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07.11

3D-printed Heat Pipe Array for Fusion

Nick Maassen

12 December 2017



VDL Enabling Technologies Group



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Dutch Institute for
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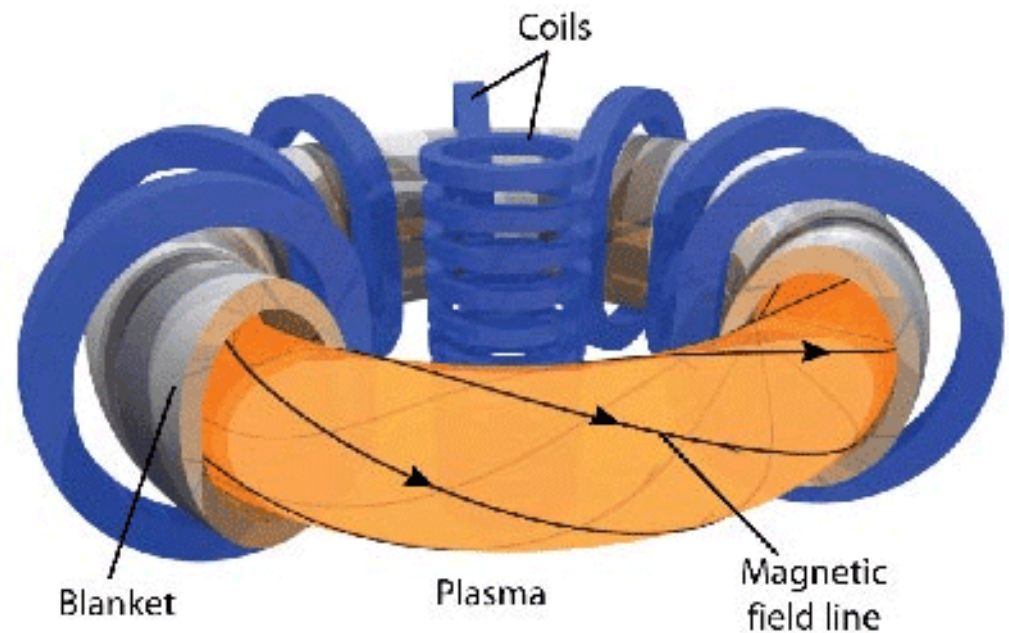
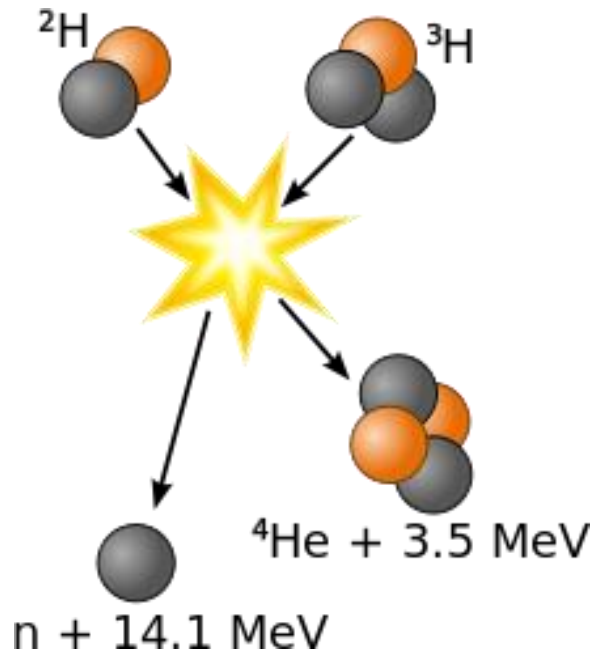
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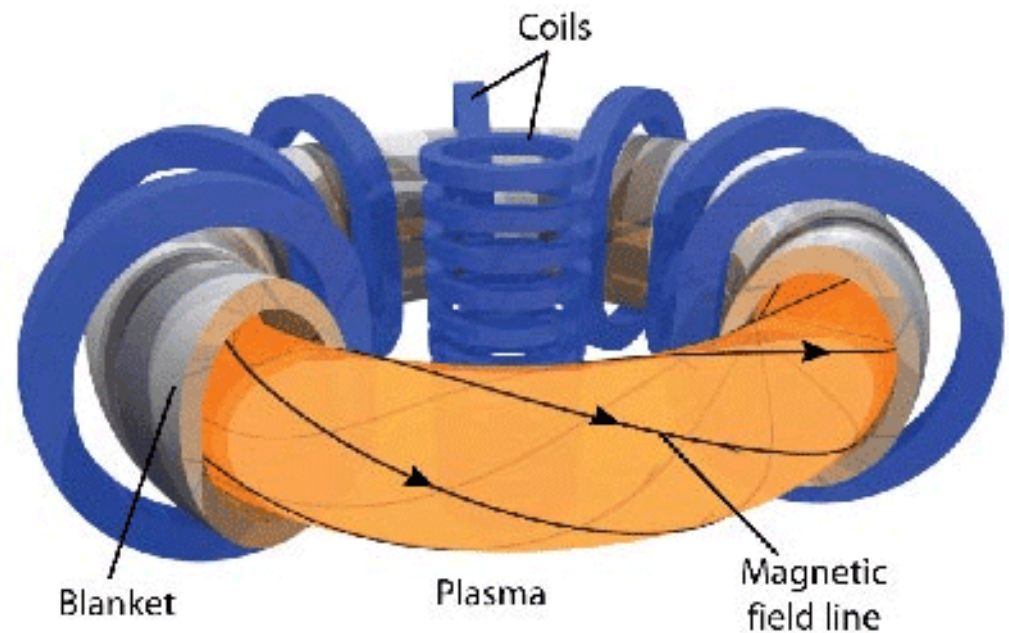
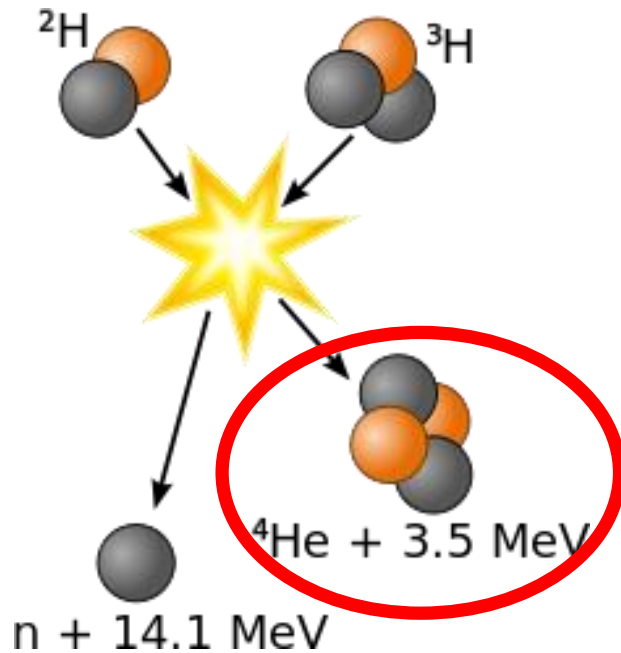
Magnetic fusion

