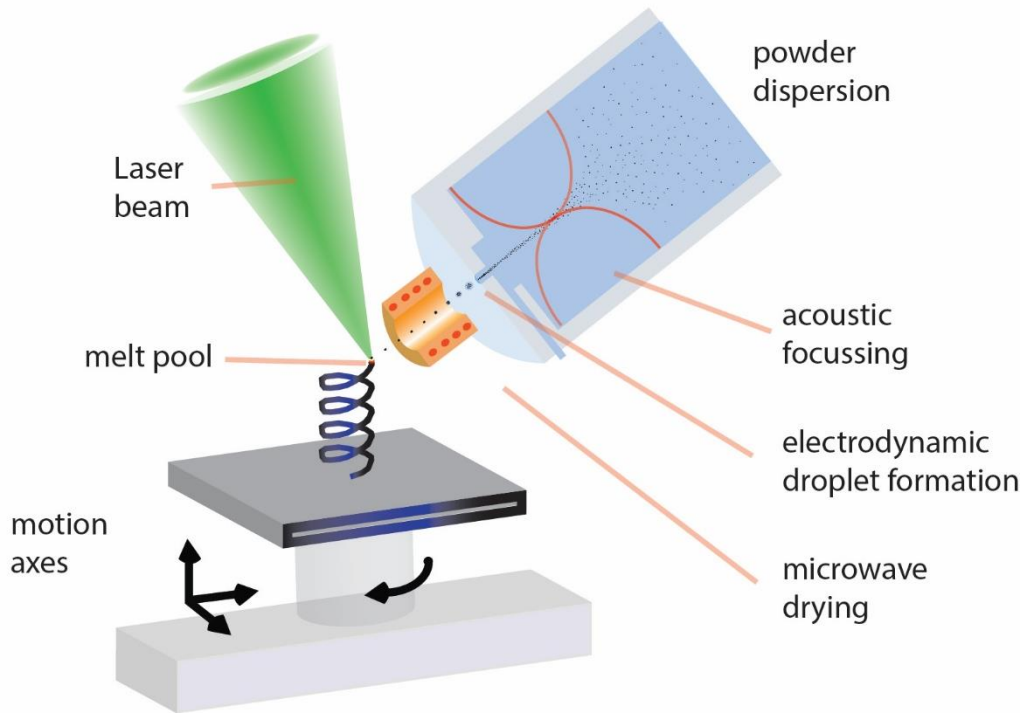
Powder focusing for beam induced laser 3D printing



