EUROfusion

Task 4. Model capillary and surface liquid flow and heat flows in realistic conditions for CPS/microchannel array
Task 5. Study microchannel flow in high magnetic field

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Results in 2020

Tasks:

4. Model capillary and surface liquid flow and heat flows in realistic conditions for CPS/microchannel array

5. Study microchannel flow in high magnetic field

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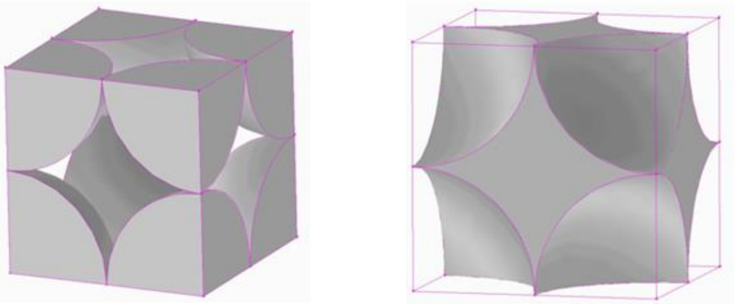
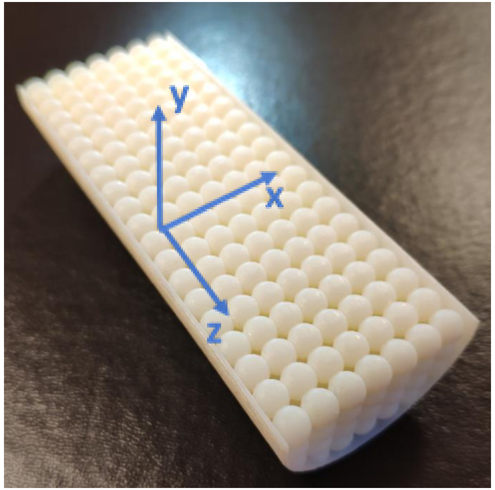
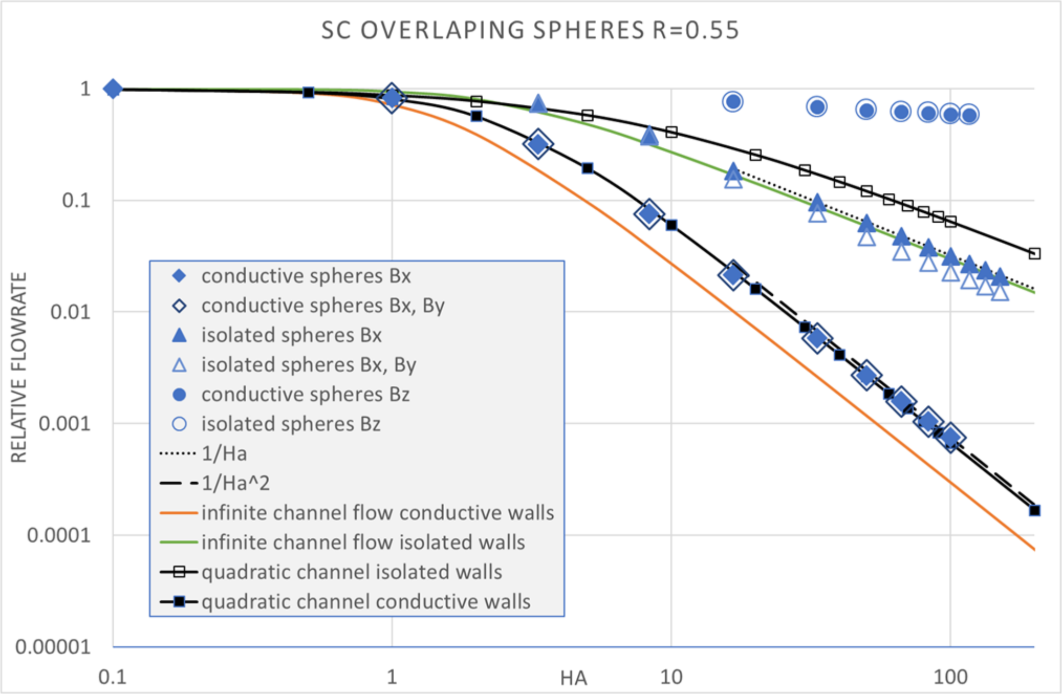
Computational cell of used BCC pore model solid matrix and pore space



