NSTX Lithium Road Map Meeting

Agenda (draft):

1. Overview of Li road map for FY2010 run (Skinner)
2. LLD coating, characterization, and decommissioning LLD (Kugel)
3. Updated density reduction calcs including Li on C - if available (Maingi)
4. High heat flux on LLD - plans/program at end of run (all/any?)
5. R11-3 Milestone language

NSTX will assess and utilize the LLD in 4 stages

PAC25-14

Dry run version of Road Map:

1. Commission LLD for pumping
2. Characterize LLD pumping, plasma response to LLD
3. Utilize LLD pumping in milestone/high priority experiments
4. Assess high heat flux handling capability of LLD

3-week bakeout
30 min He-GDC

LLD coating XMP
Objective: 250nm Li on LLD.

Plasma Startup XMP
Objective: Develop reference shots with unheated LLD, IBD strike point: R=0.35, 0.5m

Yes

LLD commissioning 1
Objective: Test LLD pumping with LLD at 210°C, IBD strike point: R=0.35, 0.5m, ± LiTER, HFS or SGI fueling.

Is Ne ≈33% lower with LLD Li at 210 °C but LiTER off ?

No

Is LLD wet ?
more Li?
more GDC ?

Test LLD wetting: Reproduce XP827 ref. shot (lower Ne, reduced ELMs) with LLD Li at 210 °C but LiTER off

LLD commissioning 2
Objective: Test LLD pumping with OBD strike point on bull nose at R=0.63, LLD at 210°C, ± LiTER, HFS or SGI fueling. Optimize strike-point control as needed.

Is Ne ≈50% lower with LLD Li at 210 °C & LiTER off?

LLD physics XPs

LLD pumping characterization XP

LLD physics survey XP

Need more D pumping?
More Li?
Need impurity control?
- work on ELM pacing
- assess impurity sources

Complete NSTX research milestones and priority 1 XPs

Assess LLD pumping and power handling at moderate to high heat flux with strike point on LLD at R=0.75m, extend to long pulse

Decommission LLD

- *Note 25% changed to 33%, in line with Rajesh's calc. for XP827 shots.*
- *There are no calculations for R=0.63 yet so leave at ≈ 50%.*
- *Difference is not so significant compared to uncertainties in recycling and exponent.*

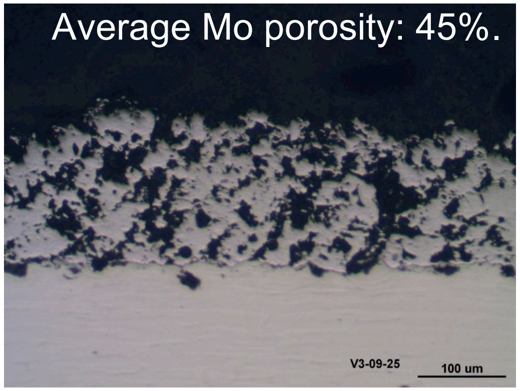
NSTX will assess and utilize the LLD in 4 stages

PAC slide:

PAC25-14

1. Commission LLD for pumping
   - Begin with 3-week bakeout + HeGDC
   - 1 day LiTER for 250 nm Li coating of LLD
2. Characterize LLD pumping, plasma response to LLD
   - Strike point on inboard divertor
   - Test Li wetting of LLD
   - LiTER shuttered, LLD Li molten @ 210°C, SGI fueling
   - Compare to 2009 performance and pumping predictions.
3. Utilize LLD pumping in milestone/high priority experiments
   - Develop scenarios for all TSGs
4. Assess high heat flux handling capability of LLD
   - Move strike point onto bullnose, then LLD
   - Compare to 2009 and pumping predictions
   - Decommission LLD at end of run (evaporate remaining Li)

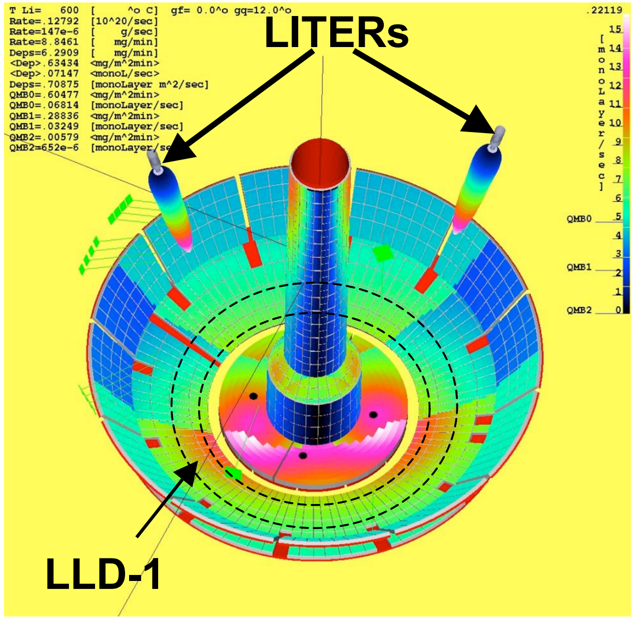
Cross sectional views of plasma sprayed porous molybdenum LLD sample

