Karlsruhe Institute of Technology

CFD-Based Evaluation of Nozzles for Plasma Based H_2O_2 Production in Microgravity

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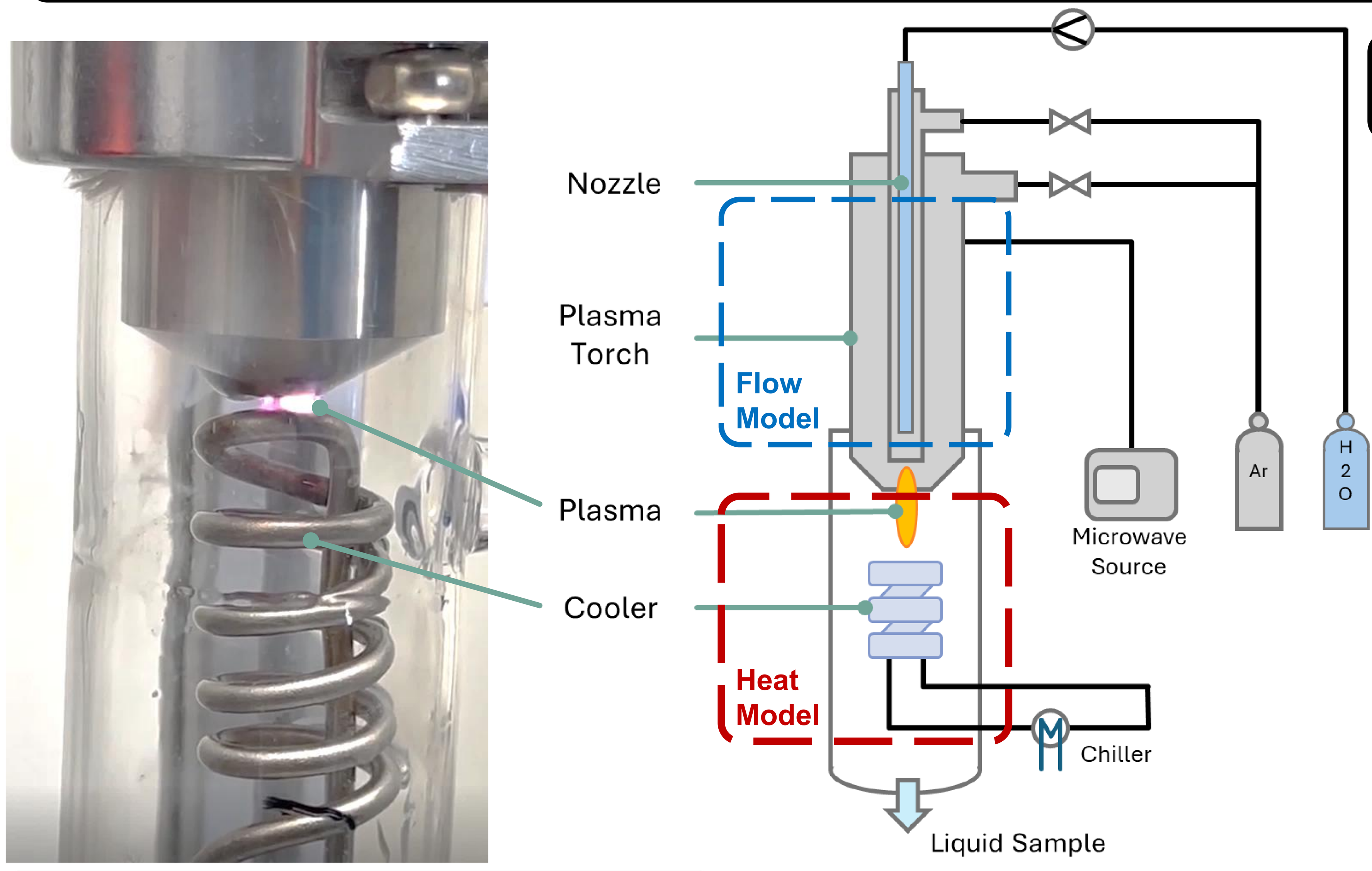
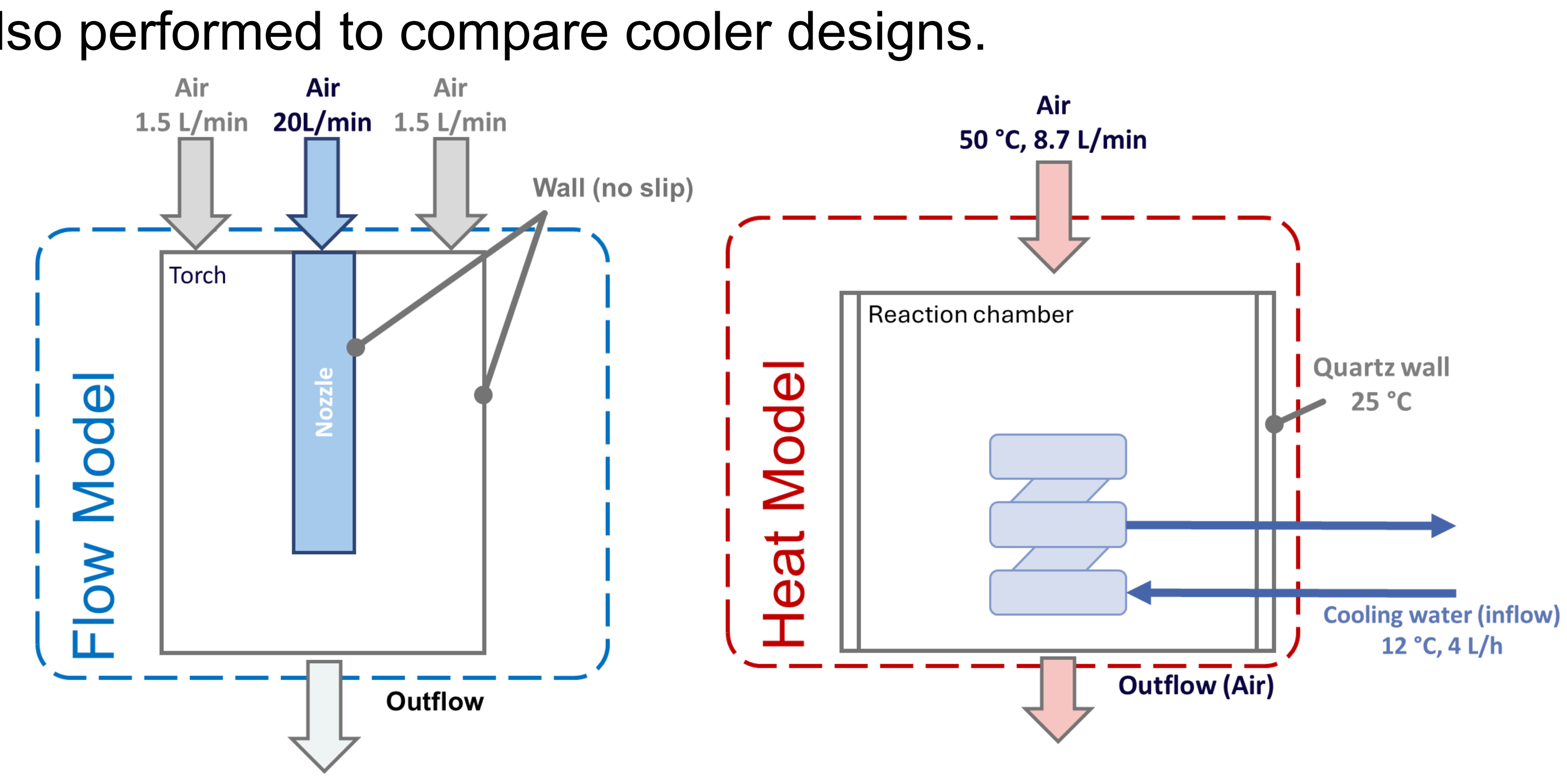
Motivation

As part of GreenSWaP, we aim to adapt a **plasma–liquid H_2O_2 reactor**, previously demonstrated for continuous operation (achieving already commercial concentrations), to space-relevant conditions [1]. In microgravity, **reliable gas–liquid contact**, **residence-time control**, and **efficient heat removal** are essential to maintain reactor performance and limit H_2O_2 degradation.