B_x and B_{xy} orientations of magnetic field



5. Study microchannel flow in high magnetic field



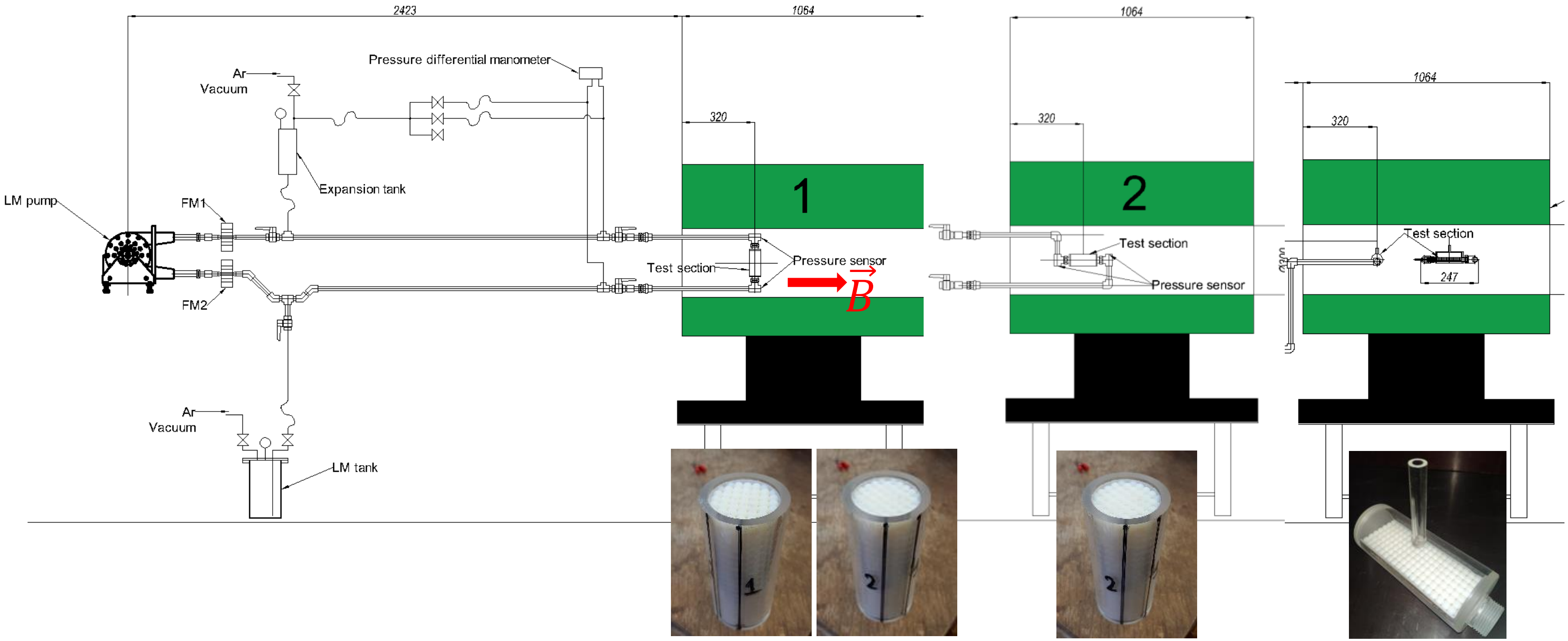
Numerical simulations

For magnetic field orientation perpendicular to the main flow, electrical conductivity of porous matrix are essential. Isolated spheres tend to have asymptotic behavior as 1/Ha, but ideally conducting as $1/Ha^2$, what is in accordance with theory for infinite and rectangular channel flows in strong magnetic field. That means that for high magnetic fields nonconductive solid matrix is preferable if convective heat transport is to be considered important, because the flowrate ratio between these two cases grows as Ha.