- Abundant and clean
- Extreme temperatures
- Magnetic confinement



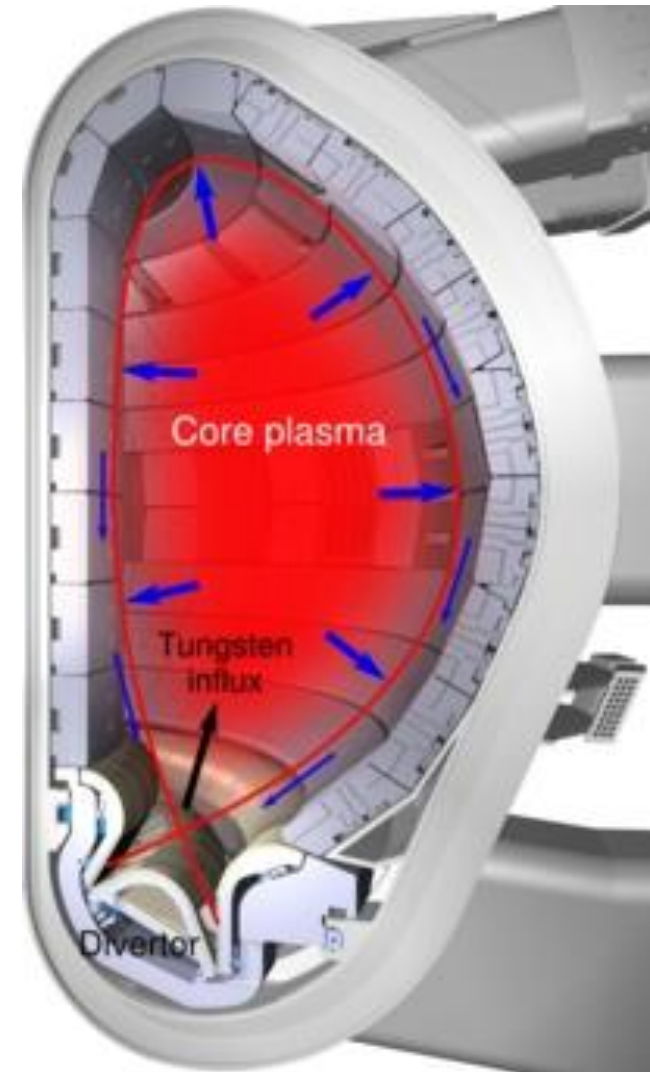
Magnetic fusion

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Power sink

- Power exhausted to divertor
- Poor scaling heat flux



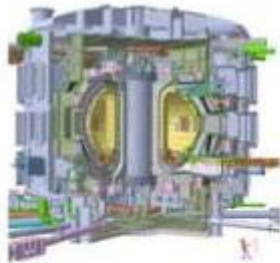
Power sink

- Power exhausted to divertor
- Poor scaling heat flux
- Commercial power plant
- Continuous operation



JET

16 MW



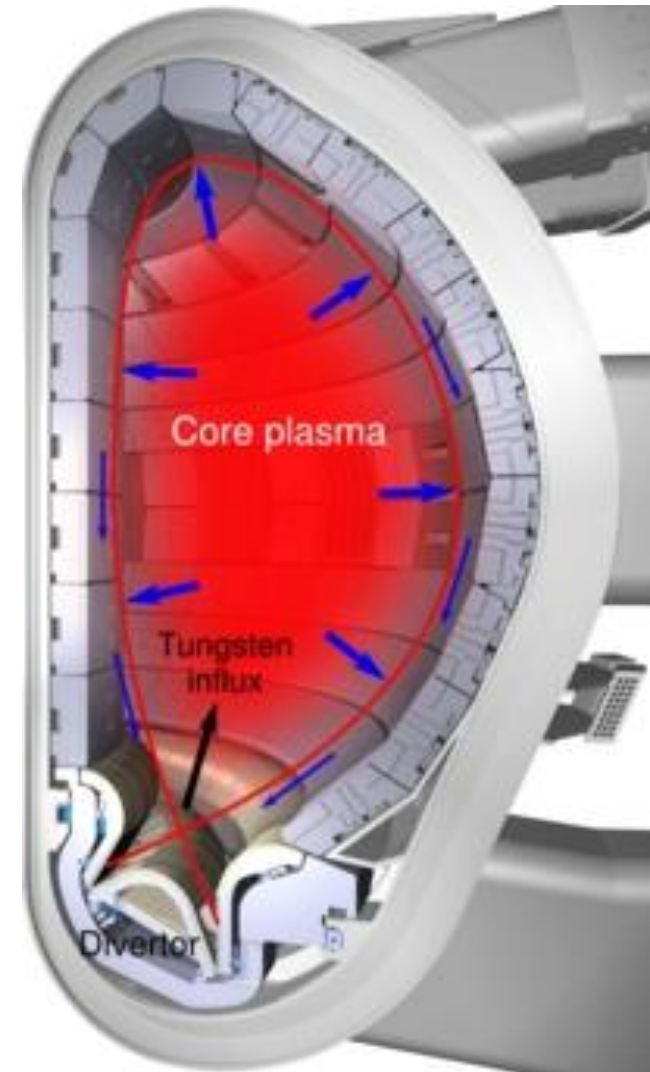
ITER

500 MW
10 MW/m²



DEMO

3000 MW
20 MW/m²



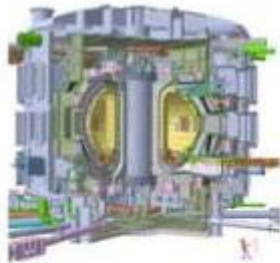
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- Commercial power plant
- Continuous operation
- Heat pipes?



