Behavior of Li on the LLD

Lithium Research Topical Science Group meeting
August 23th, 2010, 1:00 – 2:30 PM B252

Agenda:

- Li behavior on PISCES & CDX, Charles Skinner, Robert Kaita (10 mins)
- Results from LLD spectroscopy, Vlad Soukhanovskii (10 mins)
- Results from visible cameras, Filippo Scotti (10 mins)
- Results from IR thermography, Adam McLean (10 mins)
- Results from the Langmuir probes, Mike Jaworski / Josh Kallman (10 mins)
- Preliminary 2010 Fueling Characteristics with LLD, Henry Kugel and Michael Bell (10 mins)
- Characteristics of low triangularity, low flux expansion discharges with higher fueling requirements" Rajesh Maingi (10 mins)

Li conditioning on PISCES

Doerner JNM 290-293 (2001) 166
Baldwin Nucl. Fus. 42 (2002) 1318:

- In spite of handling under argon, Li had native oxide/hydroxide layer that was difficult to remove from Li in its solid state.
- Li was cleaned by few mins of He or D plasma exposure of liquid sample.
- Physical sputtering believed to be mechanism.
- OI 777 nm emission not detectable from solid, but rises with increasing temperature then decreases as oxygen is depleted from surface.
- Prior to cleaning samples are gray, after they appear metallic, highly reflective.
- XPS after cleaning still shows O related peaks.
- Partial pressure of O and H_2O ~ 1e-6 Pa, 7.5e-9 torr. Monolayer coverage in 10 mins - faster than XPS measurement.

R.P. Doerner et al. / Journal of Nuclear Materials 290–293 (2001) 166–172

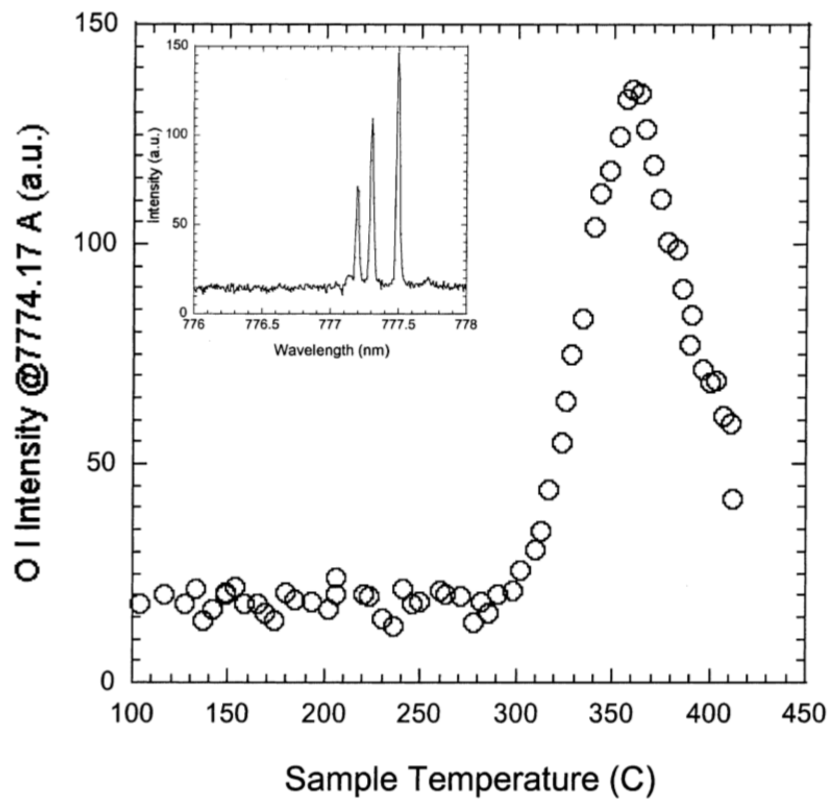


Fig. 1. Variation of the OI line radiation from a lithium sample exposed to helium plasma during a `cleaning' run. OI emission peaks and then decreases as the surface hydroxide layer is removed. Subsequent plasma exposures show no detectable OI emission from the sample. Inset shows the distinctive three line series of OI emission from the plasma at 777.2, 777.4 and 777.5 nm.

