PPPL PRINCETON PLASMA PHYSICS LABORATORY

Slow-Flow Capillary Porous System Tests

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2nd MPEX Users Research Forum, Sept. 13-14, 2021

Tokamak and Stellarator Experience

- **Capillary porous systems (CPS) have been tested in linear devices:**
  - T.W. Morgan, et al., Nucl. Mater. Energy 12 (2017) 210–215.
  - A.B. Martin-Rojo, et al., Fusion Eng. Des. 117 (2017) 222–225
  - L. Han, et al., Fusion Eng. Des. 121 (2017) 308–312.
- **… and in toroidal confinement devices:**
  - S.V. Mirnov, et al., Plasma Phys. Control. Fusion 48 (2006) 821–837.
  - H.W. Kugel, et al., Fusion Eng. Design 87 (2012) 1724 – 1731.
  - G. Mazzitelli, et al., J. Nucl. Mater. 463 (2015) 1152–1155.
  - F.L. Tabares, et al., Nucl. Mater. Energy 12 (2017) 1368–1373.
  - J.P.S. Loureiro, et al., Fusion Eng. Des. 117 (2017) 208–211
  - R. Dejarnac et al., Nucl. Mater. Energy 25 (2020) 100801
- **Heat fluxes up to 20 MW/m^2 have been tolerated without damage.**
  - But meshes can lift off thermal substrates. 3-D printed CPS more robust.
    P. Rindt et al., Nucl. Fusion 61 (2021) 066026

Surface Vapor Shielding of 3-D Printed CPS at Magnum PSI

Up to 16 MW/m^2

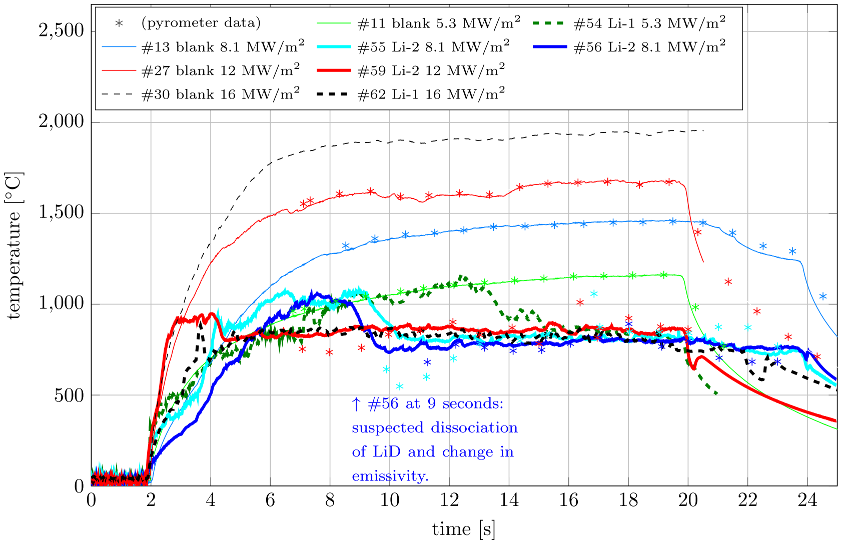


Figure 3. Overview of temperature measurements during steady state deuterium loading. IR measurements are matched to pyrometer measurements when available. Shot 30, 54 and 62 use emissivity and transmission coefficients from shot 27, 55 and 59 respectively. Temperatures on blank targets increase with the deposited power, while temperatures on the lithium targets do not. A steep drop is observed on the Li targets (at $\sim$ 9 s for shot 56 and 55). It is suspected that at this point the LiD layer dissociates, and consequently the emissivity is reduced. The temperature on all targets is calculated with a constant emissivity.

P. Rindt et al., Nucl. Fusion 61 (2021) 066026

Lithium Vapor Box at PPPL (J. Schwartz, PSI 2020)

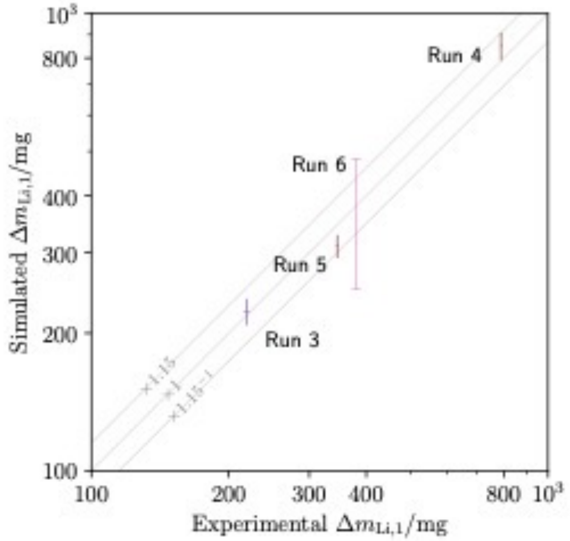


Figure 2: Comparisons of the experimentally-measured Li transfer with their simulated values for each of the six runs.