JET

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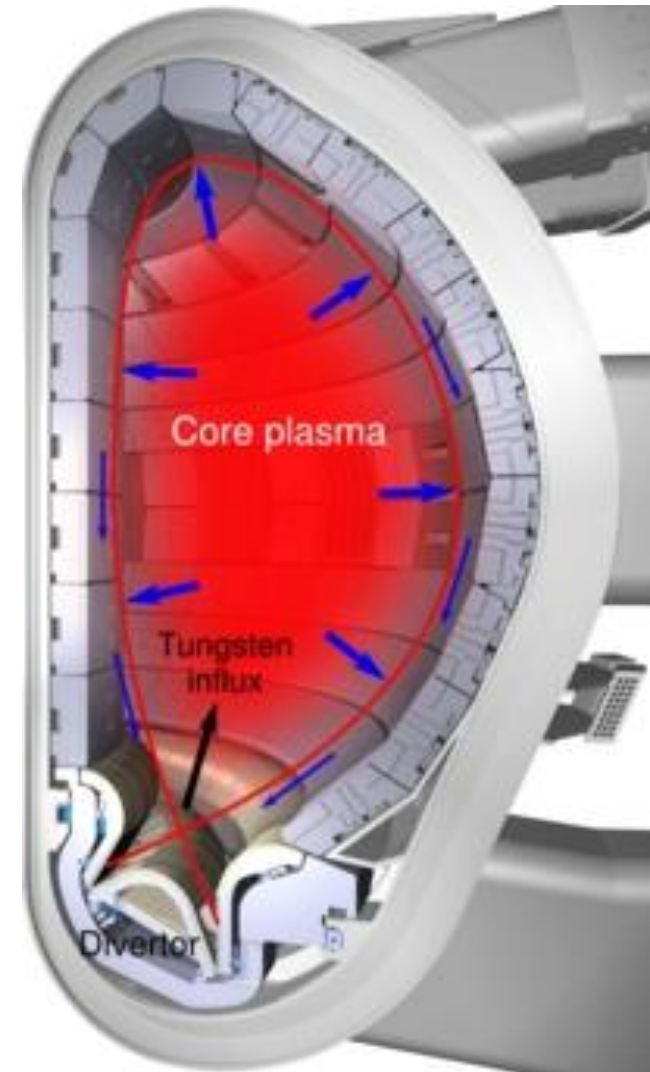
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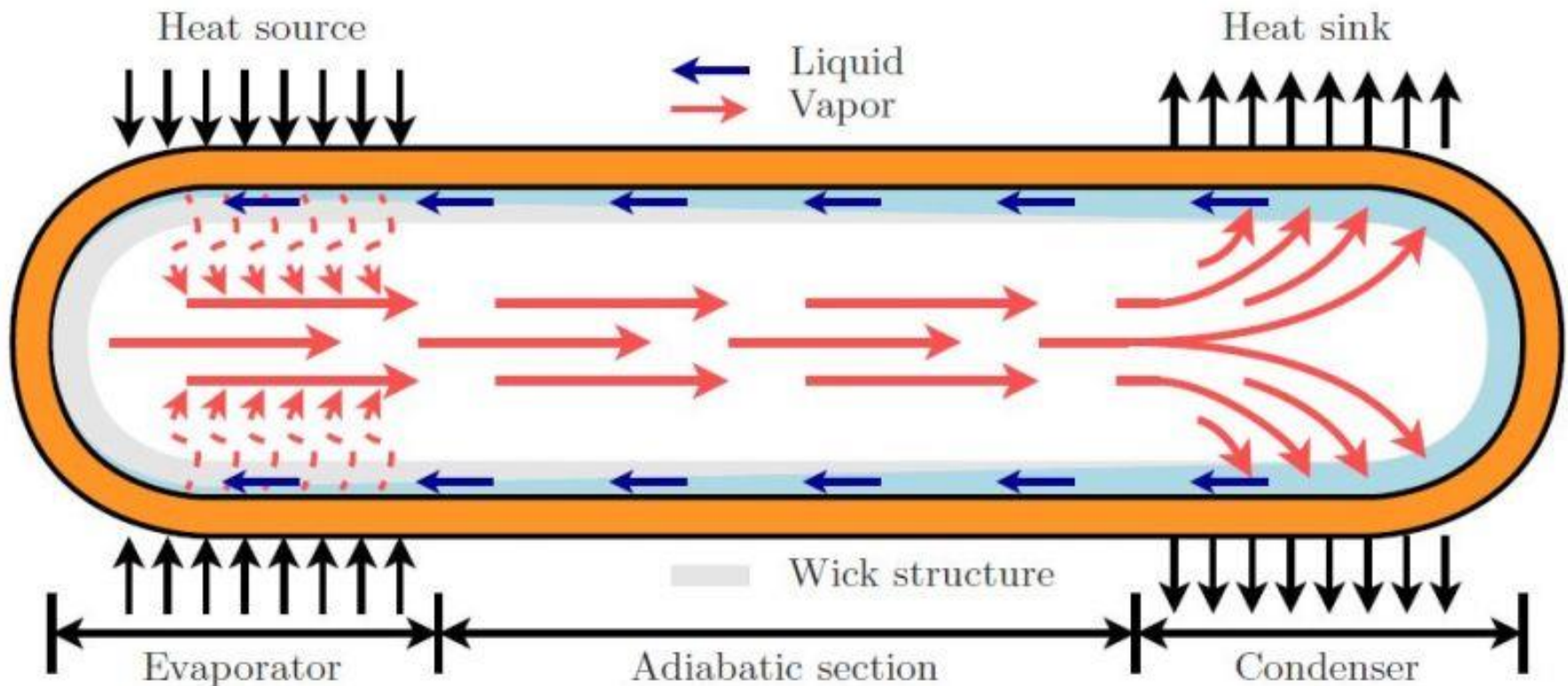