D retention in liquid Li on PISCES

Full retention of incident D ions

Table 1. Comparison of plasma conditions at the location of the sample in PISCES-B during these experiments, with the edge plasma of current confinement machines.

	PISCES-B sample-plasma conditions	Typical magnetic confinement device (edge region)
Ion flux ($m^{-2} s^{-1}$)	10^{21}–10^{22}	$\sim 10^{23}$
Ion energy (eV)	~50 (sample biased)	10–300 (thermal)
Heat flux ($MW\ m^{-2}$)	1–10	~10
T_e (eV)	20–40	1–100
n_e (m^{-3})	$\sim 10^{17}$–10^{19}	10^{18}–10^{20}
Pulse length (s)	Continuous	10–30
Plasma species	D	H, D, T, He

Baldwin Nucl. Fus. 42 (2002) 1318:

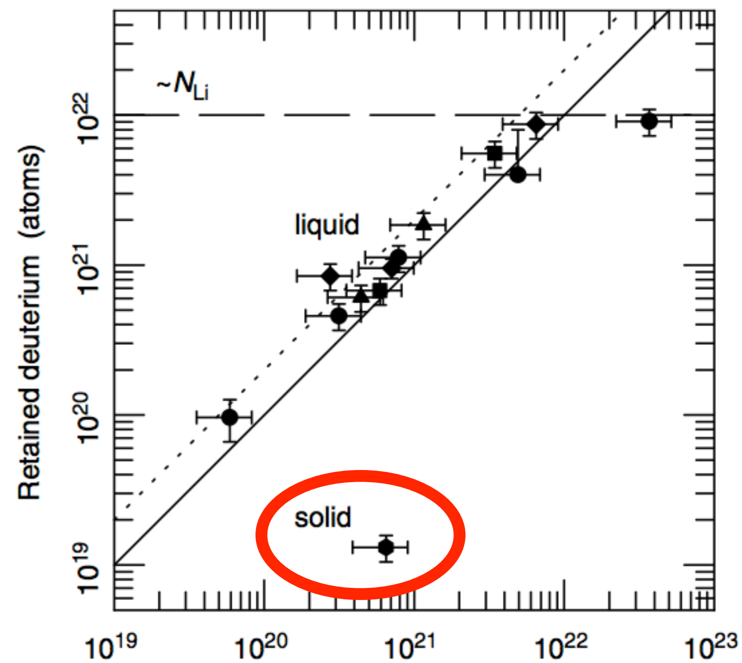


Figure 5. Plot of deuterium atom retention against plasma ion fluence. Data points are TDS measurements for lithium samples (liquid and solid) exposed to deuterium plasma. The sample exposure temperatures were: (solid) 323 K, (liquid) 523 K,573 K, 623 K, 673 K. The solid line indicates full retention of ions. The upper dashed line is the number of lithium atoms in samples. The dotted line is an estimate of the total atom fluence received by samples: the sum of the measured ion fluence and calculated neutral atom fluence [34].

PISCES:
0.1 g Li 99.9% purity pressed into disk-shaped Mo holder with Li well 12 mm dia, 3 mm deep.

Biased -50v w.r.to plasma

D content measured by TDS

100x less retention by solid Li.

Best Operating Temperature ?

D is released when Li-LiD evaporates.

Large surface area of porous Mo increases LLD Li evaporation.
Could exceed LiTER deposition at LLD temperatures ~ 300 C
(effective LLD surface area and hence temp limit uncertain).

