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NSTX Physics Requirements for Liquid Lithium Divertor Conceptual Design

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Conceptual Design Review

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NEPA #1413
Work Planning #1382

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Liquid Lithium Divertor Physics Design Goals

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- Design Goals

1) LLD-I (FY09) : Achieve density control for inductionless current drive capability in the range (from recent simulations):
   - $n_e \sim 5 \times 10^{19}\ m^{-3}$ at Ip = 700 kA, (15-25% n_e decrease from present exps)
   - highest non-inductive fraction discharges presently often evolve toward n_e/n_{GW} -->1

2) LLD-II (FY10): Enable n_e scan capability in long pulse H-mode (e.g.,~ x2) by varying lithium thickness
   - Increase filling rate to a TDB surface
   - Test ability to operate at significantly lower density
     - NHTX (n_e/n_{GW} = 0.5) and ST-CTF (n_e/n_{GW} = 0.25)

3) LLD-III (FY11-13): Investigate power handling with long-pulse LLD-III for high heat-flux

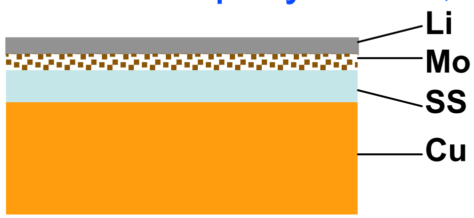
Candidate Surfaces We Have Considered for LLD-I

- Key properties for an acceptable LLD-I lithium surface
  - wetting capability (ability to flow over the surface)
  - minimize Li temperature rate of rise -> rapid heat transfer from Li to baseplate

- Two candidate Li surfaces have been under investigation

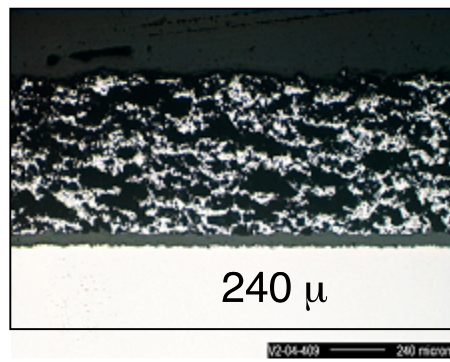
1) Thin flame sprayed Mo, on thin SS barrier on thick Cu baseplate

ADOPTED FOR FY08

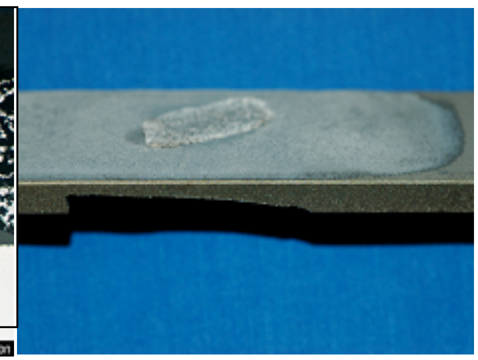


- LTX style plate (tested offline)
  (prepared by Plasma Processes Inc)