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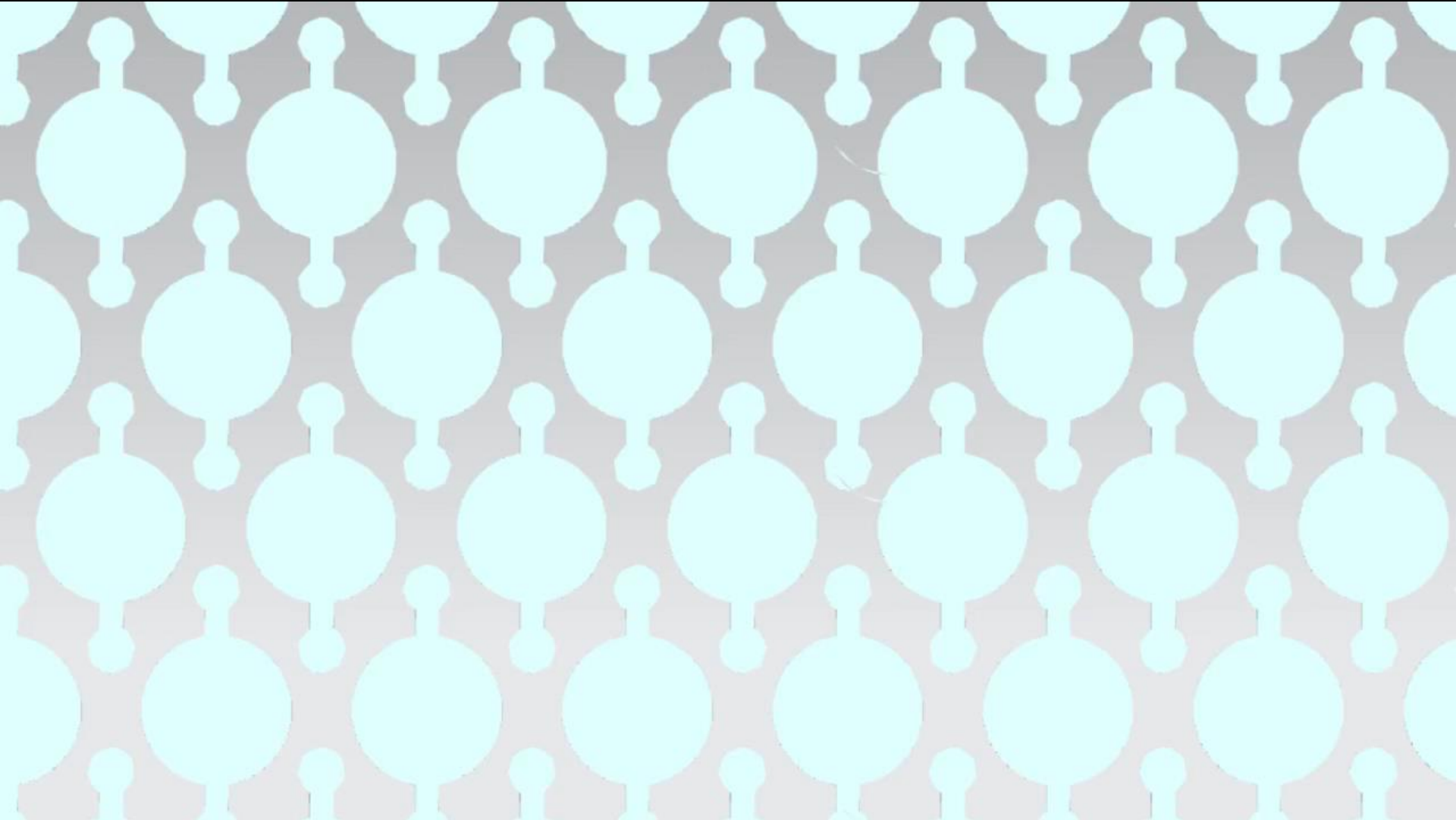
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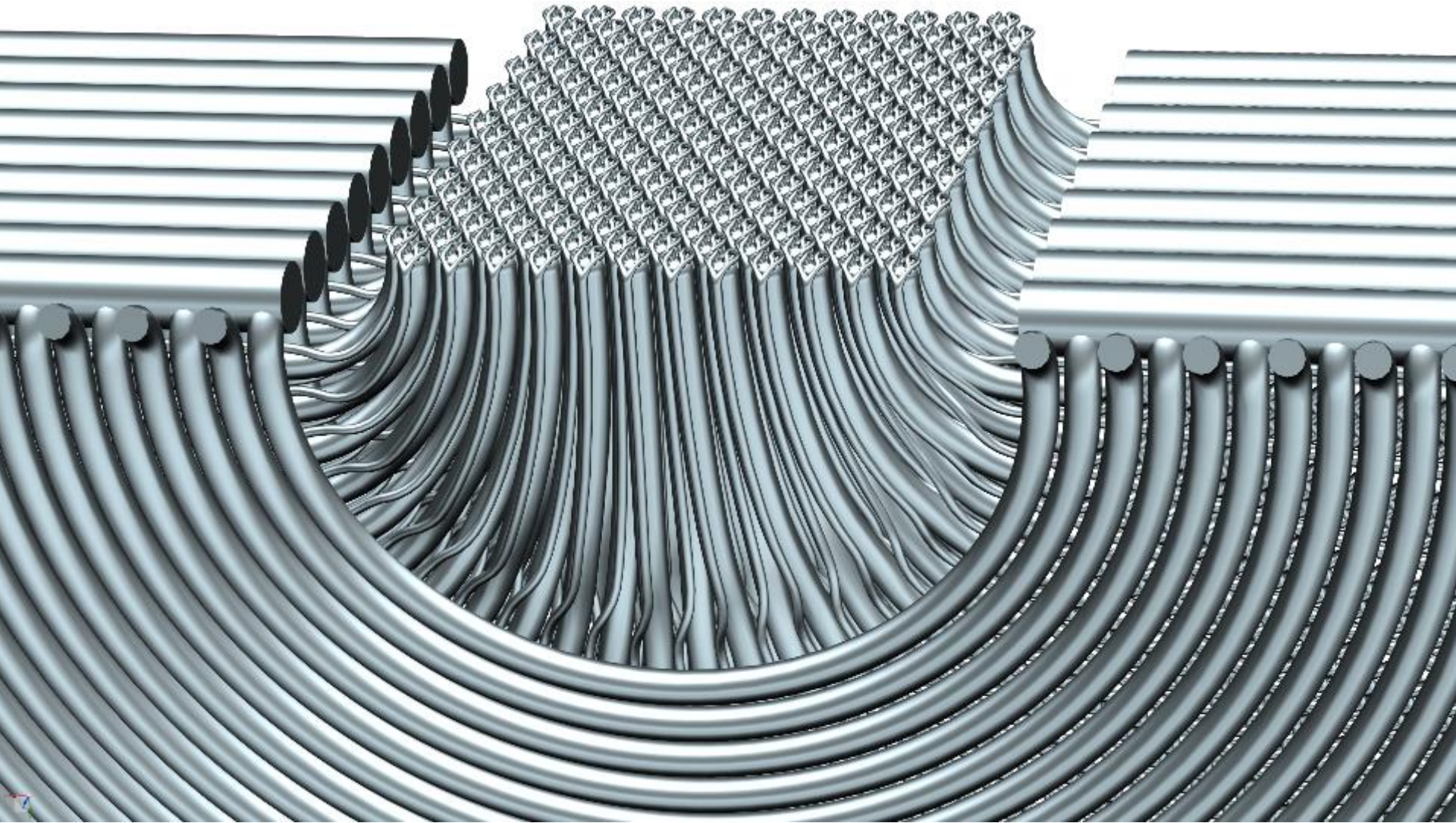
Heat pipe