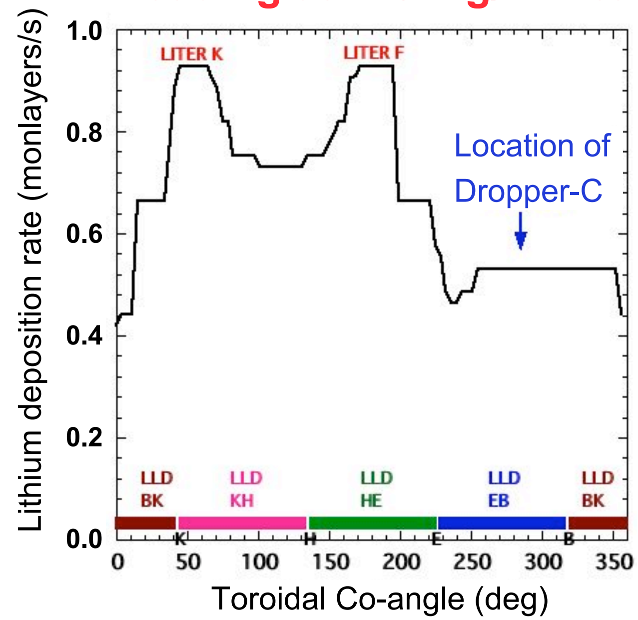


152 μm Mo

200 μm stainless

Plan to wet and fill LLD with lithium from dual LITERs, possibly supplemented by lithium Droppers





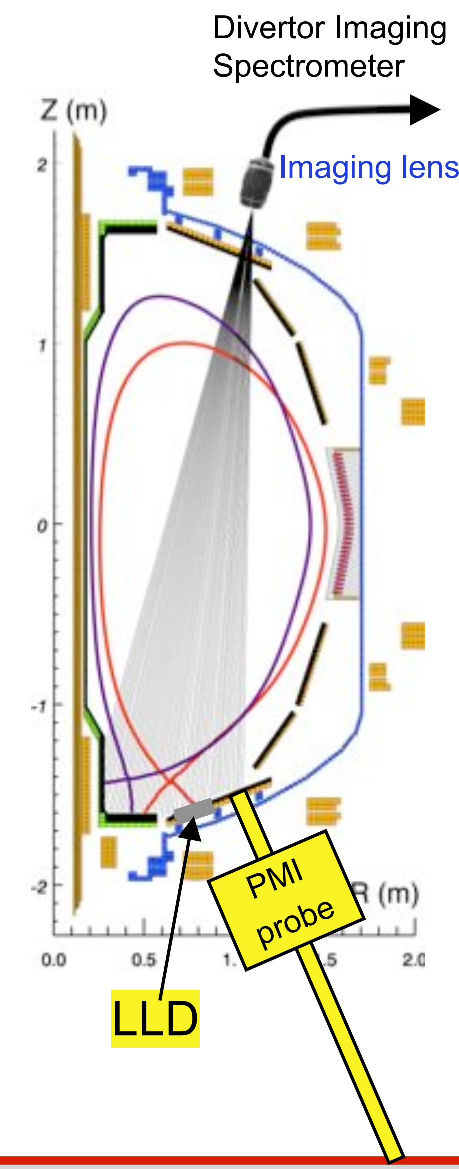
- Rely on liquid wetting the porous Mo surface to spread the lithium
- Wettable area in porous Mo estimated at ~8 times plate area
  - 1.1g lithium on LLD would coat wettable area to 250nm penetration depth of incident $D^+ \Rightarrow$ 15g evaporated ~ 1 day at normal evaporation rate.
  - 7% of lithium evaporated by LITERs reaches LLD-1 plates.
- Estimate ~40g lithium required to fill porous volume in Mo coating
- Lab tests of Li evap. + Li flow techniques to load LLD more efficiently

How to tell LLD is coated sufficiently with lithium ?

PAC backup slide:

Assume 250 nm coating with Li will not make LLD glisten and Li coating on LLD will not be visibly obvious.

- Divertor Imaging Spectrometer will monitor Mo (384nm), LiI (670nm), LiII (485nm) emission from LLD. Also VIPS2 visible spectrometer.
- Fast cameras filtered with Mo (384nm), LiI (670nm) LiII (485nm) filters will view whole LLD.
- LLD sample will be exposed with PMI probe at LLD temperature and analysed at Purdue using:
    - X-ray photo electron spectroscopy (XPS)
    - Low Energy Ion Scattering Spectroscopy (LEISS)
    - Direct Recoil Spectroscopy (DRS).
  - PMI probe is further in the wings of LiTER distribution than LLD but is direct measurement of material surface.
- Purdue can perform lab experiments on Li coating of LLD samples in presence of carbon coatings.
- Unipolar arcing may be visible on fast cameras or on PMI probe samples.