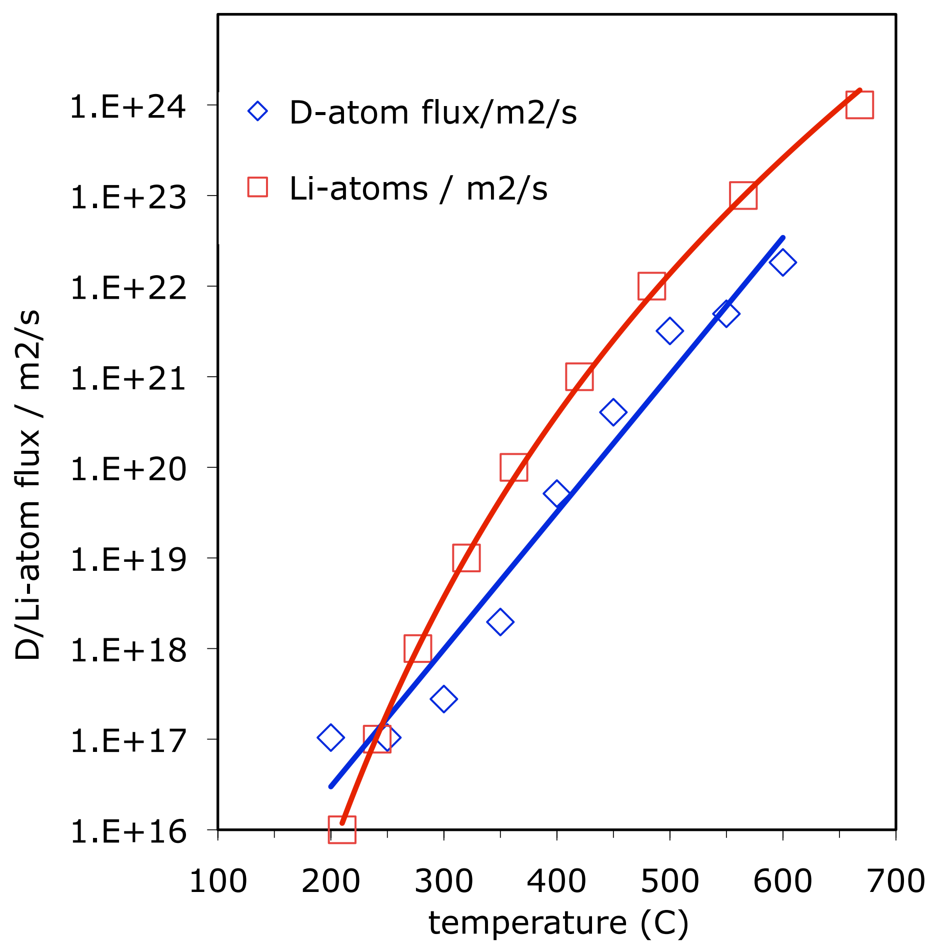
Rognlien calculates limiting temp of T < 380 C from Li influx.
[JNM 290 (2002) 312]

Thermal instability above 527 C due to additional electron conduction (Smirnov, Contrib. Plasma Phys. Sept 2009, 1)

Melting temperatures:

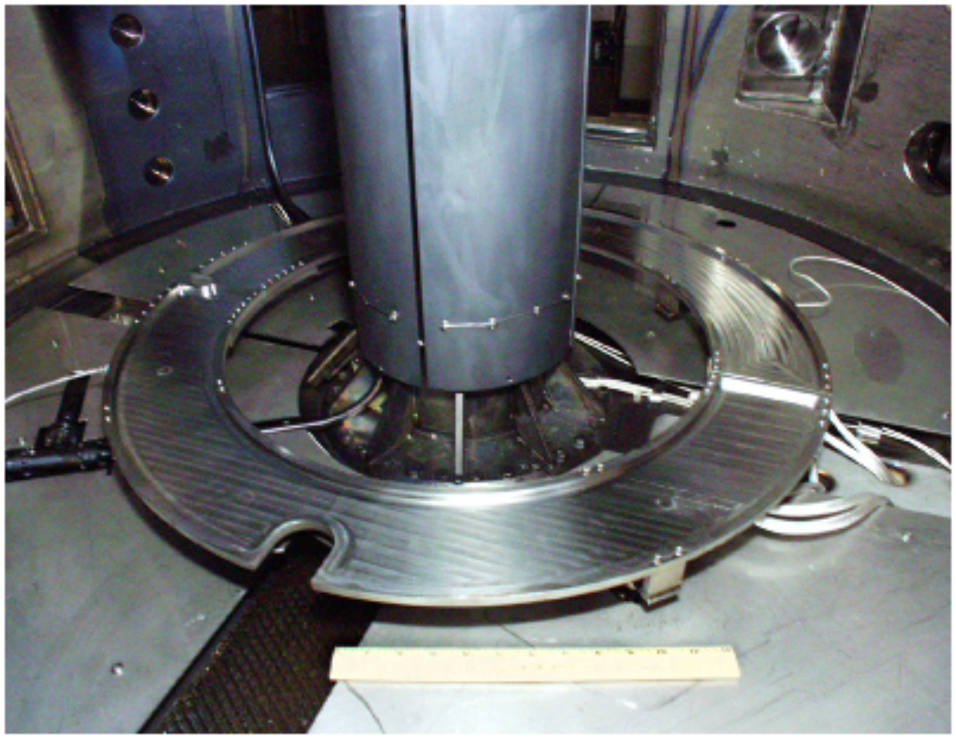
Li	180 C
LiOH	462 C
LiD	690 C
Li_2CO_3	723 C
Li_2O	1570 C !

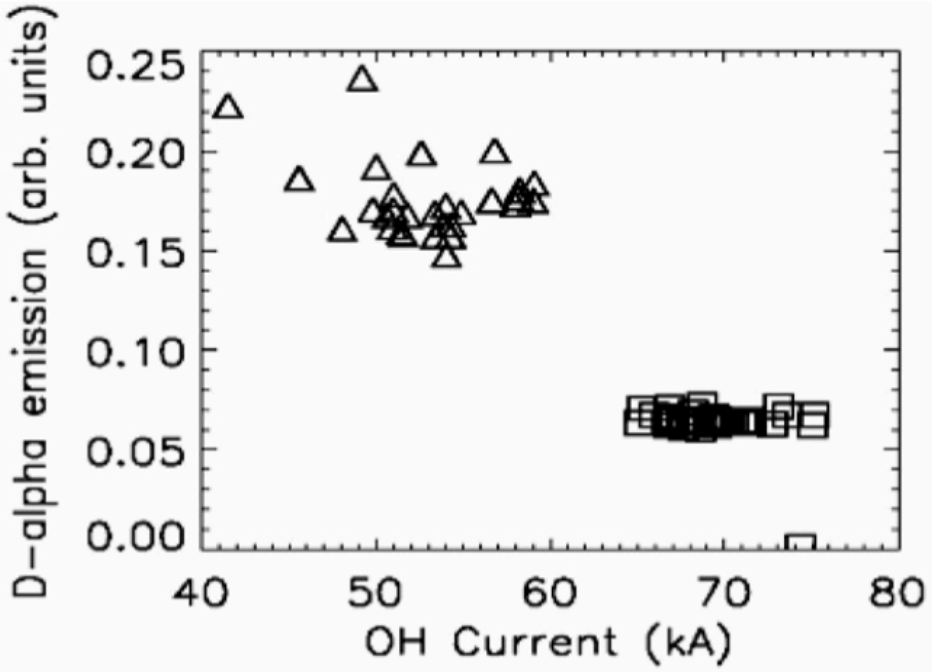
D flux (Baldwin NF Fig.3) cf Li evap. (Moir)



First issue for Li on CDX-U – lowered recycling

- Recycling drop observed with filterscope viewing tray from directly overhead
- Reduced recycling deduced from drop in D-alpha emission
  - No visible emission change across LLD suggests need for “persistence” experiment
- Correlated with improved confinement reflected in higher plasma currents at same Ohmic input power