- Closed system
- Two-phase working fluid
- Capillary pumped





Heat pipe array



Project goals

- **Ultimate goal:** Develop a heat pipe array to withstand the plasma exhaust on the divertor of a commercial fusion reactor during its lifetime.
- **Company goal:** Investigate and gain experience with 3D-printed heat pipes for other applications.

Phase	Working fluid	Envelope	Structure	Heat flux requirement
I	Water	Titanium	Single	5 MW/m ²
II	Water	Titanium	Array	5 MW/m ²
III	Sodium + Potassium	Tungsten	Single	10 MW/m ²
IV	Lithium / Sodium	Tungsten	Array	20 MW/m ²

Project goals

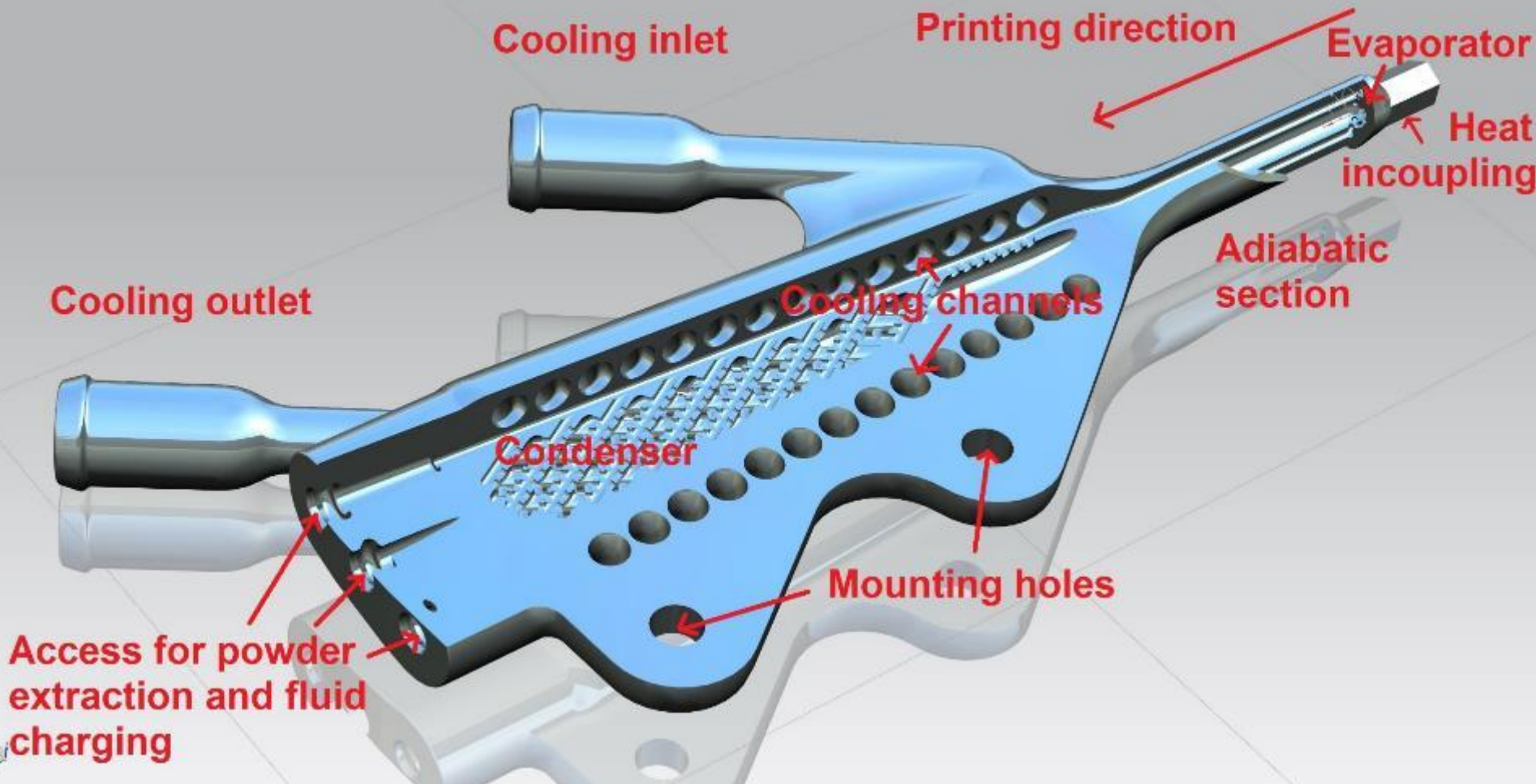
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Plan of approach

- **Functional, robust prototype**
 - Design nominal single heat pipe
 - 3D-print, CT-scan and prepare heat pipe
 - Construct experimental setup and test functionality
- **Design of Experiments**
 - Design variations of heat pipe
 - Improve experimental setup and test heat flux
- **Determine optimal dimensions**

Single heat pipe

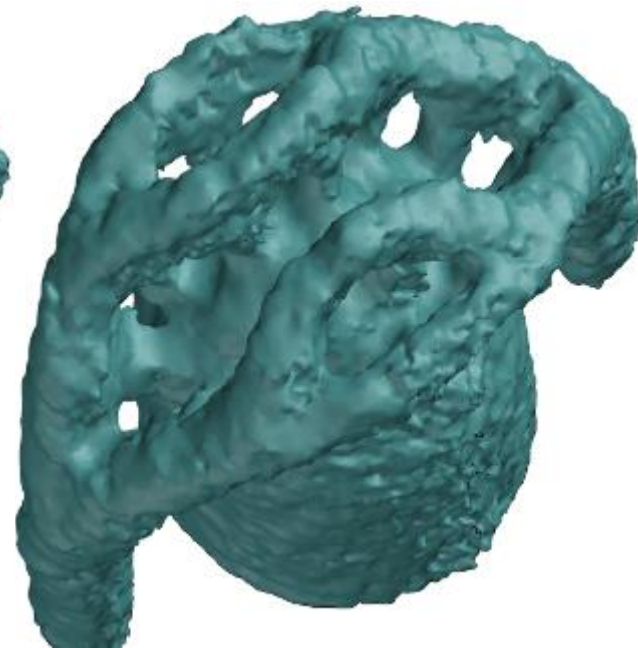
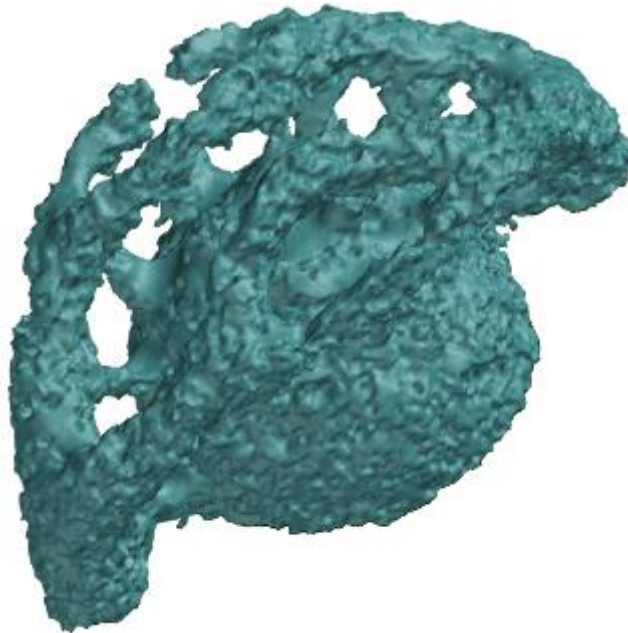


CT-scan

CAD

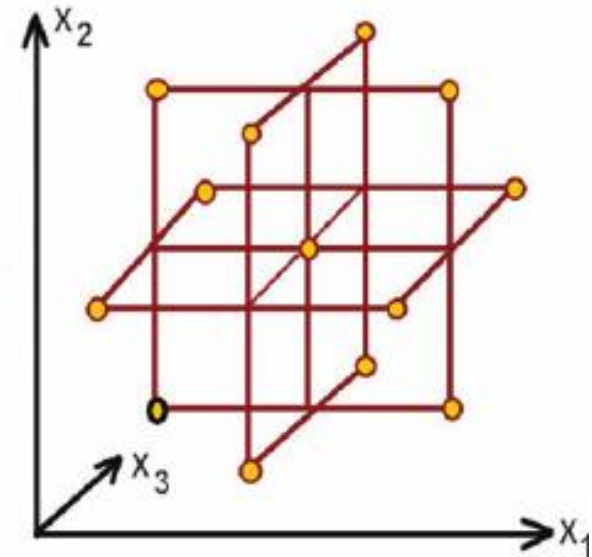
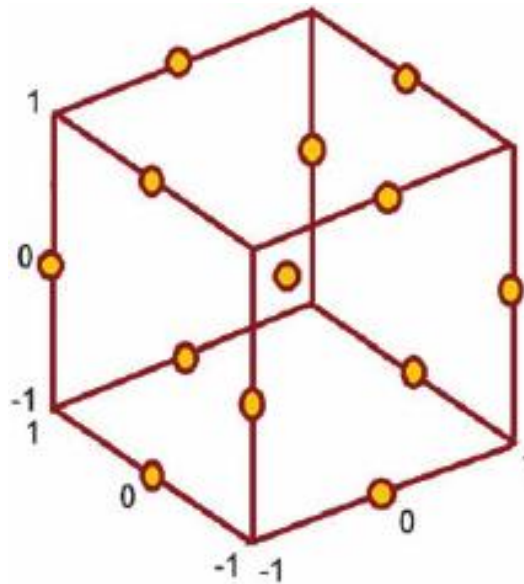
0.22 mm

0.25 mm



Design of Experiments

- **Response variable: Heat flux**
- **Factors:**
 - Artery diameter
 - Vapour core diameter
 - Condenser length
- **Design: Box-Behnken**
 - 3 levels
 - 12 edge points
 - 1 center point



Current status and future work

- **Current status**
 - Successful procedure for preparing heat pipes
 - Heat pipes have been tested up to 1.1 MW/m^2
 - Input power is limited in current setup
- **Near future**
 - Increase input power
 - Perform design of experiments
- **Far future**
 - Create tungsten-liquid metal heat pipe array
 - Build fusion power plant...