Teams complete - project on track

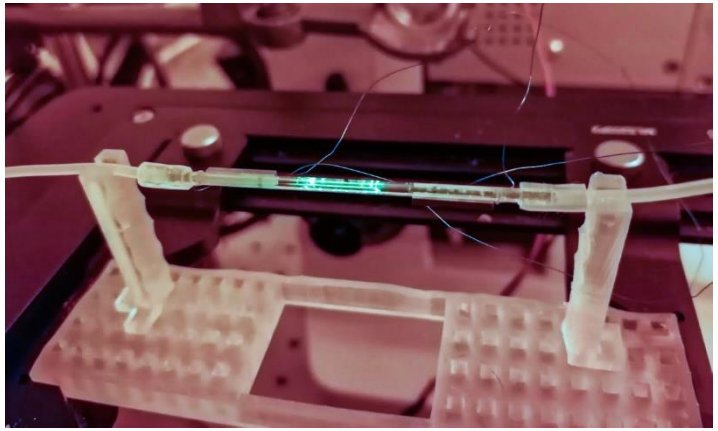
Copper + Silicon as powders selected

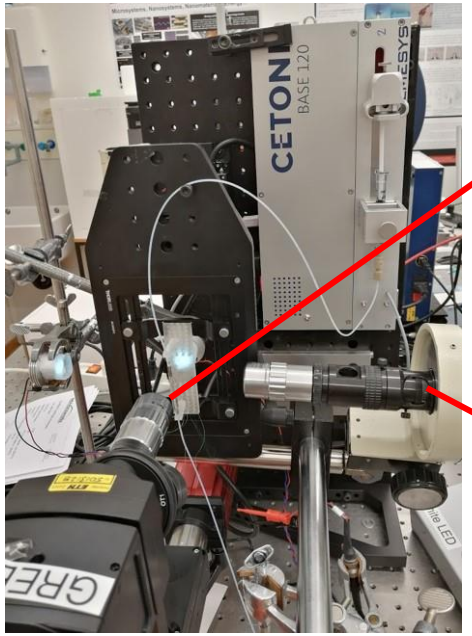
Sub-systems ready

- Powder focusing
  ETHZ IMES J. Dual, PhD Michael Gerlt
- Electrohydrodynamic droplet formation
  ETHZ LTNT D. Poulikakos, PD Patrik Rohner
- Powder drying on flight
  PSI M. Pouchon, PhD Kwanghoon Choi
  Empa S. Vaucher
- Simulation of liquid – particle drying process
  EPFL LFMI F. Gallaire, PhD Shahab Eghbali
- Integration into focused laser 3-D printing system
  Empa LAMP P. Hoffmann, PD B. Lanfant
  Dr. S. Vaucher, Dr. M. Leparoux

