Draft Mission and Specifications for an Integrated PMI-PFC Test Facility

(Primary Focus: Liquid Metal PFCs)

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PPPL
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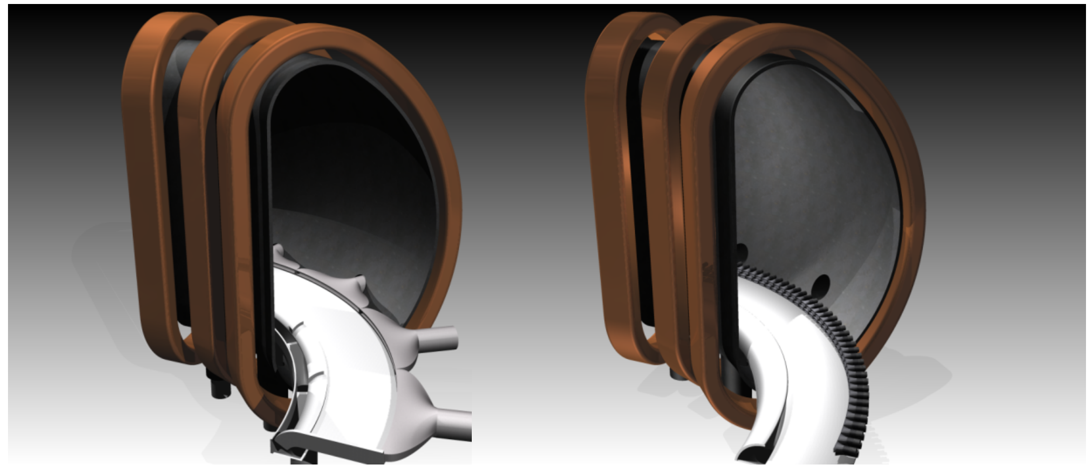
Laboratory - Directed R&D

Need Integrated Capabilities for Liquid Lithium PMI-PFC Tests

- Realistic highly tangential magnetic field structure to test erosion and redeposition, lithium flow across **B** in PFC.
- Realistic steady and transient plasma impingement to test radiative self-shielding, recondensation, pumping
- Realistic steady and transient SOL currents
- Extensive surface diagnostics
- Extensive plasma diagnostics
- Extensive PFC engineering diagnostics
- Extensive modeling
- Would complement other facilities world-wide
  - Combination of PMI + Liquid PFC
- Would require a strong national collaboration.

