” temperatures, turbulent flow, and lower flow rate (13% lower), resulting in greater losses
- The “rounded” variant partially eliminates the problems of the original concept—the flow is smoother, “hot spots” are largely eliminated, and heat dissipation is improved
- The gyroid structure dissipates heat most effectively, even when the flow is partially turbulent
- Even with a slower fluid flow, it is the most efficient due to the largest heat transfer surface area and has a minimum of “hot” spots—maximum temperature around 340 K (compared to the original concept, where the maximum temperature was around 400 K
- another advantage of the gyroid variant over the “rounded” one is the

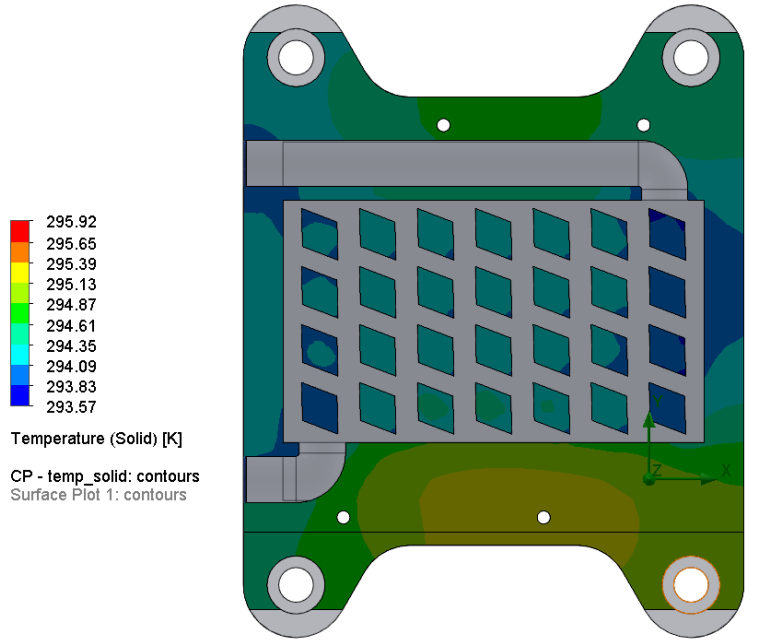
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Water-cooled cooling plate for a laser module – Second concept

- *Extensive development of a **water-cooled cooling plate for a laser module** was carried out during a hands-on meeting at FTMC (September 2026)*
- *A number of cooling strategies were proposed and simulated*
- *Further development and optimization are to be carried out in parallel – comparing a more conventional channel system with a mathematical structure (TPMS)*







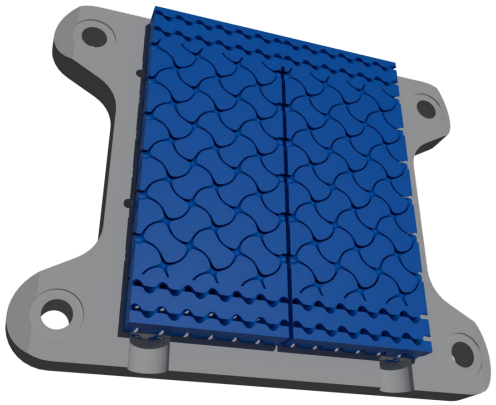
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T3.4 – Cooling plate TPMS branch

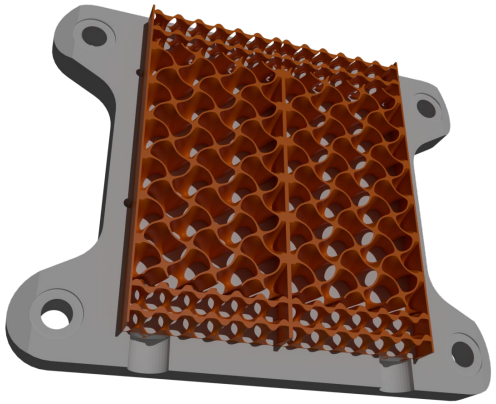
Current status: TPMS alternative to the engineered cooling-channel layout for the laser module

A Porous redistribution zone

Open low-density gyroid distributes liquid between consecutive flow passes.



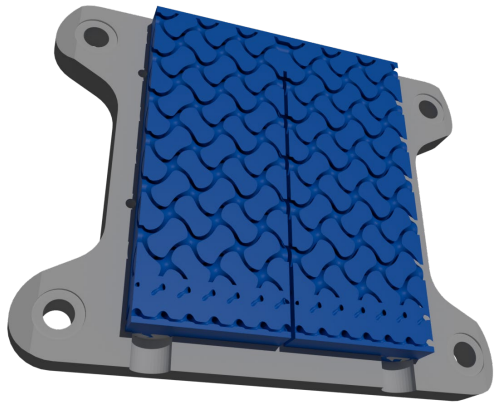
fluid



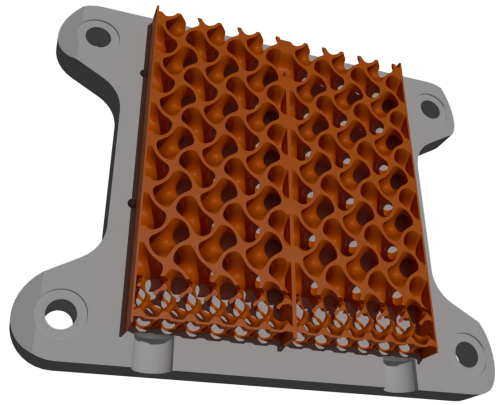
solid

B Connected t-gyroid passages

Main t-gyroid channels are locally connected across macroscopic baffles.



fluid



solid

Design review:

- TPMS heat-transfer surface + engineered macroscopic flow management
- controlled inter-pass transition, not only porous infill
- ready for comparison with conventional channel baseline

Comparison criteria: pressure drop, flow distribution, hotspot reduction and printable geometry.

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Next steps

T3.4: Utilisation of 3D printing technologies for thermal and mechanical stability of lasers

- **Beam dump** – completion of 2nd iteration testing and evaluation → component closed
- **Cooling plate** – decision on the cooling structure, printing of the 1st iteration prototype, testing
- **Fiber cooling stack** – printing of the 1st iteration prototype, testing, evaluation
- **Laser housing** – specification finalised, redesign for 3D printing + simulations

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Thank you for your attention

Speaker‘s contact

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