- High-Z *plate with thin Lithium film is highest confidence initial approach*



Micrograph of highly porous moly



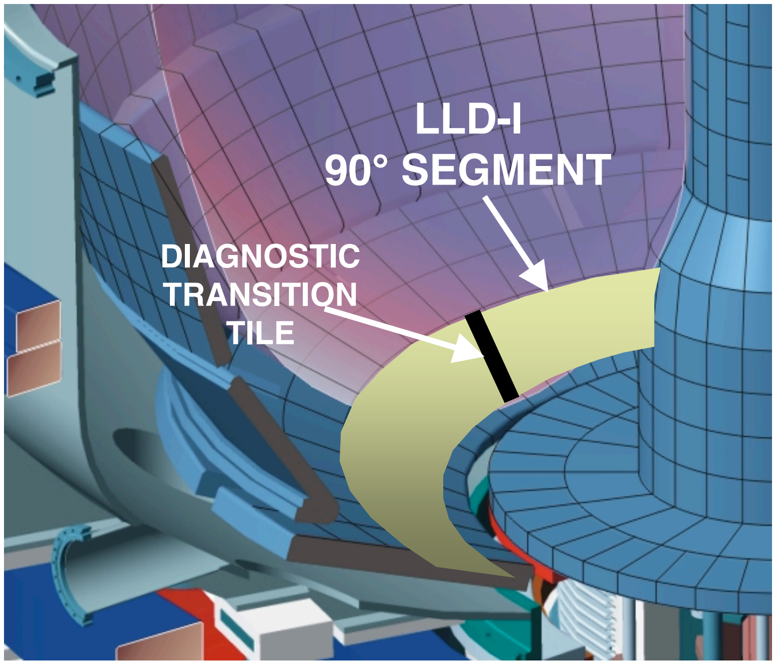
Successful lithium wetting test on porous moly

2) Chemical vapor deposited Mo on pyrolytic carbon mesh from Ultramet

- under investigation at SNL (R. Nygren, C.Harjes, P. Wakefield)
  (prepared by Ultramet Inc.)

-> possibility for LLD-II if tests are successful

The LLD-I Plate Design With Thin Lithium Film on High-Z Bonded to Copper is Highest Confidence Approach



- *3 rows of graphite tiles to be removed to storage*

- Location - lower outer divertor in four 90°sections
- Width - ~20 cm, starting 5 cm outboard of CHI gap
- Shape - replaces present graphite tiles
- Structure - 0.02 cm Mo flame-sprayed on 0.05 cm SS barrier bonded to 2.2 cm Cu containing resistive heaters and cooling lines for maintaining 200-400°C
- Lithium Loading - 2 lithium evaporators

- Each toroidal section electrically grounded to vessel at one mid-segment location to control eddy currents (A. Brooks simulations)

- Each toroidal section fastened at its 4 corners to existing divertor copper baseplate with fasteners providing structural support, electrical isolation, and accommodate thermal expansion

