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A Cryogenic Platform for Investigating Wetting Dynamics in Deterministic 2PP Foams for IFE

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The realization of Inertial Fusion Energy (IFE) requires target injection rates of approximately 10 Hz. Furthermore, a perfectly homogeneous Deuterium-Tritium (DT) layer inside the target is strictly required, as even minor asymmetries in the fuel distribution will amplify during implosion, preventing ignition. To meet this demand while minimizing the active Tritium inventory, wetted foams are essential, as they facilitate rapid fuel distribution via capillary forces.

However, implementing this presents significant physical and modelling challenges. The fuel must wick evenly throughout the entire foam volume, even against gravity. Additionally, the subsequent liquid-to-solid phase transition often generates unwanted voids due to density changes. Validating predictive fluid simulations for these processes is hindered by the stochastic nature of conventional chemical foams and the lack of specific wetting data for novel materials.

To address these issues, we report on the commissioning of a cryogenic apparatus dedicated to investigating wetting properties and filling behavior in deterministic foams. These foams are fabricated via Two-Photon Polymerization (2PP), providing the reproducible geometry essential for benchmarking simulations. The setup achieves temperatures down to 11.0 K with high stability, permitting the study of wetting and
freezing using hydrogen as well as deuterium. Utilizing a custom optical diagnostic with a spatial resolution better than 5 μm, the system allows for the visualization of liquid-gas phase boundaries relative to the pore geometry. Finally, we discuss strategies for applying controlled thermal gradients to drive directional solidification to counteract void formation during the freezing process.

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