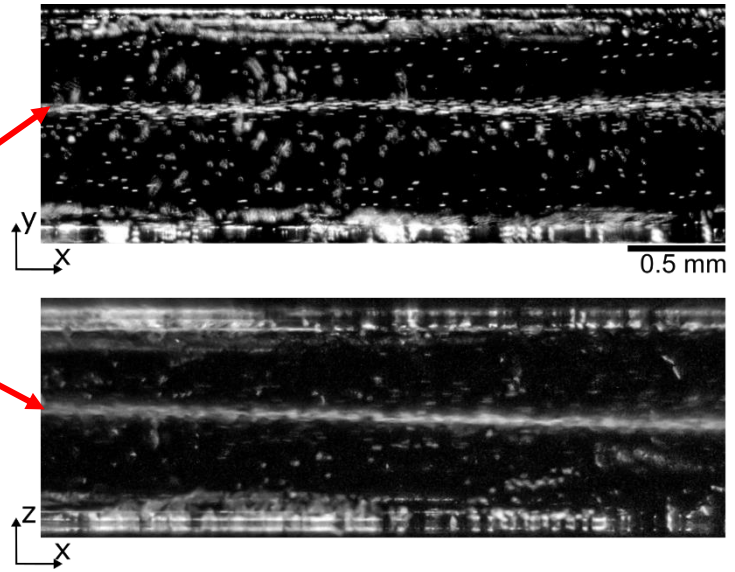
Acoustic powder focusing

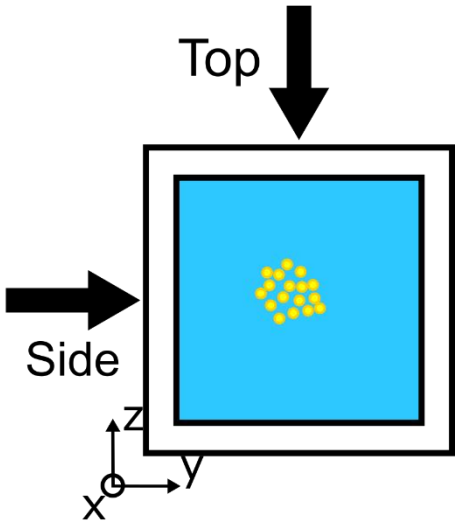
Experimental Setup





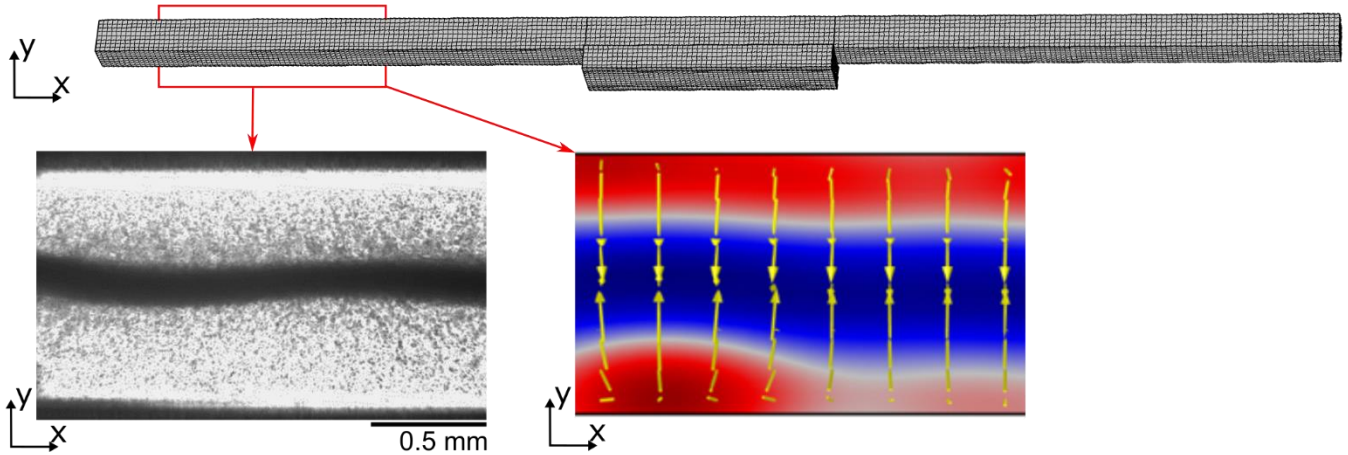
PS Particle - d = 5 µm



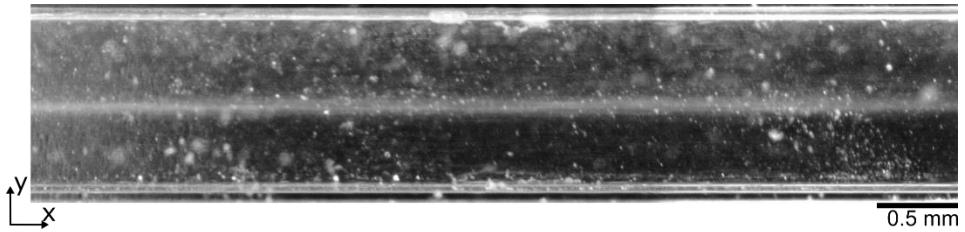


Top: 57 µm ± 28 µm, Side: 89 µm ± 25 µm.

3D Numerical Model



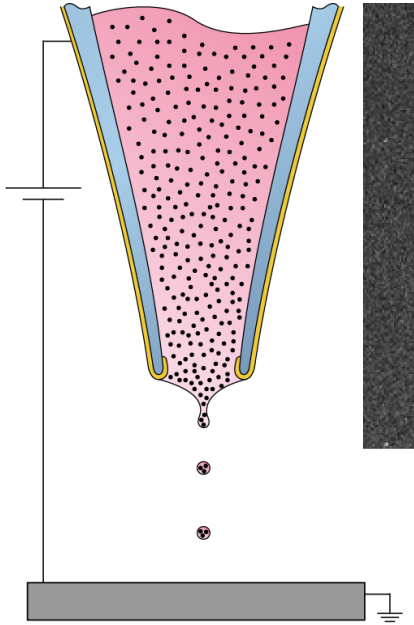
Silicon shards - d= 0-15 µm

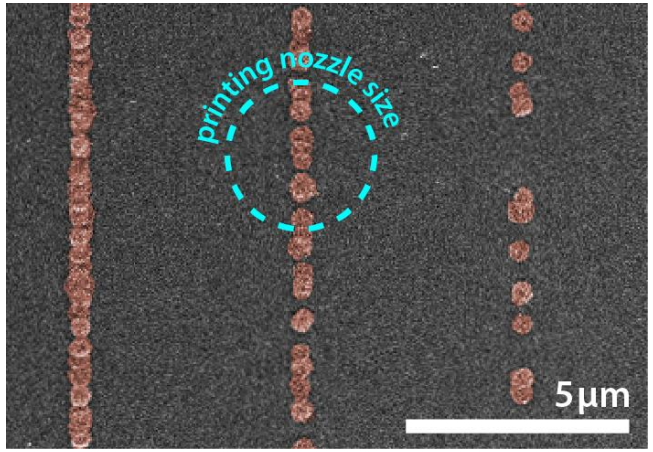


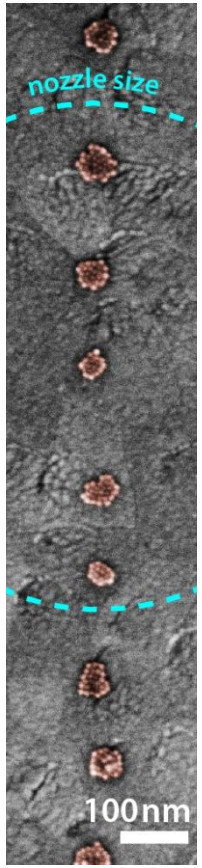
Linewidth: 92 µm ± 17 µm.