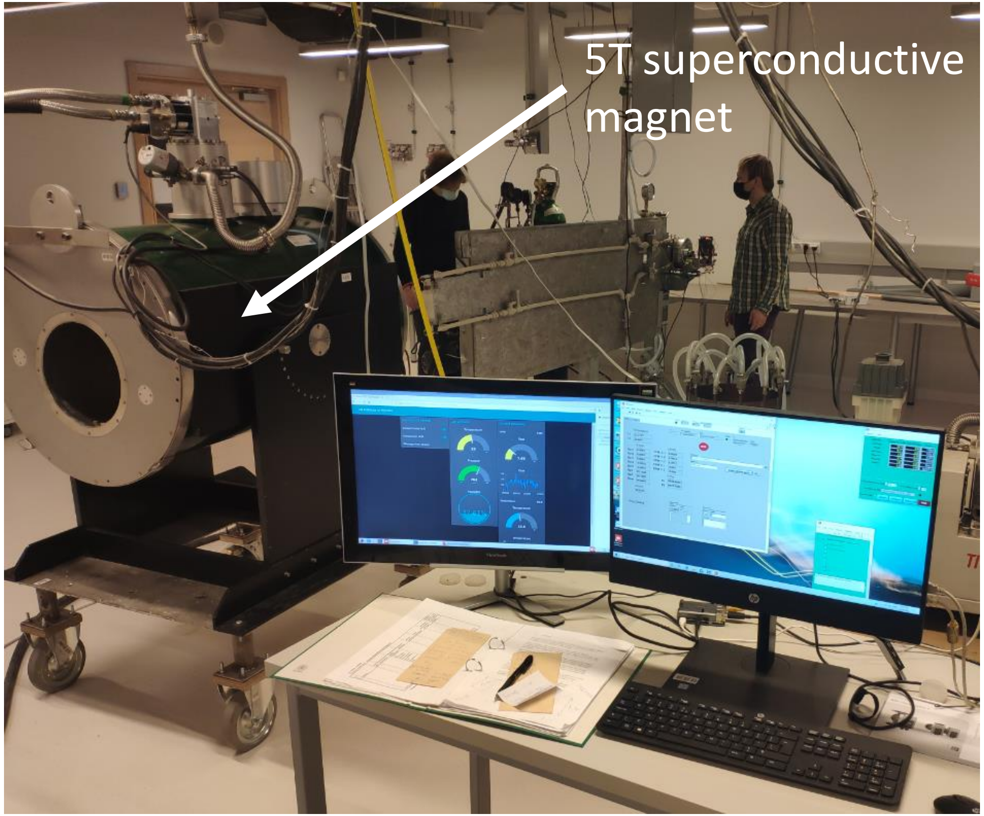
Experimental facility with 5T superconducting magnet