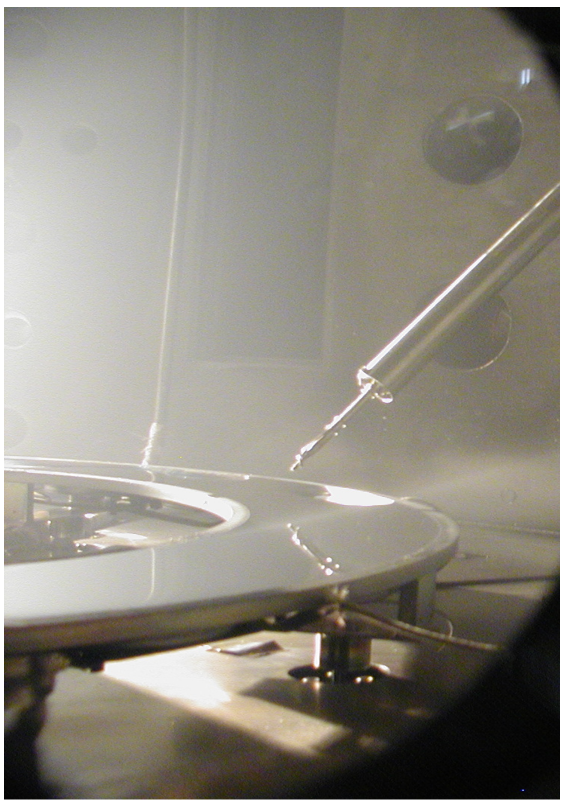


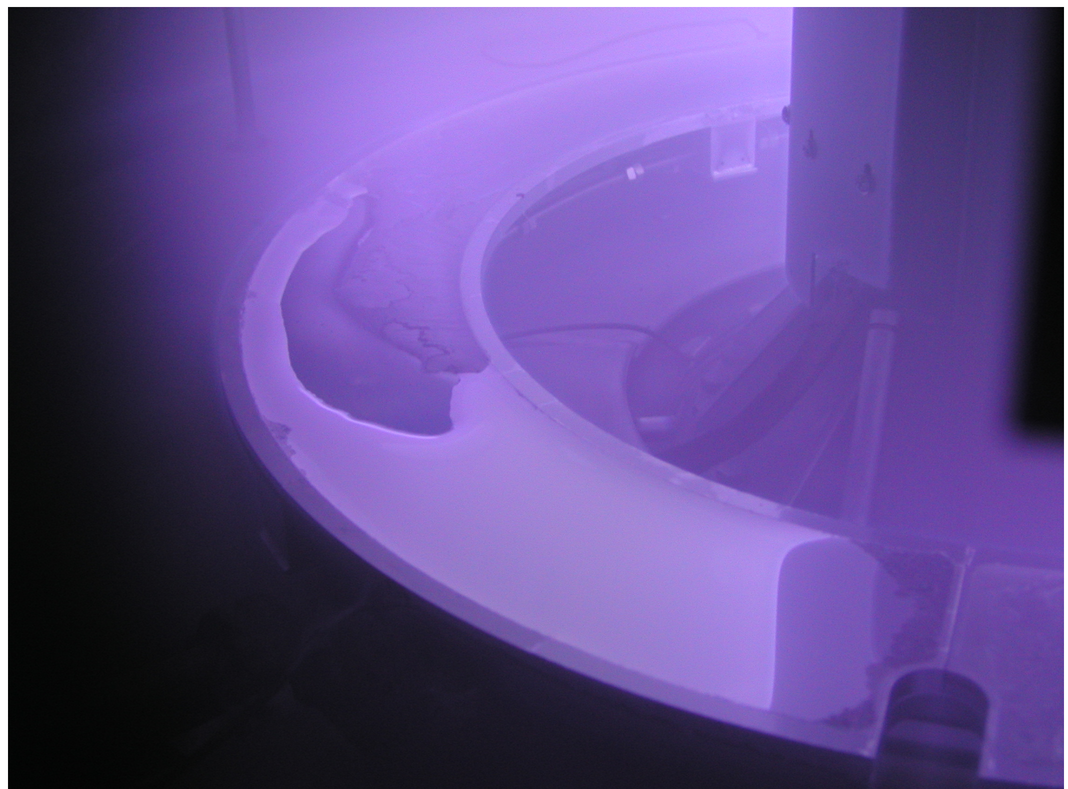


Comparison of edge Dα emission for pre-lithium (△) and post-lithium (□) discharges. The baseline evident in the lithium discharges is very consistent, and may be background Dα emission due to gas puffing.

Second issue for Li on CDX-U – surface conditions

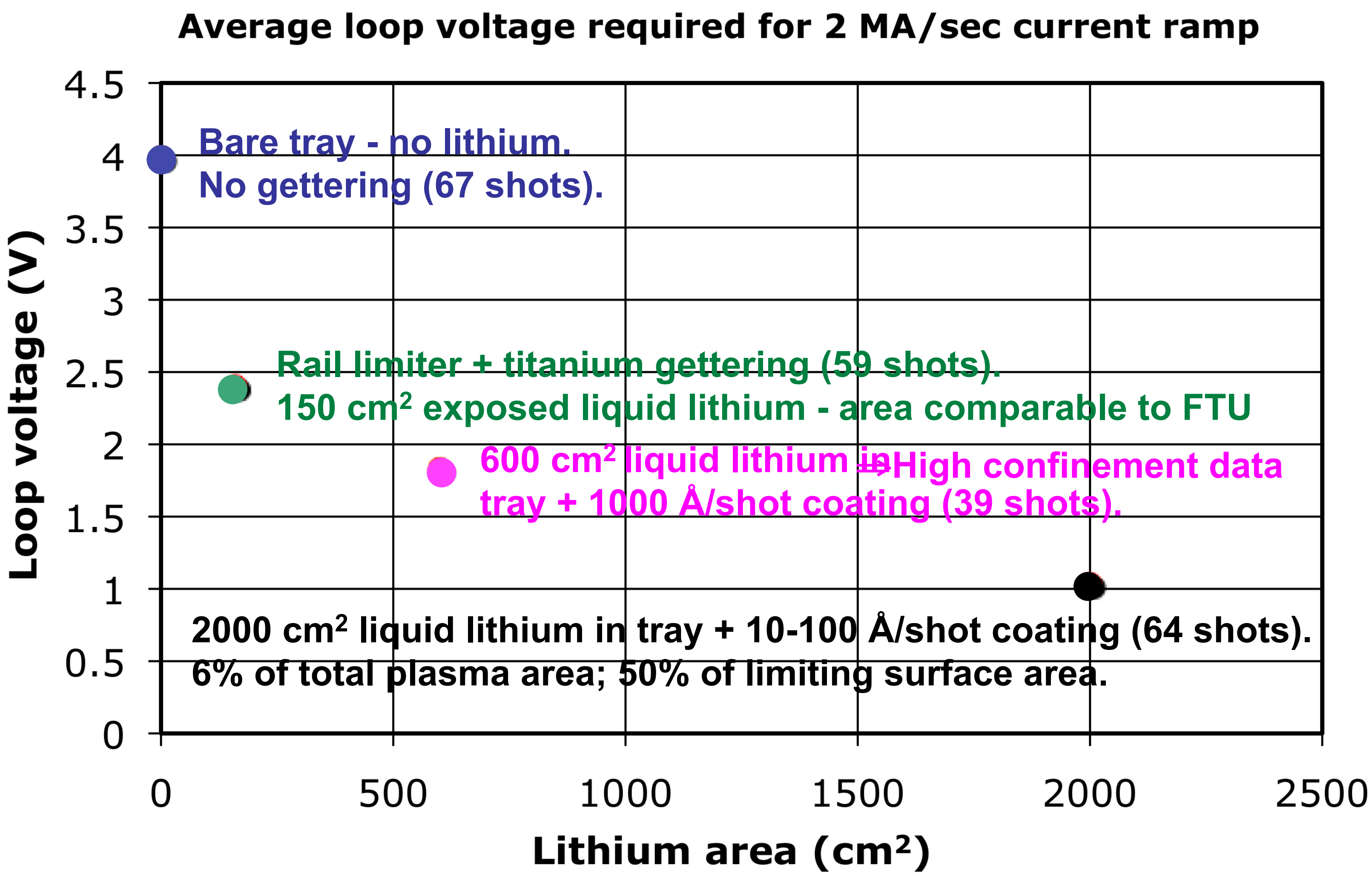
- Highly-reflective surface indicates clean lithium
- Optimum lithium temperature – 350 degrees C
  - Need to determine why lithium evaporation rate too high for porous Mo surface
- Existed immediately after filling of tray limiter with liquid lithium
  - Suggests need for liquid lithium filling system for LLD
- Achieved after lithium solidification only with at least four hours of Ar GDC
  - May require LLD segments to be reconfigured so that are electrically isolated