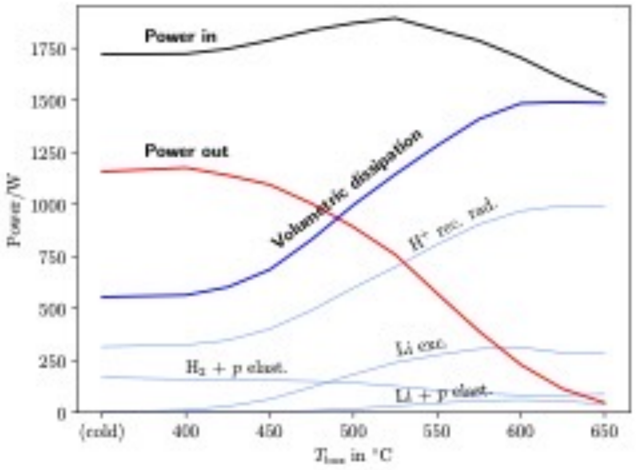
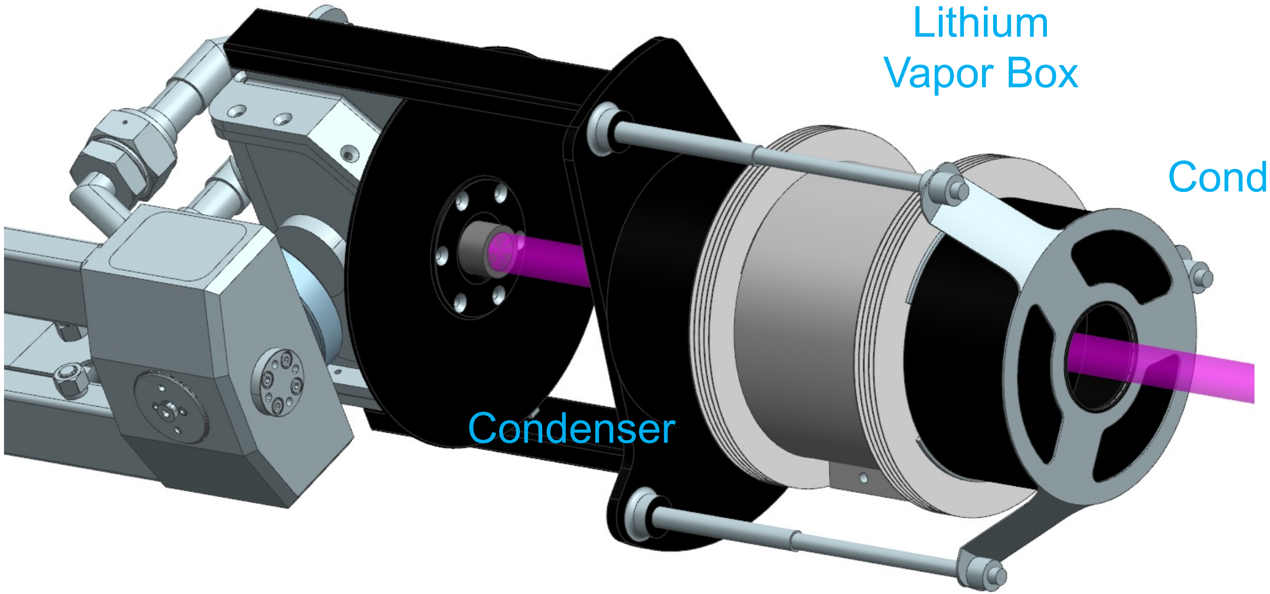


Figure 4: Power into and out of the set of vapor boxes, power volumetrically dissipated within the boxes, and the four largest channels of volumetric dissipation.

Control of lithium efflux from linked "Vapor Boxes" well predicted by SPARTA DSMC code.