Questions

- Thank you for your attention
- Any questions?



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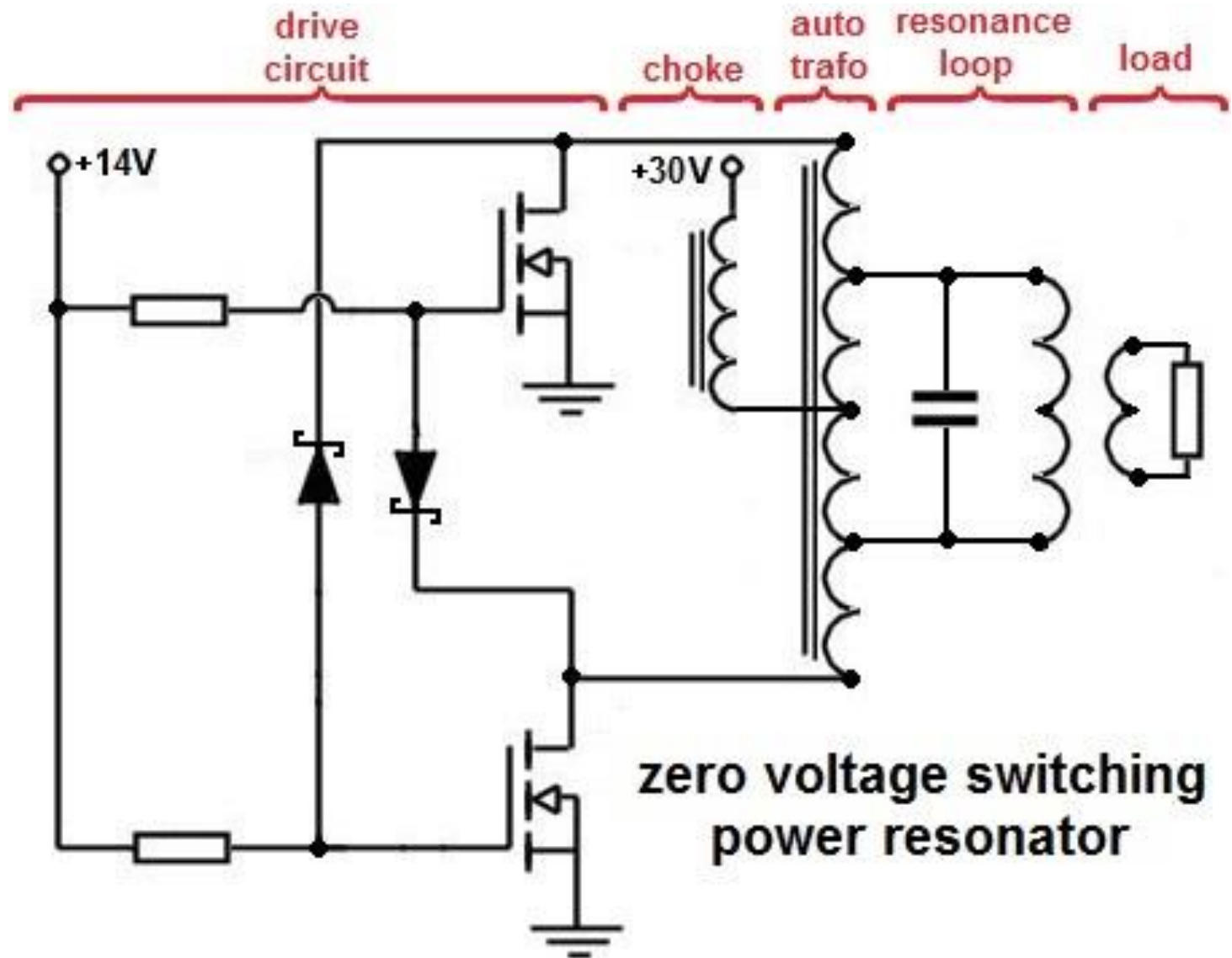


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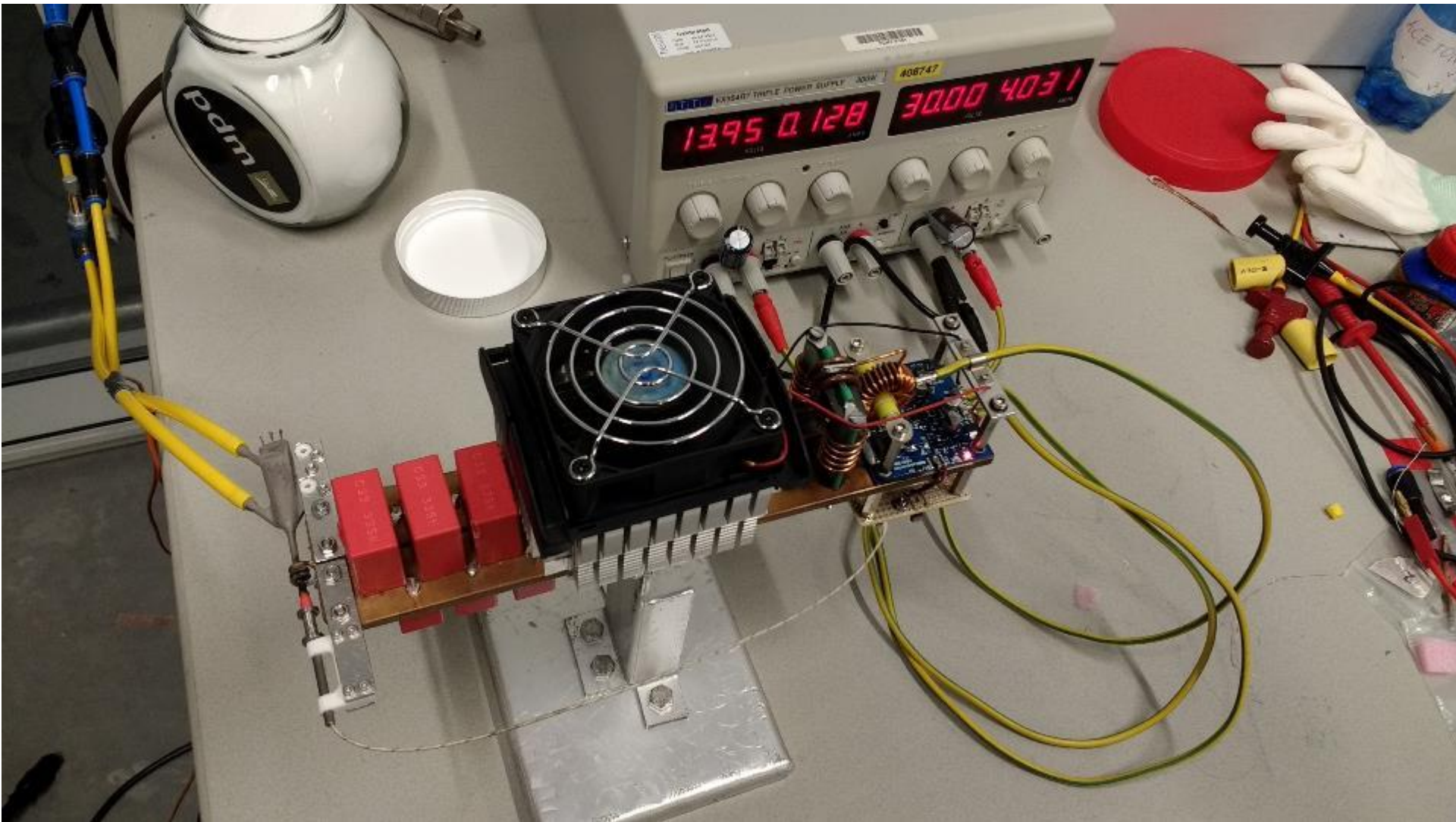