R11-3 milestone language Stan / Charles version1:

- **Research Milestone R(11-3): Assess the relationship between lithiated surface conditions and edge and core plasma conditions**
- The plasma facing components (PFC) of fusion devices play a key role in determining the performance of the fusion plasma edge and core by providing particle pumping and fueling and acting as a source of plasma impurities. On NSTX, coating the divertor carbon PFCs with evaporated lithium has resulted in transient particle pumping, increased energy confinement, and suppression of edge localized modes (ELMs). To extend the duration of particle pumping, and to investigate the impact of liquid lithium on plasma performance, a liquid lithium divertor (LLD) will be installed in FY2010, and the relationship between lithiated surface conditions and edge and core plasma conditions will be determined. To understand pumping, D retention will be studied as a function of LLD temperature and divertor electron density and temperature, strike-point location, and flux expansion. The temperature evolution of the LLD surface will be measured to understand its heat transfer properties, to determine the allowable peak flux onto the LLD, and to relate the LLD surface temperature to the measured influx of lithium and hydrogenic species. A Lyman-α AXUV diode array will be utilized for deuterium recycling and retention measurements. An in-situ materials analysis particle probe situated near the LLD will provide measurements of retention and surface composition in the outer divertor region. The retention measurements will be compared to retention models. Finally, D, Li, and C sources from the divertor and Li transport from the plasma edge to the core will be measured. This research will provide the scientific understanding of LLD operation necessary to begin to comprehensively assess liquid lithium as a possible PFC solution for NSTX and next-step ST facilities.

R11-3 milestone language Michael version2:

- **Research Milestone R(11-3): Assess the relationship between lithiated surface conditions and edge and core plasma conditions**
- The plasma facing components (PFC) of fusion devices play a key role in determining the performance of the fusion plasma edge and core by providing either particle pumping or fueling and acting as a source of impurities. On NSTX, coating the divertor carbon PFCs with evaporated lithium has resulted in transient particle pumping, increased energy confinement, and suppression of edge localized modes (ELMs). To extend the duration of particle pumping, and to investigate the impact of liquid lithium on plasma performance, a liquid lithium divertor (LLD) has been installed in FY2010. The relationship between LLD conditions and the edge and core plasma will be determined. The temperature evolution of the LLD surface will be measured to determine its heat transfer properties and allowable peak flux, and to relate the LLD surface temperature to the measured influx of lithium and hydrogenic species. A Lyman-α AXUV diode array will be used to measure deuterium recycling and retention as a function of lithium coverage and temperature, and of the divertor electron density and temperature, strike-point location, and flux expansion. An in-situ materials analysis particle probe situated near the LLD will provide measurements of retention and surface composition in the outer divertor region for comparison with retention models. Finally, D, Li, and C sources from the divertor and Li transport from the plasma edge to the core will be measured. This research will provide the scientific understanding of LLD operation necessary to evaluate liquid lithium as a PFC solution for the NSTX upgrade and next-step ST facilities.

R11-3 milestone language Bob version3:

- **Research Milestone R(11-3): Assess the relationship between the liquid lithium divertor and edge and core plasma conditions**
- The plasma facing components (PFC) of fusion devices play a key role in determining the performance of the fusion plasma edge and core by providing particle pumping and fueling and acting as a source of plasma impurities. On NSTX, coating the divertor carbon PFCs with evaporated lithium has resulted in transient particle pumping, increased energy confinement, and suppression of edge localized modes (ELMs). To extend the duration of particle pumping, and to investigate the impact of liquid lithium on plasma performance, a liquid lithium divertor (LLD) will be installed in FY2010, and the relationship between the liquid lithium divertor and edge and core plasma conditions will be determined. To understand pumping, D retention will be studied as a function of liquid lithium divertor conditions such as lithium coverage and temperature, and as a function of divertor electron density and temperature, strike-point location, and flux expansion. The temperature evolution of the LLD surface will be measured to understand its heat transfer properties, to determine the allowable peak flux onto the LLD, and to relate the LLD surface temperature to the measured influx of lithium and hydrogenic species. A Lyman-α AXUV diode array will be utilized for deuterium recycling and retention measurements. An in-situ materials analysis particle probe situated near the LLD will provide measurements of retention and surface composition in the outer divertor region. The retention measurements will be compared to retention models. Finally, D, Li, and C sources from the divertor and Li transport from the plasma edge to the core will be measured. This research will provide the scientific understanding of LLD operation necessary to begin to comprehensively assess liquid lithium as a possible PFC solution for NSTX and next-step ST facilities.

Jon guidance

- Until we have a LLD replenishment system that can operate without LITER, I think we need to deal with surface conditions in NSTX that result from a combination of LITER and LLD operation. Please write the milestonetaking this into account.   Can you promise LITER-free LLD operation in FY11?(I wouldn't) and for all we know, we'll want to run LITER and LLD together to get the best plasma conditions!
- finally, I don't think MAPP can measure conditions at the LLD, it'll be farther out in major radius. hence all the vague-ish language - it's there for a reason - to protect you ;)

Stan/Charles	Michael	Bob	Final
Research Milestone R(11-3): Assess the relationship between lithiated surface conditions and edge and core plasma conditions	**Research Milestone R(11-3): Assess the relationship between lithiated surface conditions and edge and core plasma conditions**	**Research Milestone R(11-3): Assess the relationship between the liquid lithium divertor and edge and core plasma conditions**	
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