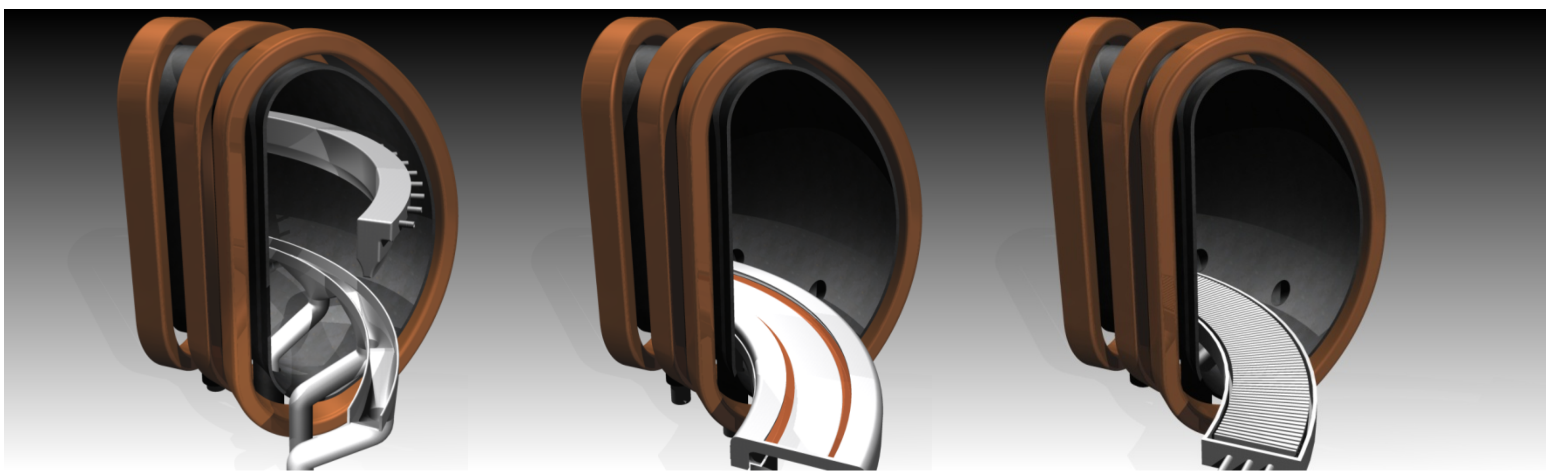
Test Heat Removal with Fast-Flowing Li

- Designs use convection to exhaust incident power
- Thickness ≈ 1 cm



Pressure driven

Jets



Curtain Limiter

JxB

TEMHD

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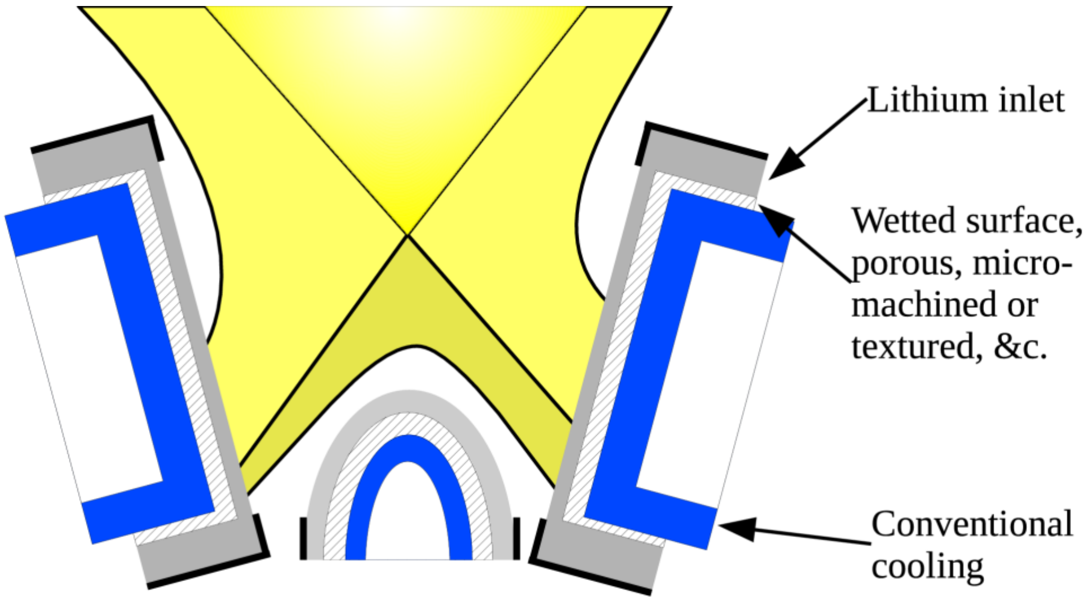
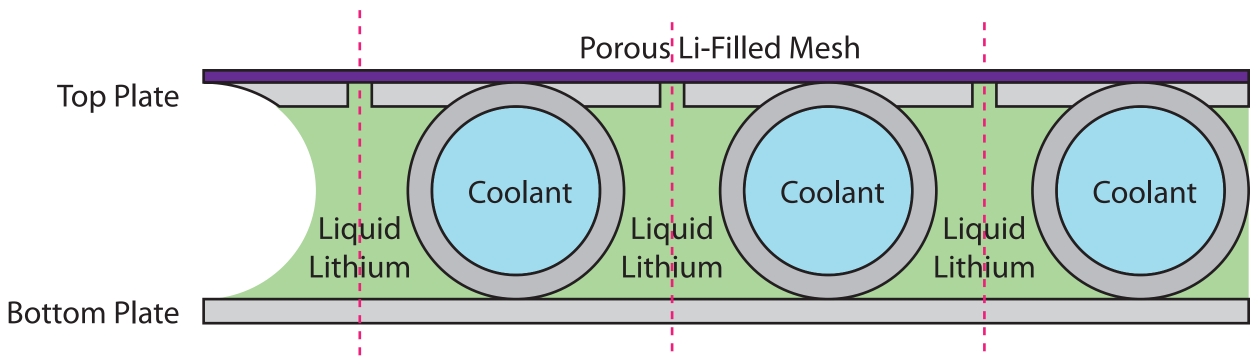
Test CPS Lithium with Active Coolant