Electrohydrodynamic printing

- Micro- / nanodripping mode

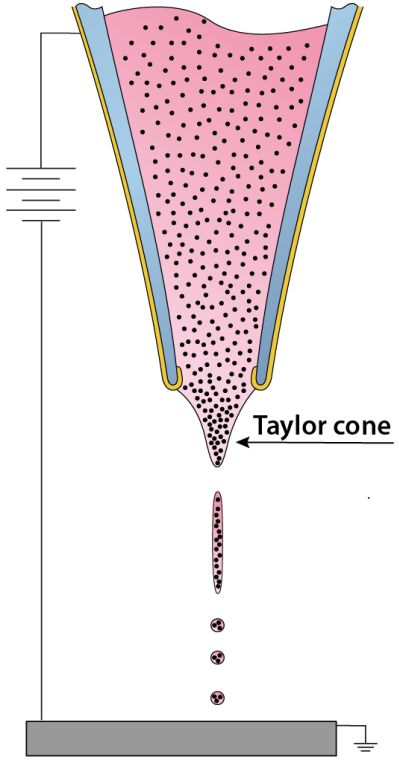


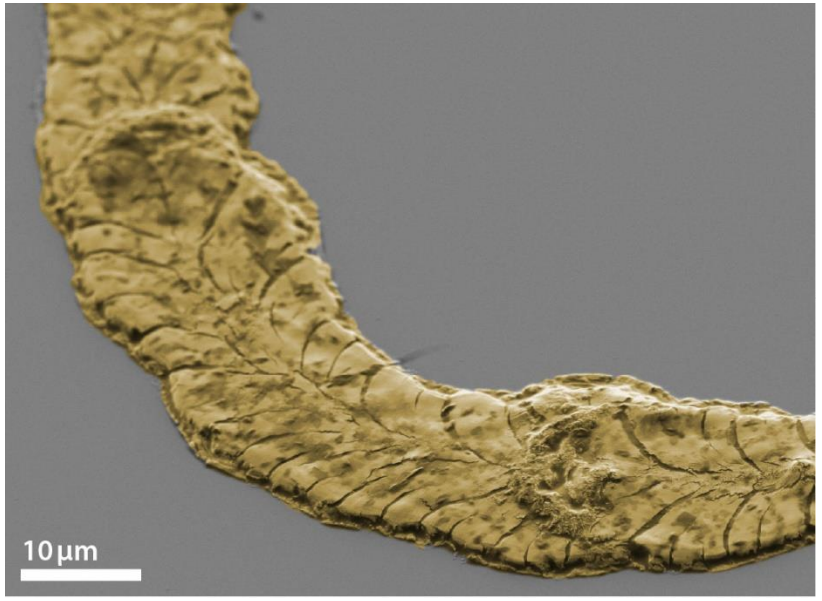




- Nanoparticles used: CdSe quantum dots, d = 8 nm
- Nozzles range from 800 nm to ~ 40 µm
  - Picture above: 4 µm
  - Picture on the right: 800 nm
- Dripping frequencies usually below 1 kHz