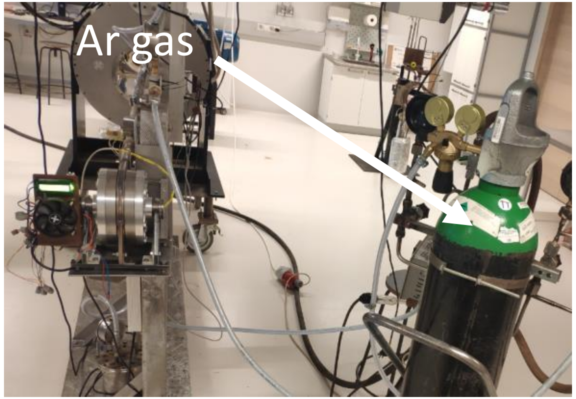
Task 5

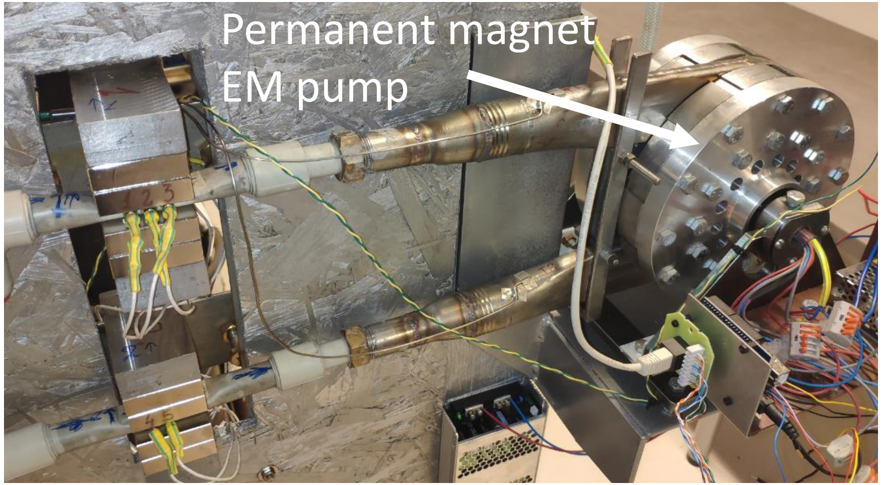
Task 4



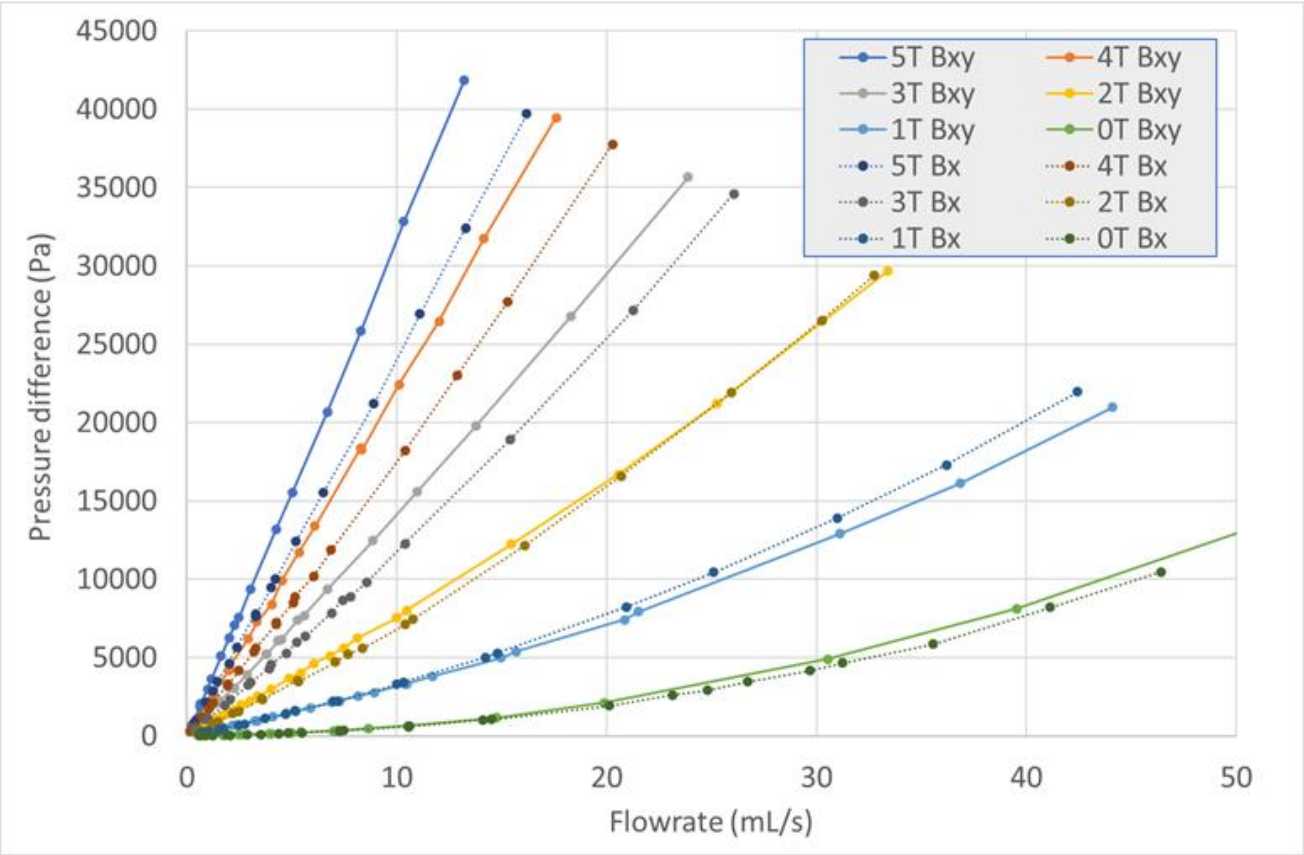
Experimental facility with 5T superconducting magnet