- Lithium “soaker-hose” wets plasma-facing surface
- Gas coolant
  + evaporation
  + radiation
  removes heat

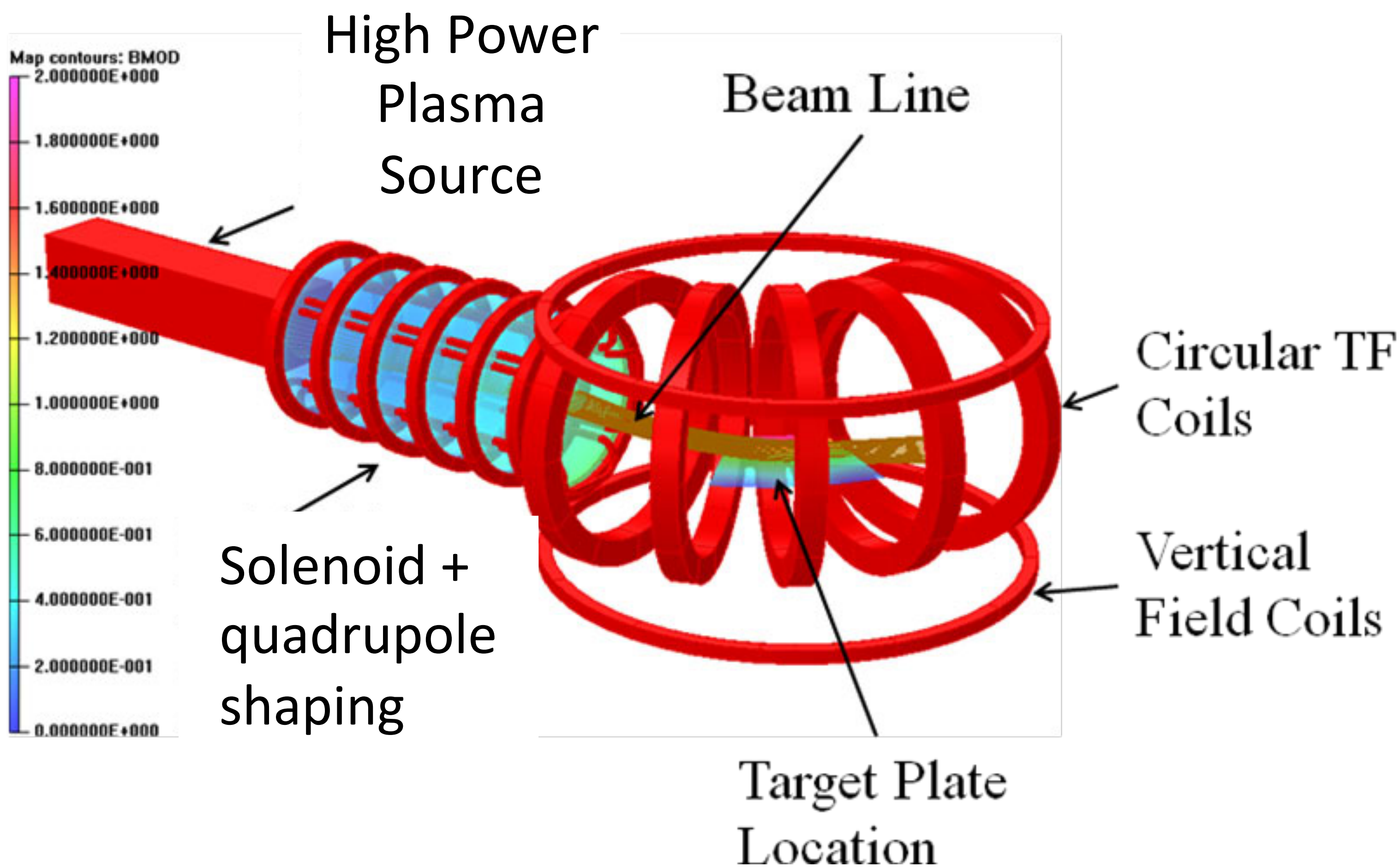


M. Jaworski

Draft Magnetic Field and Geometry for First Phase of PMI-PFC Test Facility

- Toroidal magnetic geometry is required to simulate flows of liquid metals in the radial direction of a tokamak.
- 1 T toroidal magnetic field (modeled on NSTX-U for now)
  - dB/dR = 1.25T/m (implies R_o = 0.8m)
  - 0.02 – 0.15 T vertical B-field to model flux expansion
- PFC component 0.5m in toroidal direction (1/10 of torus), 0.5m in poloidal plane.
- PFC surface tilt variable from horizontal to vertical, including inverted.
- Excellent access for plasma, PMI and PFC diagnosis.
- Can we start with simpler geometry?