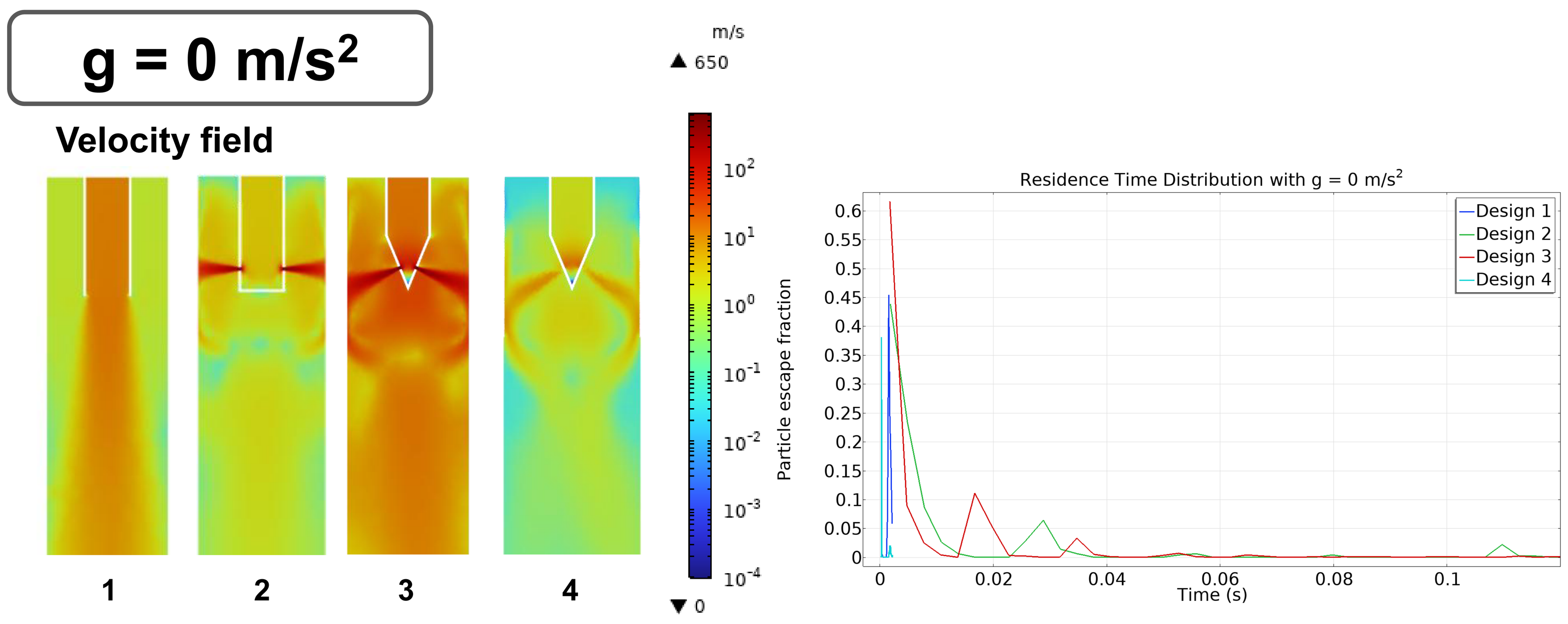
Methodology

Cold-flow simulations were carried out in COMSOL [3] using a **RANS k–ε turbulence model**. Gravity and microgravity cases were compared using **particle tracing** to evaluate **residence-time distributions**. Heat-transfer simulations without radiation were also performed to compare cooler designs.