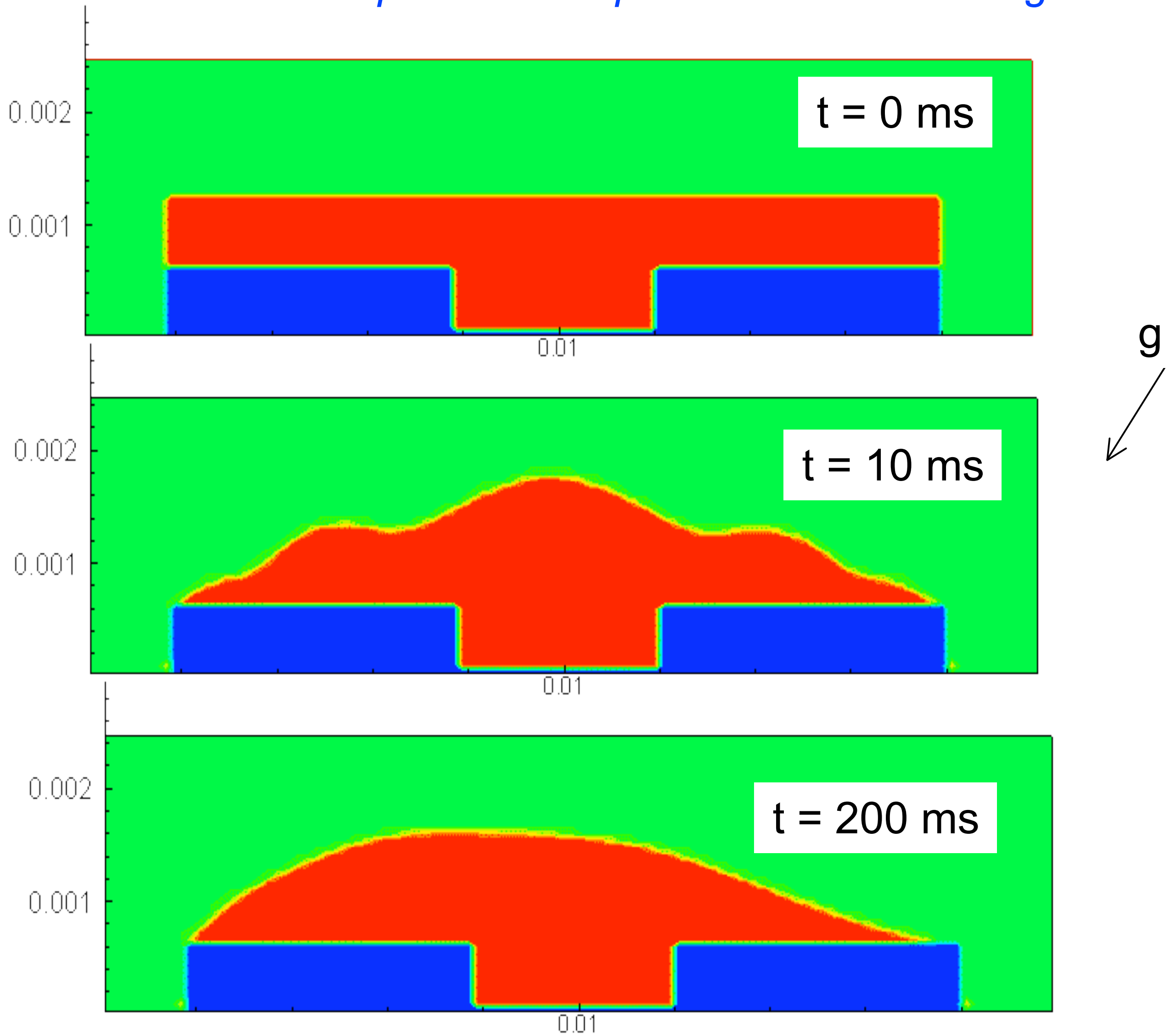
- Narrow graphite tile transition regions between sections contain thermocouples, an array of Langmuir probes, and magnetic or current sensors

2D simulation of lithium film adherence to dimpled wetted plate tilted at 21.5 degrees

Pinning at sharp corners and small contact angle between lithium (red) and wetted substrate (blue) allows surface tension to support the film

This wide dimpling aids only slightly by supporting a little of the weight on pore walls

More analysis with thinner films and small feature porous surface is underway (2D and later 3D if useful)



• Simulation of the impact of magnetic field on surface tension driven flow from a heated spot is in progress (UCLA / HYPERCOMP, INC)