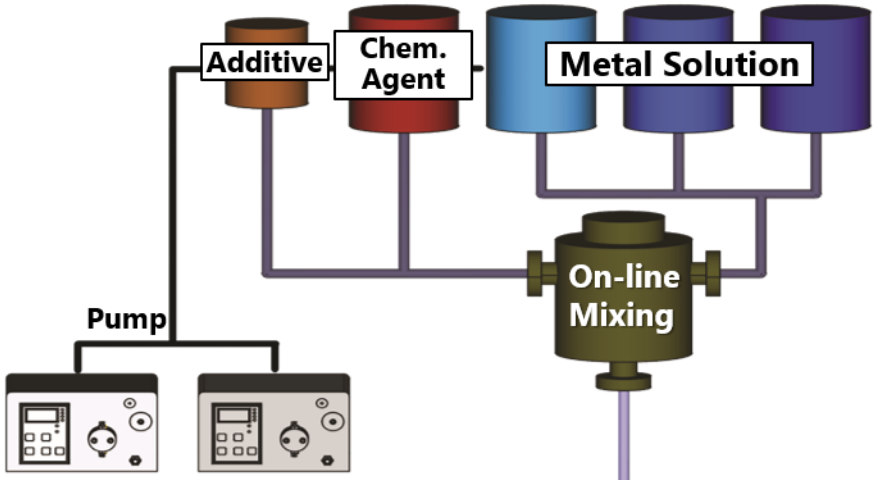
- Cone jetting mode



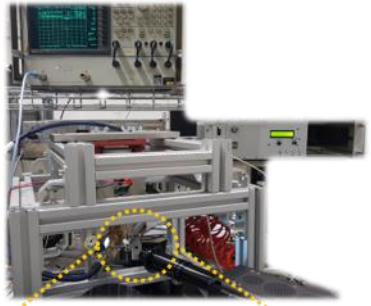


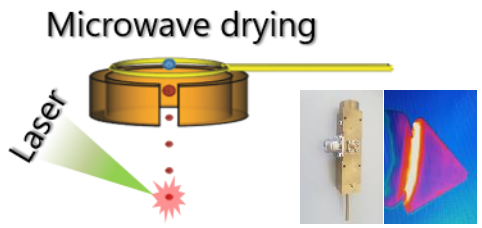
- Nanoparticles used: Gold, 5 nm
- Nozzle diameter: 30 µm
- Stage translation speed: 0.3 mm/s
- Depending on the solvent (e.g. for water), the printing resolution is now limited by the solvent evaporation

High-throughput droplet generation and microwave resonator

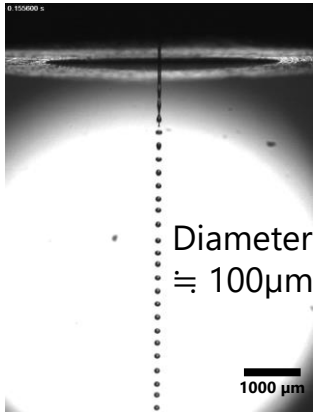


Experimental setup





High-throughput droplet generation

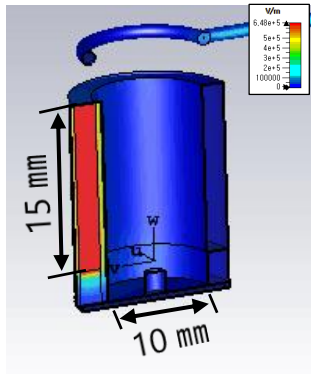


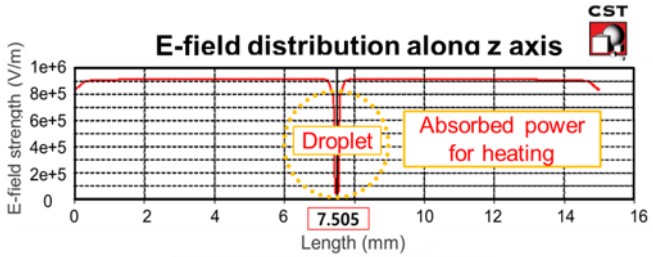
OpenFOAM

Material	Water (20°C)
Nozzle dia.	60 μm
Flow rate	0.5 ml/min
Frequency	15 kHz
Droplet size Exp. vs. Sim	3.5%

High-throughput droplet generation (15kHz) with simulation are validated.

Loop-gap resonator microwave drying





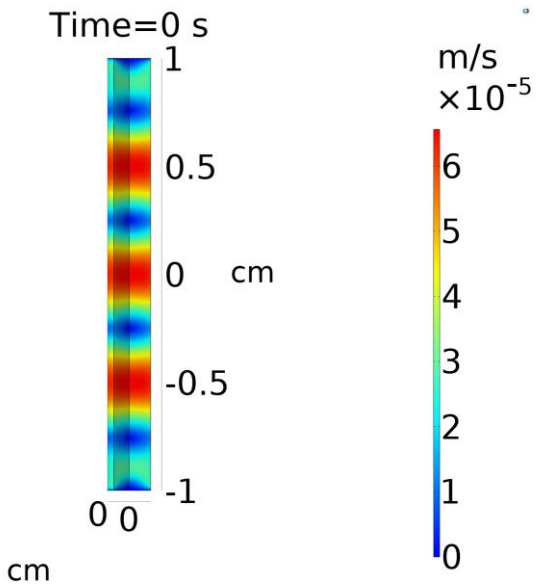
Strong and uniform E-field of resonator is designed.