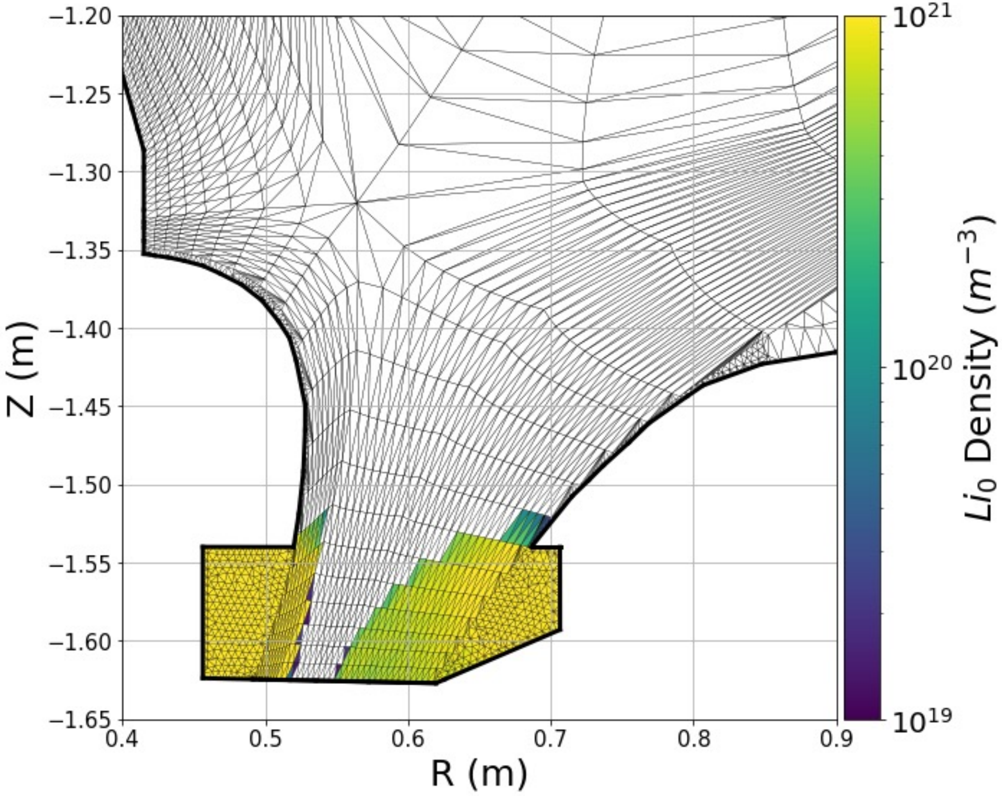
Similar configuration can be used to demonstrate volumetric vapor shielding on Magnum PSI

Volumetric Detachment Experiment Planned at Magnum



Victor Tanke, Fabio Romano, Tom Morgan, DIFFER
Design is progressing well. Expect initial experimental results by Spring 2022.

SOLPS-ITER Modeling at PPPL



Eric Emdee

Vapor box configuration appears favorable for limiting upstream lithium.

Possible Lithium CPS Experiments at MPEX

- **Continuous Surface Vapor Shielding**
  - Operate for long pulses – say 5 depletion times – and demonstrate continuous external feed of lithium during the pulse, from a feed ring around the target.
  - 5 cm diameter target, 3 mm deep = 1.5 g lithium. X 5 ~ 7.5 g ~ 1 Mole.
- **Real-Time Lithium Recirculation**
  - Surround target area with warm CPS and demonstrate lithium condensation.
  - Recirculate lithium by capillary pressure, like a heat pipe.
- **Continuous Volumetric Detachment**
  - Form a vapor box around the MPEX beam.
  - Operate continuously with volumetric detachment.
- **Put it All Together**
  - Continuous volumetric detachment with lithium recirculation.

Key issue is presence of H species and impurities.

Requirements for MPEX

- **Demonstrate Continuous Surface Vapor Shielding**
  - Lithium reservoir in contact with feed ring around target.
  - ~ 7.5 g of lithium evaporated into vessel.
  - Pulse-length minutes to an hour (?) based on Magnum experience.
- **Demonstrate Real-Time Lithium Recirculation**
  - Condenser cylinder at ~ 300^{o} C, ~10 cm long x 7 cm diameter x 2 mm deep = 11 g lithium.
  - Less lithium evaporated into vessel than without condenser!
- **Demonstrate Continuous Volumetric Detachment**
  - Form a hot vapor box ~ 650^{o} C, around the MPEX beam.
  - Operate continuously with volumetric detachment – requires cold condenser.
- **Put it All Together**
  - Requires a longer system, with evaporator, hot condenser, cold condenser.

Plasma and surface diagnostics!