Experimental P-Q curves for B_x and B_{xy} orientation of magnetic field



Nondimensional numbers depending on flowrate and magnetic field

$$Re = \frac{Inertial\ forces}{Viscous\ forces} = \frac{U_0 L}{\upsilon}$$ - Reynolds number

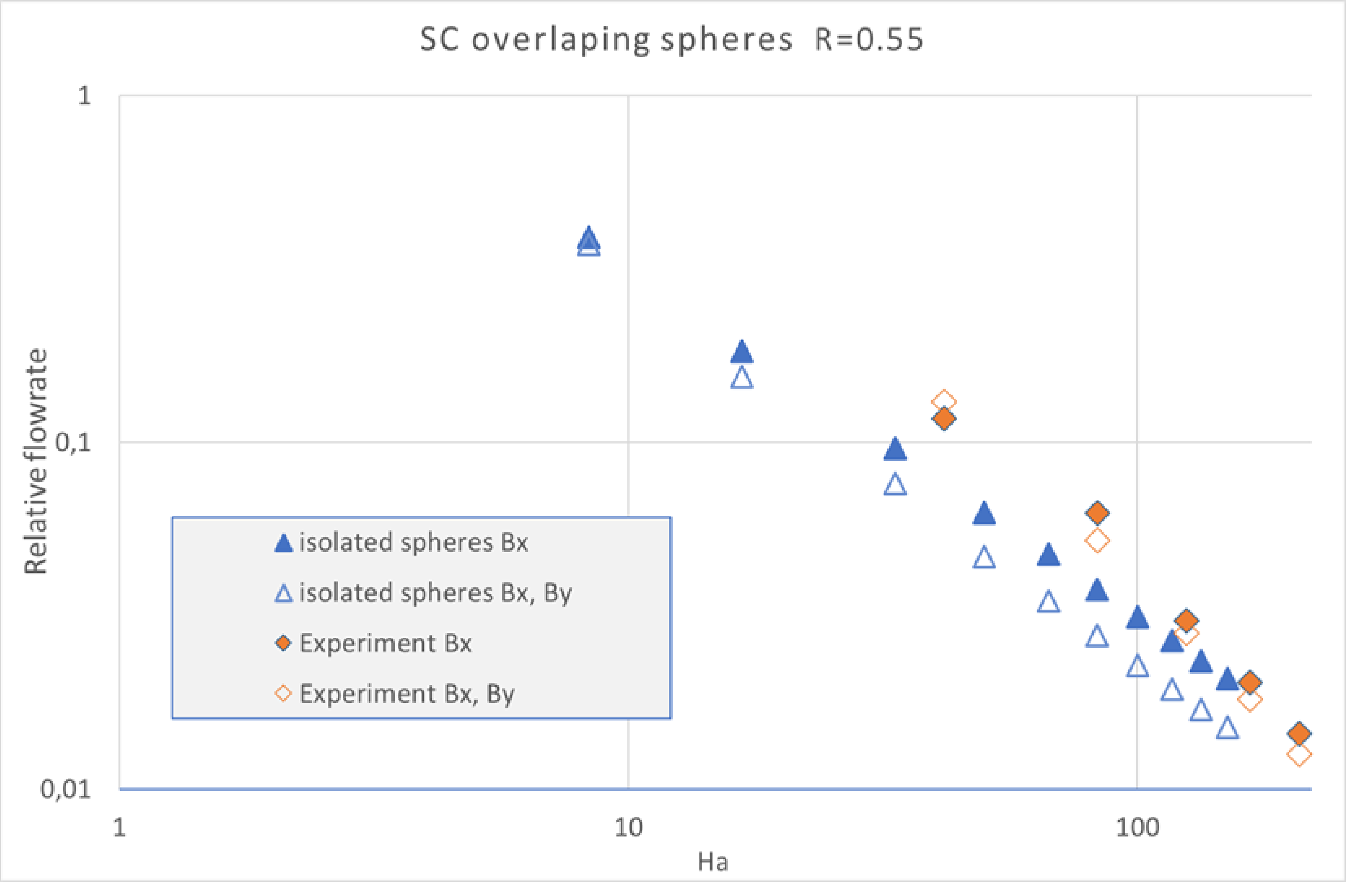
$$Ha = \left(\frac{Electromagnetic\ forces}{Viscous\ forces}\right)^{1/2} = B_0 L \sqrt{\frac{\sigma}{\upsilon\rho}}$$ - Hartmann number