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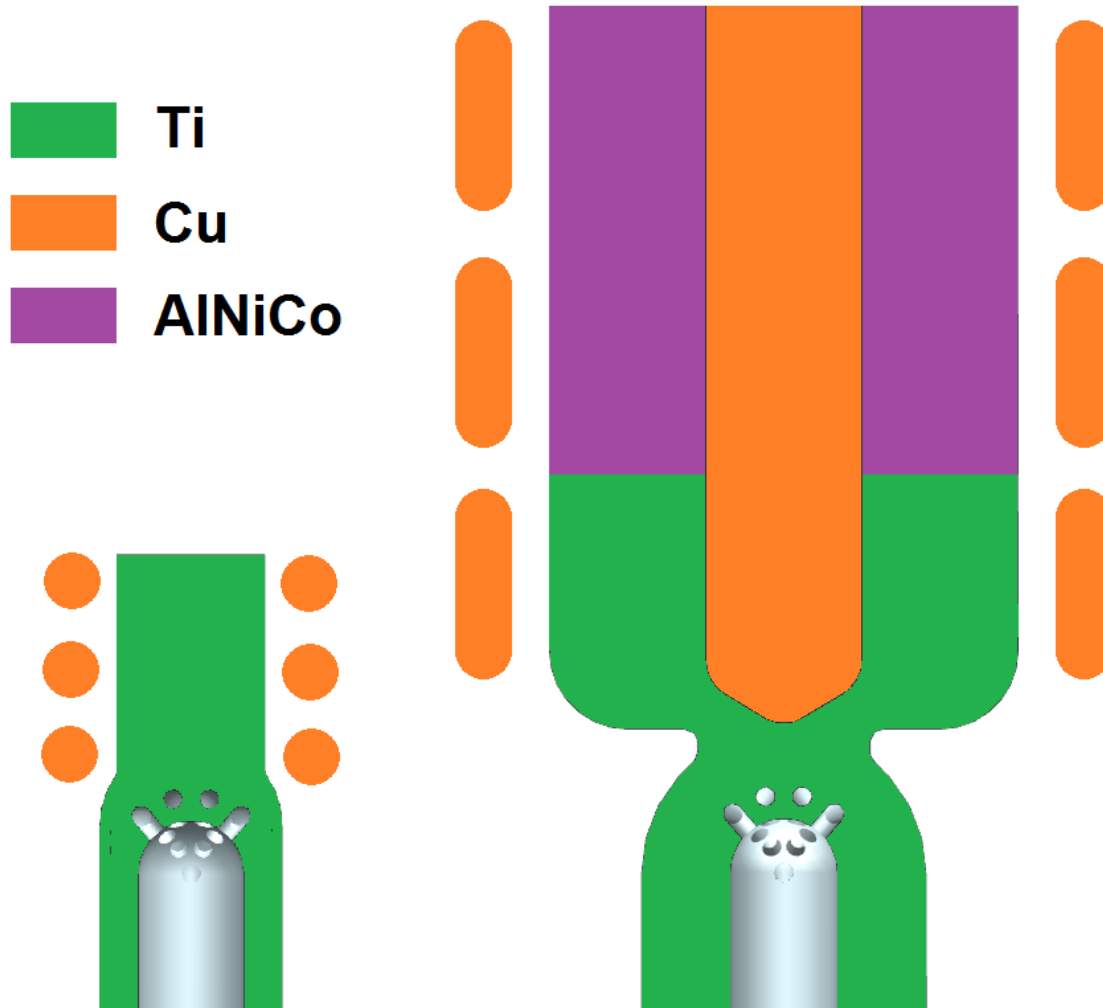
Induction heater schematic