A Quarter Torus Provides Specified Fields



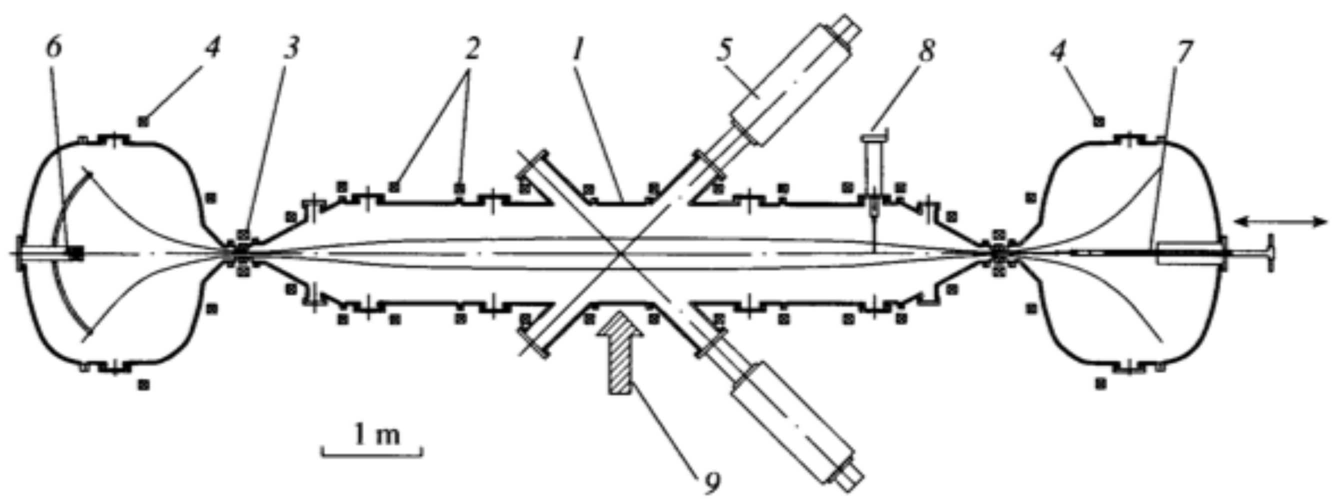
The multi-colored sections are contours of the magnitude of the local B-field.

Draft Power and Plasma Flux for First Phase of PMI-PFC Facility

- P/L in the toroidal direction up to 2MW/m.
  Implies up to 1 MW delivered to target.
- 5 second pulse adequate for first phase (liquid surface)
- Heat flux width variable from 0.04m to 0.2m
  (Greater width goes with lower vertical field)
  - Implies local heat flux of 10 – 40 MW/m^2
- Equivalent to heat flux parallel to **B** ~ 400 MW/m^2
  - 1 MW in 25 cm^2
- A few $10^{19}/m^2$, 50 – 100 eV , upstream plasma would allow realistic tests of surface and plasma effects.
- Can we start with Inductively Coupled Plasma (e.g., helicon) + heating + electrical bias?

GDT Plasma (!)
Approximates Tokamak Edge

- Upstream parameters of T_e = 50 – 100 eV, n_e = 2 – 5 $10^{19}/m^3$ should provide the right parallel heat flux and collisionality, as well as realistic $T_e(z)$ for radiative self-shielding.
- These are achieved in the Novosibirsk Gas Dynamic Trap
- Magnetic flux carrying 1 MW at Novosibirsk ~ 25 Tcm^2
- But… pulse length at Novosibirsk is only 5 msec.



Conclusions

- **An integrated PMI-PFC test stand would be a major step along the route to implementing liquid lithium systems in fusion energy systems.**
- **It is not a simple undertaking to simulate even current experiments. It may be necessary to approach in stages.**
- **Implementing a PMI-PFC test stand will need to be a collaborative undertaking.**
- **We are taking a first look, and welcome your ideas and collaboration.**