$$N = \frac{Electromagnetic\ forces}{Inertia\ forces} = \frac{Ha^2}{Re} = \frac{\sigma B_0^2 L}{\rho U_0}$$ - Stuart number (interaction parameter)

$$Ca = \frac{Viscous\ forces}{Capillary\ forces} = \frac{\upsilon\rho U_0}{\gamma}$$ – Capillary number

$q\left(\frac{mL}{s}\right)$	$Re = \frac{U_0 L}{\upsilon}$	$Ca \cdot Re = \frac{\rho U_0^2 L}{\gamma}$	$N = \frac{Ha^2}{Re}$				
			$B_0 = 1\ T$, $Ha = 36$	$B_0 = 2\ T$, $Ha = 72$	$B_0 = 3\ T$, $Ha = 108$	$B_0 = 4\ T$, $Ha = 144$	$B_0 = 5\ T$, $Ha = 180$
1	46.36	0.001	27.99	111.95	251.89	447.80	699.69
10	463.60	0.13	2.80	11.20	25.19	44.78	69.97
50	2318.00	3.28	0.56	2.24	5.04	8.96	13.99

Comparison of experiment and numerical simulations



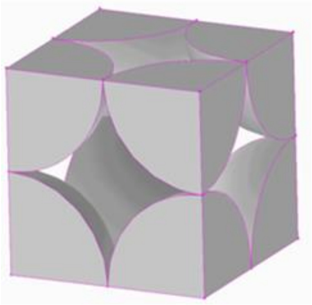
Key results (2020)

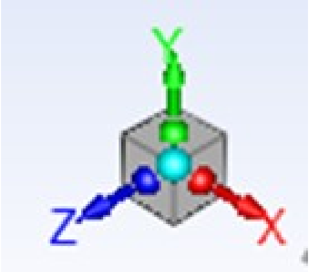
- SC based test sections are prepared without and with free metal surface
- New low flowrate conduction type flowmeters are fabricated and calibrated with volumetric method
- New type permanent magnet electromagnetic pump for low flowrate is designed, fabricated and tested
- Maintenance of superconductive 5T magnet has been carried out and magnet prepared for experiments (bigest delay due to the Covid)
- Experimental session is finished (three SC orientations in magnetic field – Task 5, one – Task 4, all up to 5T)