Experimental setup

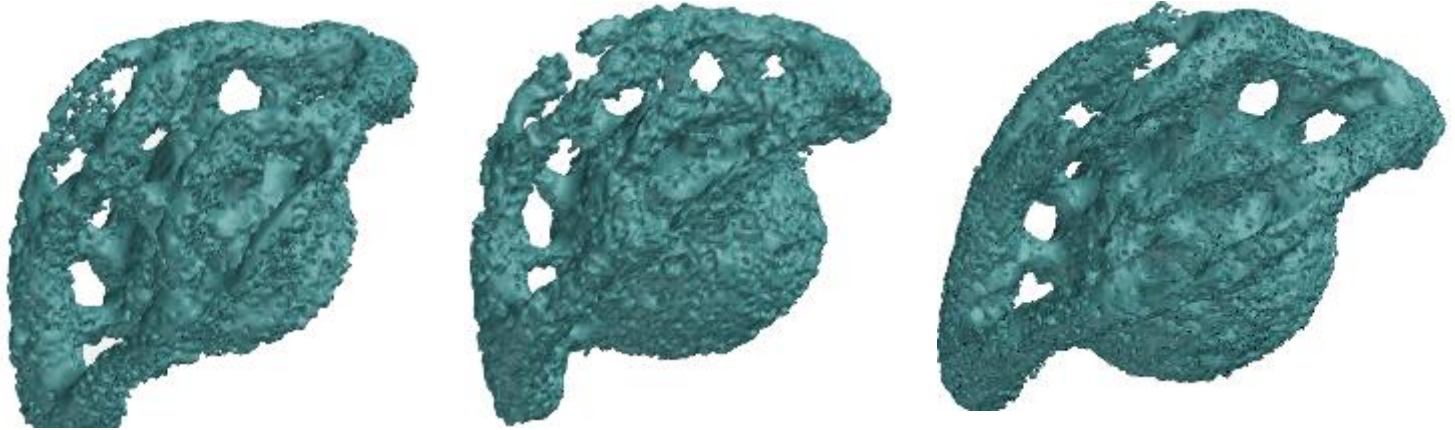


Improved induction heater

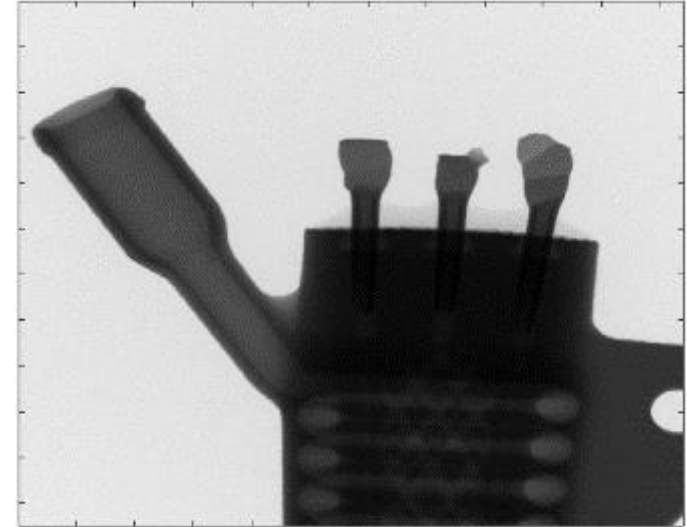
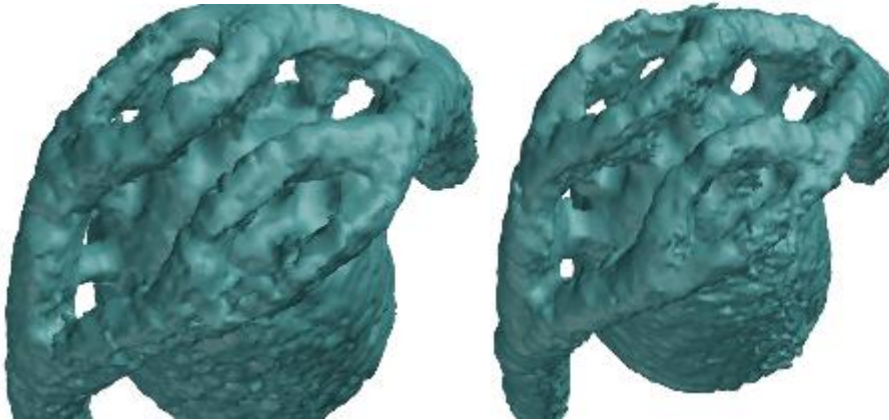


Additional CT-scan images

- 0.22 mm

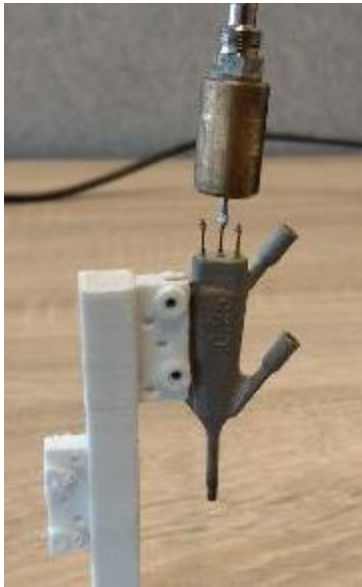


- 0.25 mm

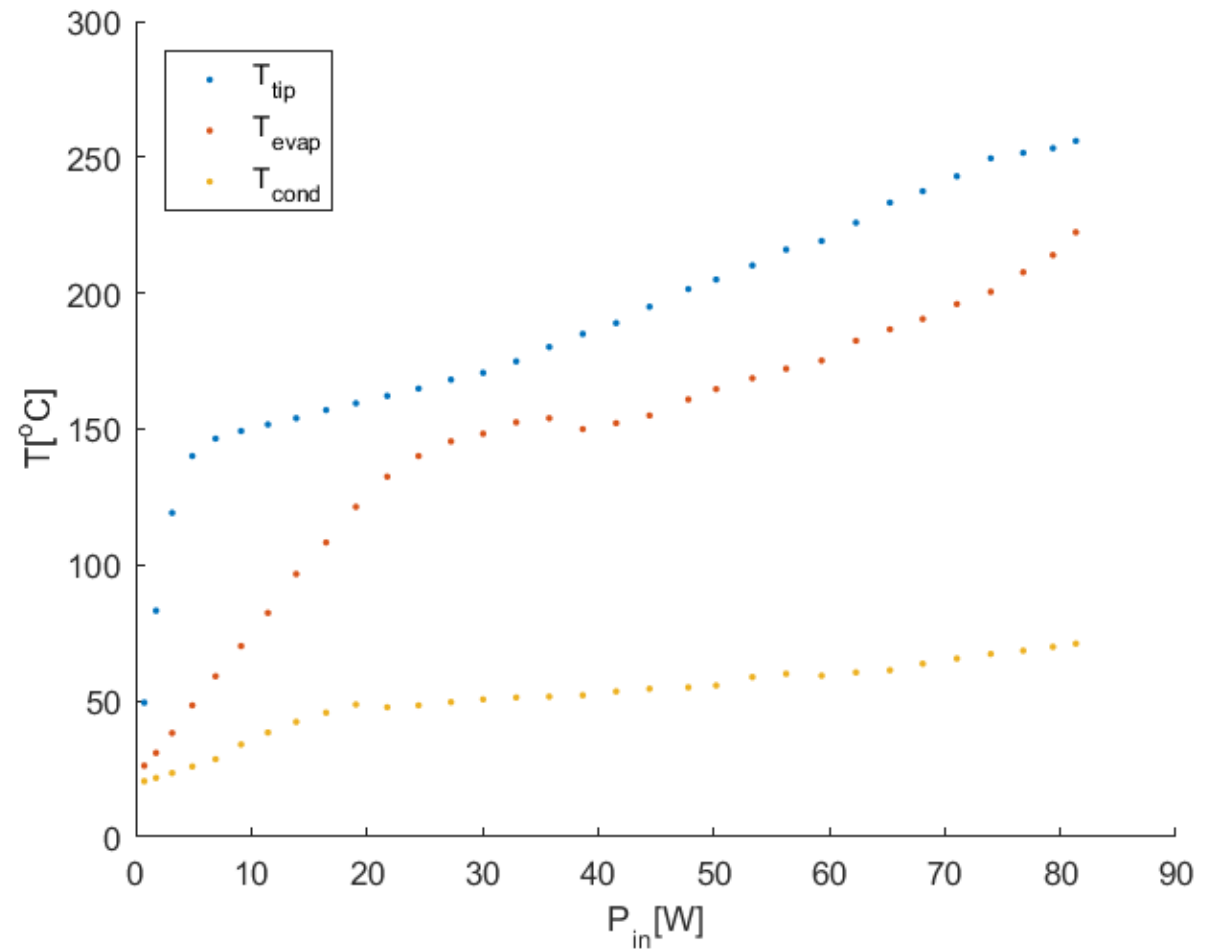


Preparation of heat pipes

- Tap copper tubes into access holes
- Fix tubes to heat pipe with two-component epoxy
- Insert predetermined amount of water and freeze
- Apply vacuum, pinch off tubes and solder caps



Heat pipe characteristics



Miscellaneous