- Problematic:
  - What is the effect of solid particles on laminar jet destabilization?
    - **Methodology:** Numerical Simulation
- Observations
  - Multistage non-linear modification of the pinch-off dynamics
  - **Outlook:** How to control the output of particulate jet destabilization?

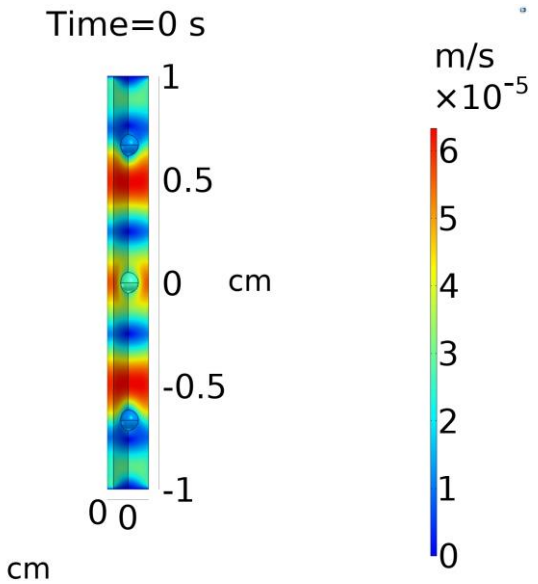
Break up time:

Parameters
$Oh = \frac{\mu}{\sqrt{\rho\gamma R}} = 10$
$R_p = 0.6$
$\rho_s/\rho = 10$