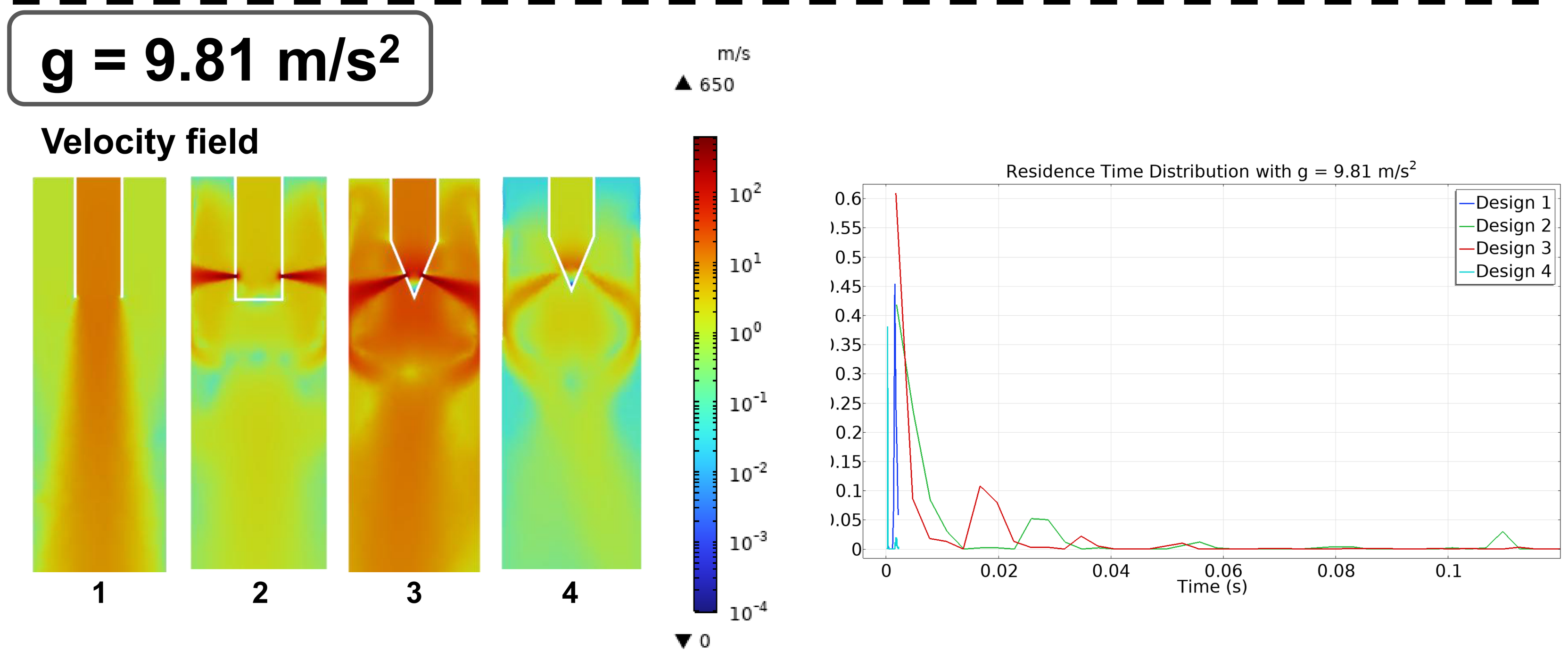


Flow Simulation - Nozzle

g = 0 m/s²



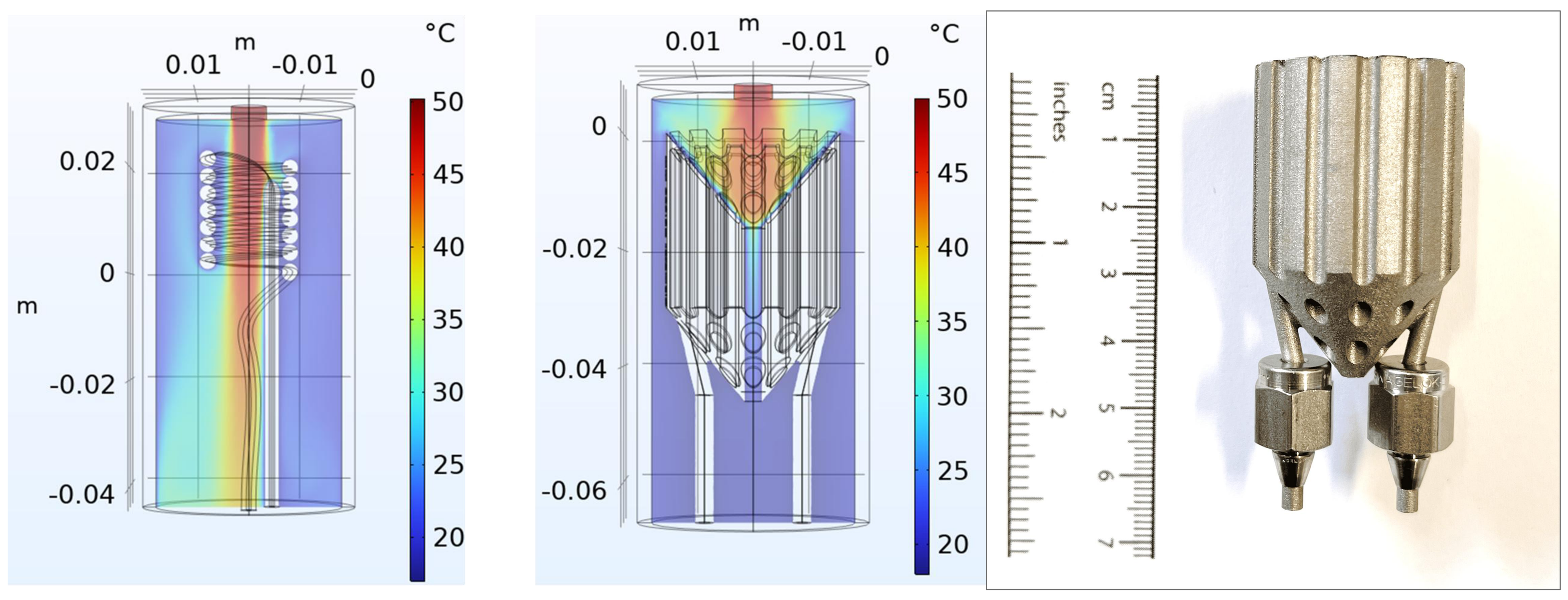
g = 9.81 m/s²



- **The flow behavior is primarily governed by nozzle geometry**, while gravity moderately reduces residence time relative to microgravity.
- **Microscale nozzles** have been fabricated, and experimental validation is currently underway.
- Two-phase models are being developed to capture **droplet dispersion and plasma–liquid contact**.

Nozzle Design 2

Heat Simulation - Cooler



Coil | 3D-Printed | **3D-Printed Cooler**

Conclusion and Outlook

- Cold-flow CFD **provides a first screening tool** for adapting the plasma–liquid reactor to space applications.
- **Nozzle geometry predominantly governs the flow structure and residence-time distribution**, with gravity effects playing a comparatively minor role.
- Future work will include validation experiments, two-phase gas–liquid modelling, and reactive plasma–liquid simulations.

[1] Hernandez, M.S. et al. *JACS* **2026**, 148.10,10378-10387
[2] Younas, M. et al. *Fuel* **2022**, 316, 123317
[3]*COMSOL Multiphysics™ v. 6.4. www.comsol.com. COMSOL AB, Stockholm, Sweden.*