Tasks for 2021 and beyond :

Task1: Study pore structure symmetry and current influence on flow in high magnetic field

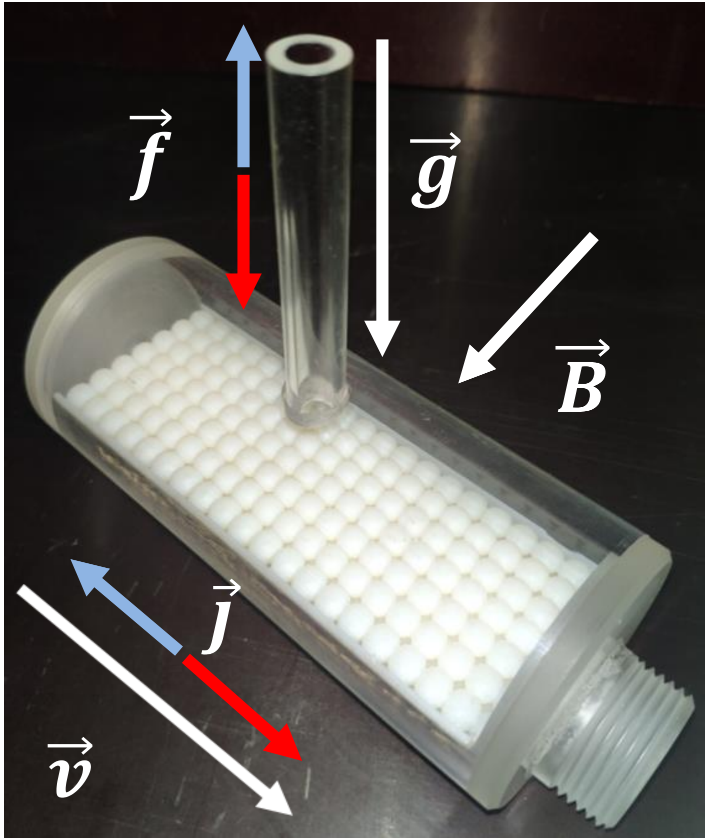
- Investigating more complex flow in periodic porous matrix, with several velocity components for main flow (previously only z-component)
- This leads to different flow interaction with magnetic field, for instance there is no possibility for flow alignement with magnetic field direction
- Investigating macroscopic electric current influence on the flow
- The origin of the current is twofold: applied outside or closing of the induced currents due to the finite size and conductive walls of construction