Dimensions in m

Concept for LLD-I Segment Clocking to Preserve Existing Mirnov Coil Location

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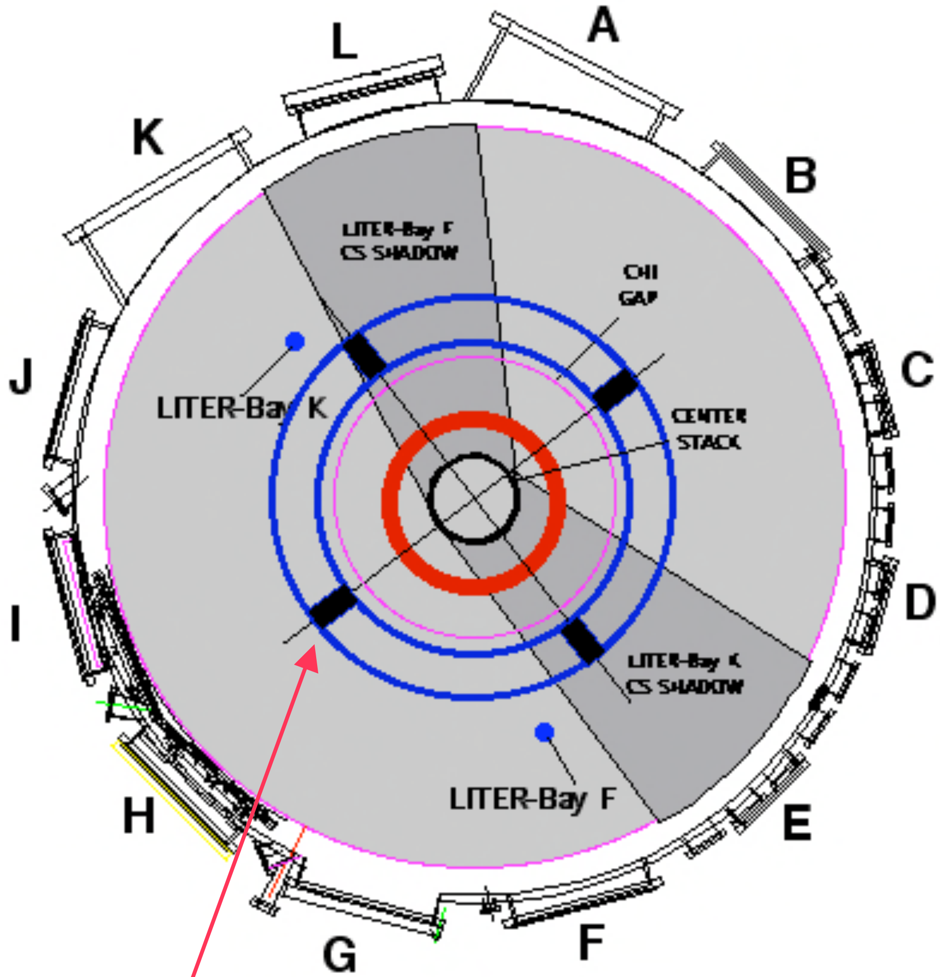

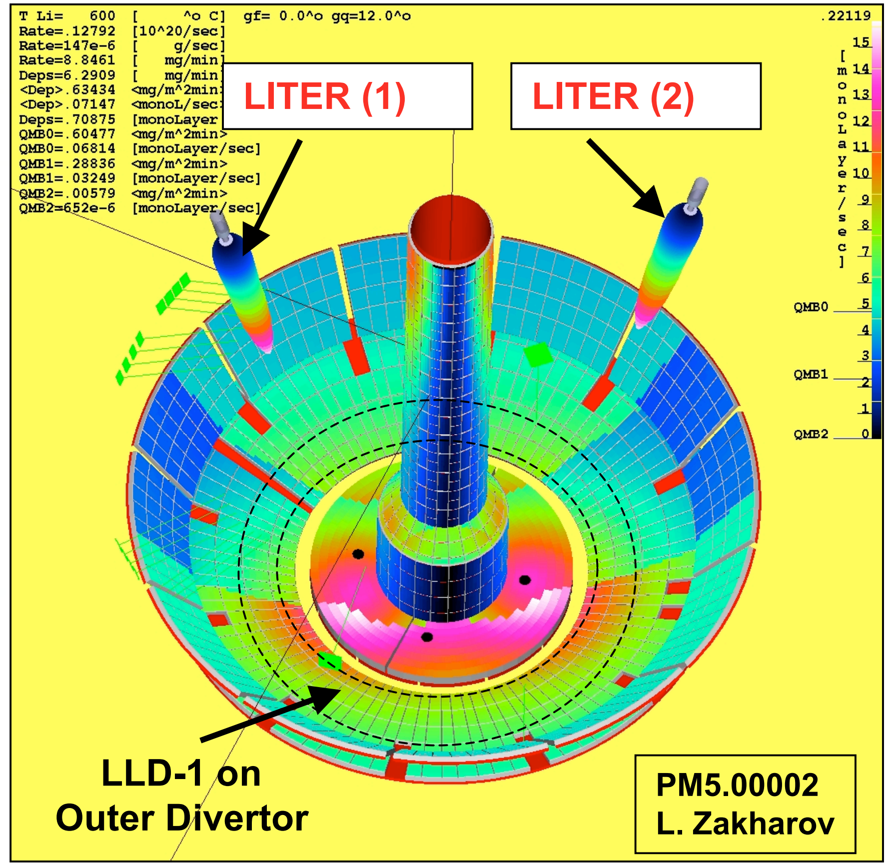

- LLD segments clocked relative to existing Mirnov coils at 217.5°

- Simulated Li deposition

PPPL
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Diagnostic Tile Langmuir Probe Configuration Considerations