Third issue for Li on CDX-U – dependence of plasma performance on surface coverage

- External loop voltage reflects plasma performance in CDX-U
- Suggests that Li evaporation may mask effect of LLD on plasma performance
  - Need to perform "persistence" experiment after heaters are repaired



Lessons and recommendations for LLD

- Surface reactivation of LLD
  - Already done in FY10?
    - Strike point appears to "reactivate" LLD so effect of lithium "persists" in absence of evaporation between shots
    - Could be serving same function as long period of Ar GDC in CDX-U
      - *Reminiscent of electron beam heating of lithium-filled CDX-U tray?*
    - Need to confirm by comparing with plasmas not having strike point on LLD and evaporation between shots
- Recommendations for FY11/12
  - Begin with low-triangularity fiducial plasmas with unloaded LLD
  - Fill with LLD in situ using liquid lithium loader
    - Keep hot and run low-triangularity plasmas without strike point on LLD
    - Compare performance with unloaded LLD fiducials
    - Determine if performance improvement – if observed – "persists" with hot LLD
  - Let LLD cool and compare performance when "hot"
    - "Reactivate" with strike point on LLD plus heat
    - Compare with low-triangularity plasmas without strike point on LLD
- Ideas for long-pulse after NSTX upgrade
  - Offline tests seem to indicate ability of LLD to withstand MW/m^2-range power densities for three seconds
  - Consider replacing inner horizontal inboard divertor section at minimum
    - Think of developing flowing lithium system in conjunction with LTX

Backup Slides

Discussion Points:

- What do we know about the LLD surface temperature ?
  - Is it in the ‘Goldilocks’ range of 180 – 380 C ?
- What do we know about the LLD surface - is it oxidized or metallic Li ?
- Should we aim to come closer to PISCES conditions?
  - Can we bias LLD to 50 v ? run He-GDC with LLD as electrode to clean surface ?
- Can we measure D pumping with LLD material (porous Mo) at PISCES ? (or in C129 ?)
- Should we check NSTX LLD cleaning technique on PISCES ? (or in C129 ?)
- Does higher NSTX D flux quickly saturate the LLD surface even when liquid ?
- *Should we continue with LLD next year ? (fix heaters, Ly-a diagnostic…)*
- *Install Mo on inner divertor ?*
- *Design/install more efficient surface cleaning method.*
- *Install efficient Li filling ? (LiFTER).*
- *Can we rely on Li for density/impurity control for 5 s on NSTX-U ?*
- *Is there key data we can get in remaining NSTX run time ?*
- *Experiments with one heatable LLD plate ? (or 4 gas heated plates ?)*