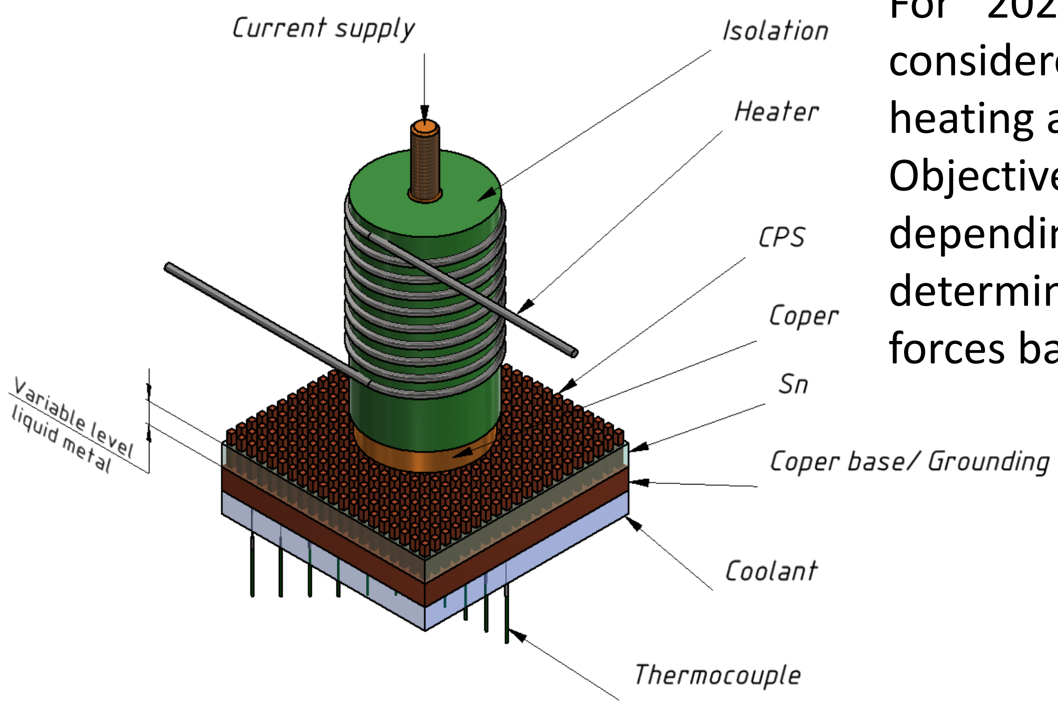


Future plans Task 2: Study externally applied electric current impact on the capillary and surface liquid flow in CPS/microchannel array

- The current with density $\vec{j}$ is applied in flow direction $\vec{v}$
- The interaction of current with magnetic field results in force with density $\vec{f} = \vec{j} \times \vec{B}$ which is colinear with $\vec{g}$ thus allowing effectively change the gravity force
- Changing the gravity, the stability of capillary surface is modified
- For capillary surface oriented non-horizontally, the force is oriented perpendicularly to the surface which prevents spilling out of liquid metal
- Experimental studies using the created facility and numerical studies are planned



Task 2: Study externally applied electric current impact on the capillary and surface liquid flow in CPS/microchannel array

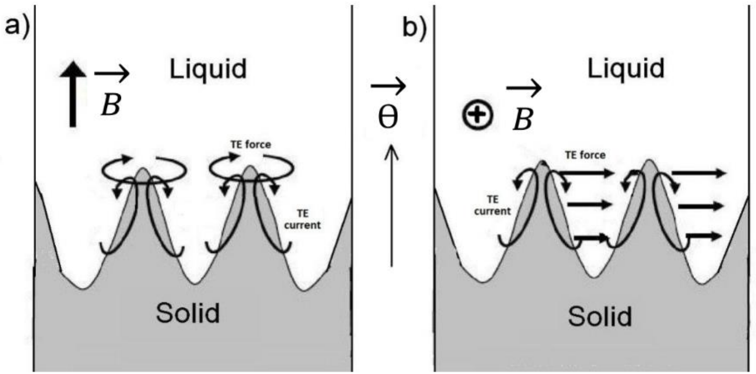


For 2022 – 202x the nonisothermal case is considered with test section with Sn surface heating and current through the test section.

Objective: investigation of heat transfer depending on liquid metal level in cps which is determined by gravitational, capillary and EM forces balance.

Task 3: Investigation of thermoelectric-magnetic effects in liquid metal CPS under high magnetic field

- In LMD solutions, CPS is subjected to high magnetic field (***B***) and large thermal gradient (***Θ***)
- Depending on materials in such conditions thermoelectric-magnetic force can became significant, even dominant
- W, Co, Ni and alkali metals have exceptionally high Seebeck coefficients *S* and high electric conductivity *σ*
- It is planned to do numerical and experimental studies to investigate CPS and free surface behavior under high magnetic field and thermal gradient
- TE force can be as high as 10^7 N/m^3 ($f = \Theta \sigma B \cdot \Delta S$). Typical numbers for W-Sn CPS: Θ=100 K/mm, $\sigma = 10^7$ S/m, B=5 T, ΔS=10 μV/K



- Different magnetic field orientation causes different liquid phase flow
- Our previous theoretical studies show that TE force is pushing liquid phase away from the hottest zone