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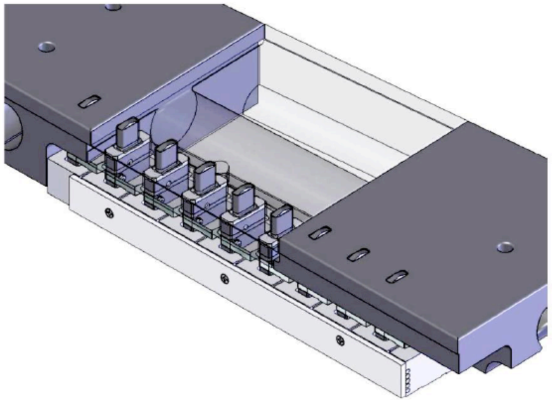
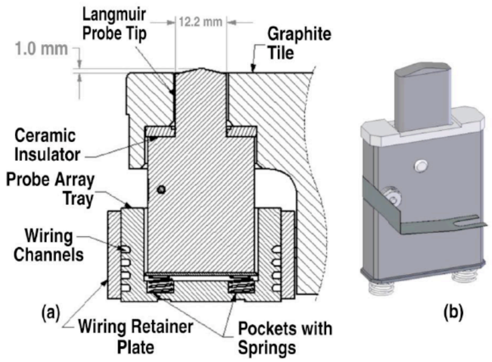
- Physics requirements
  - equilibrium (slow probes)
  - transients (fast probes)
  - spatial resolution
- Technical issues
  - arcing/shorting + codeposition
  - lithium coatings
  - thermal effects

- Comparative analysis of the DIII-D and MAST Langmuir Probe designs in progress

Possible Langmuir Probe Configurations

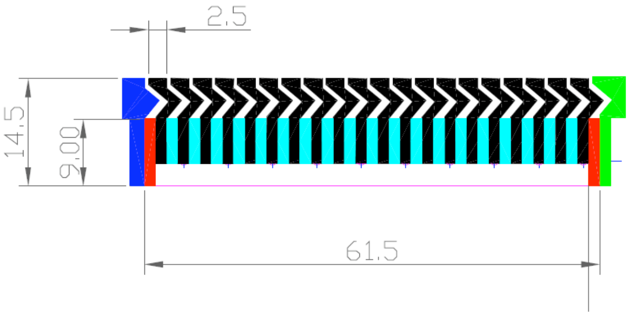
- D-IIID probes:





Taussig, D.A.; Watkins, J.G.; Boivin, R.L., "Improved Langmuir Probe Array for DIII-D," Fusion Engineering, 2007. SOFE 2007. 2007 IEEE 22nd Symposium on , vol., no., pp.1-4, 17-21 June 2007

- MAST probes:



Investigations of the Boundary Plasma in the MAST Spherical Tokamak. Joon-wook Ahn

J. Kallman

LLD-1 Design Will Support NSTX FY09 Research Program

- The LLD-I physics requirements and plans were reviewed and approved by the NSTX Program Advisory Committee
    - *LLD-I on the Outer Divertor is lowest technical and programmatic risk location for the LLD-I to the high performance, high δ, ST research program*
    - *LLD-I, 15-20 cm wide pumping on Outer Divertor provides reduction in density for high performance Inductionless Current Drive Milestone*
- Near Term Time Line
    - Conceptual Design Review (CDR), Feb. 20, 2008
    - Final Design Review (FDR), Mar., 2008
    - Goal: Installation completed in 2008