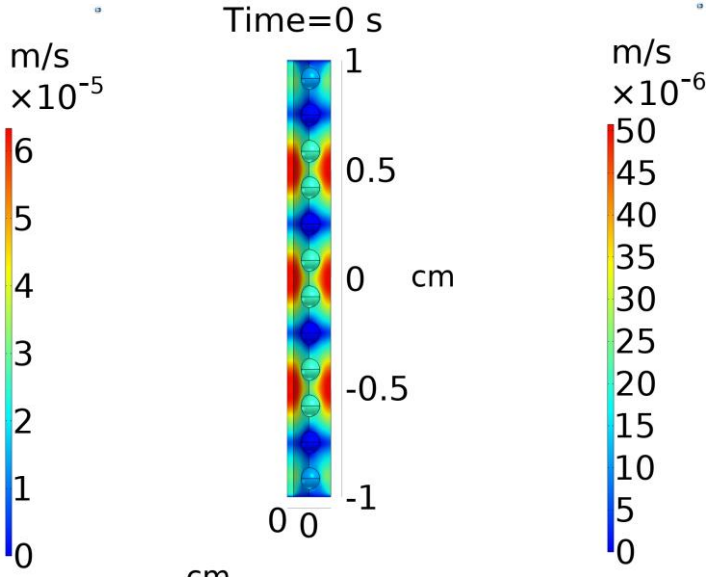
$t_p = 59ms$



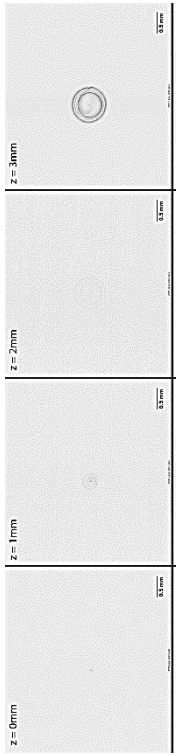
$t_p = 55ms$

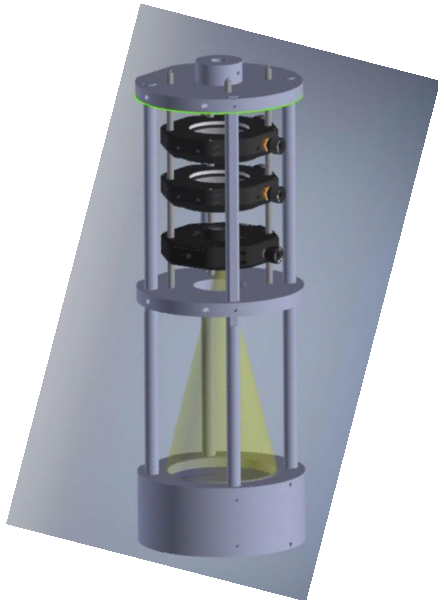


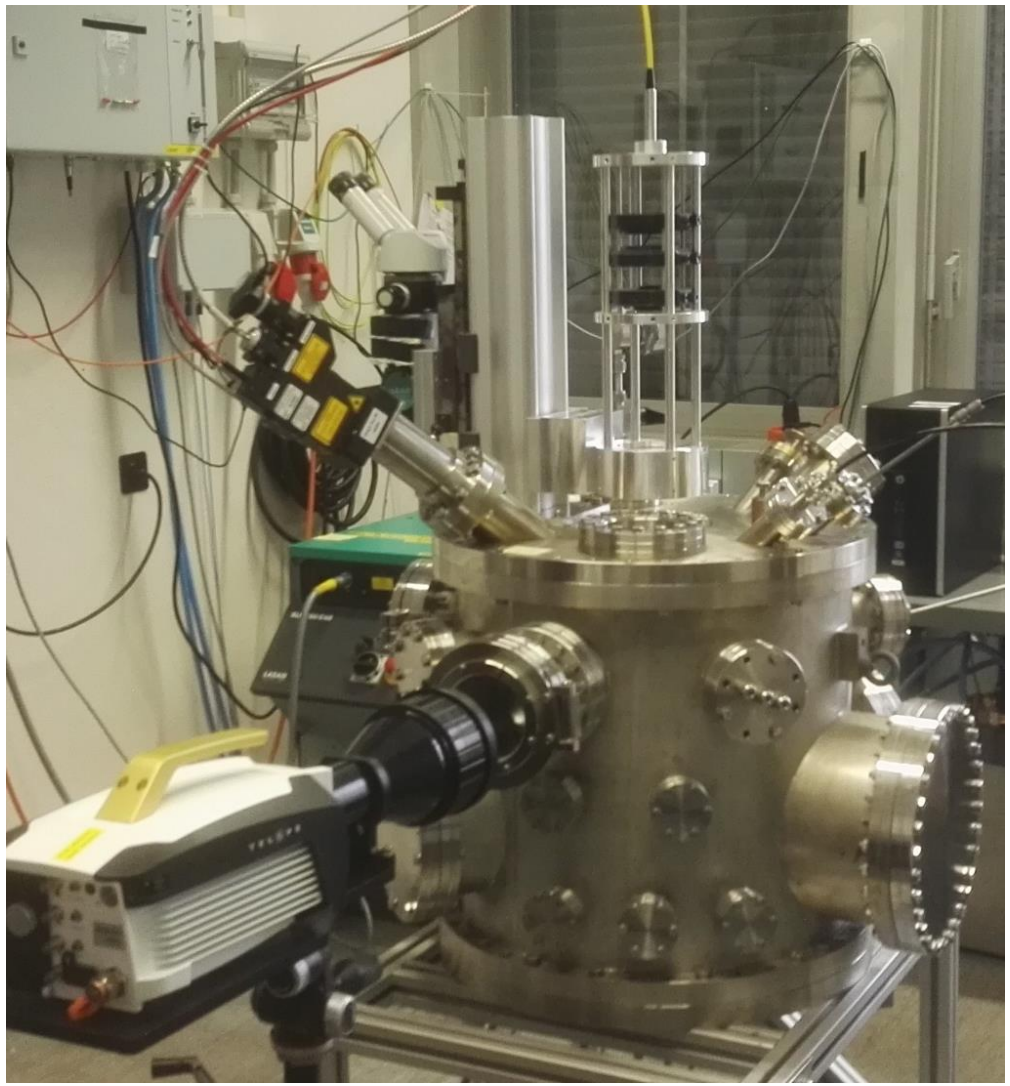
$t_p = 78ms$



WP5 - Prototype LMD reactor modification







Thank you

Axicone optical system : ***Ø: 20 µm,*** coaxial powder injection