XP1000: LLD Characterization

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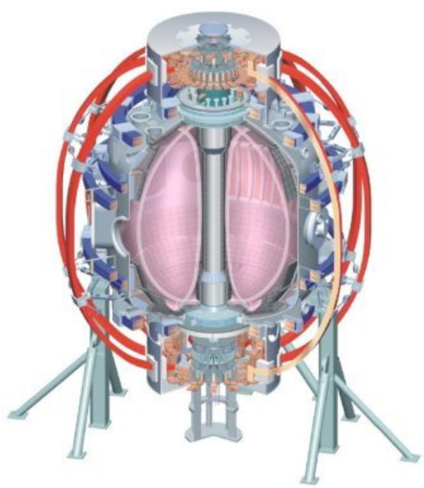
H.W.Kugel, R.Maingi, V.Soukhanovskii, et al.

Lithium Topical Focus Group
B252
2/17/2010



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Prerequisites

- Complete OP-XMP-~~48~~ 64: NSTX Start-up Commissioning and Evaluation Using Lithiumization

Princeton Plasma Physics Laboratory **NSTX Machine Proposal**		
Title: **NSTX Start-up Commissioning and Evaluation Using Lithiumization**		
OP-XMP-~~48~~ 64	Revision: ~~1~~ **0**	Effective Date: Feb 16, 20~~09~~10 *(Ref. OP-AD-97)* Expiration Date: Feb 16, 20~~11~~12 *(2 yrs. unless otherwise stipulated)*
Procedure Approvals		
Responsible author: **D. Mueller**		Date

Prerequisite XMP-64

1. **Overview:**

   This experiment will establish high plasma current NBI heated plasmas with controlled spatial trajectories for comparison with previous discharges. A shot to help calibrate MPTS is included and plasmas for RF conditioning are included since it is hoped the RF will be ready early in the run. Inner wall limited (as part of the normal start-up), single null diverted, and double null diverted discharges will be used. This task involves four basic steps: 1) plasma breakdown optimization using Lithiumization, 2) plasma control gain optimization (if needed)~~and~~, 3)plasma shape programming, and 4) testing ~~use of~~ rt-EFIT isoflux control ~~is planned~~.

2. **Justification:**

   These plasma scenarios will be the basis for many of the NBI experiments in the run.

3. **Plan:**

   I. After ISTP is completed and all systems are prepared for first breakdown, apply 2 hrs HeGDC. Record RGA spectra before, during, and after this HeGDC.

   II. With the LLD cold (at room temperature) perform a LITER deposition at 20 mg/min for at least 600 min (10hrs) to deposit 12g total ($20 x 10^{-3}$g/min x 600 min) of which 0.840g is incident on the LLD (7% of 12g) and yields an LLD Li coating thickness over its estimated physical area (8x geometric area) of 211nm ([0.840g/(0.534g/cm^3 x 8 x 9.3 $10^3 cm^2$)] x10^7nm/cm).

   III. When Step II is completed, record RGA spectrum and proceed to Step IV, while continuing to apply LITER at a rate of 20mg/min for 10 min between discharges. Monitor LLD temperatures and apply air cooling as required to maintain LLD temperature ≤ to 210 °C as soon as possible after each discharge.

   ~~I.~~IV. Establish common startup phase using preprogrammed poloidal field coil current control with a preprogrammed prefill of deuterium from an outer midplane gas injector and He puffing to maintain density. Verify that the plasma current, vessel current, and magnetic field and flux measurements used in the real time control system are being sampled and scaled appropriately in the real time the data acquisition system. Reference shot 123893, this is a 700 kA He RF conditioning target. See Phys Ops. Request Form. ~~Perform steps II-III as needed.~~ Repeat this step as needed.

XP1000: LLD Characterization, Day 1

Day	State of LLD	Outer Strike Pt R (m)	LLD °C	LITER 20 mg/min	Li g Deposited	Fueling	Pnbi MW	No. of Shots

Do Reference Shots Using Cold LLD.

1	cold	0.35	Rm temp	20		HFS	4	2
				NO/YES			6	2
							2	2
						SGI	4	2
							6	2
							2	2
						HFS	4	2
		0.50					6	2
							2	2
						SGI	4	2
							6	2
							2	2

- Candidate Reference shots: 129061, 132582.

XP1000: LLD Characterization, Day 2-3

1) Repeat Reference shots of Day-1.
2) Match $n_e(t)$ by fueling with both HFS & SGI as required.
3) Proceed to lower fueling for lower ne(t) using both HFS & SGI.
4) Power variation as needed to stay below beta limit.

DAY	State of LLD	Outer Strike Pt R (m)	LLD °C	LITER 20 mg/min	Li g Deposited	Fueling	Pnbi MW	No. of Shots
2-3	warm	0.35	210	NO/YES		HFS	4	2
							6	2
							2	2
						SGI	4	2
							6	2
							2	2
		0.50				HFS	4	2
							6	2
							2	2
						SGI	4	2
							6	2
							2	2

- Candidate Reference shots: 129061, 132582.

XP1000: LLD Characterization, Day 4

1) Select best fueling and LITER from Days #2 & #3

2) Slowly extend 2MW NBI pulse length: 100ms, 150ms, ….

DAY	State of LLD	Outer Strike Pt. R (m)	LLD °C	LITER 20 mg/min	Li g Deposited	Fueling	Pnbi MW	Pulse ms	No. of Shots
4	warm	0.63	210	NO/YES			2	100	2
		0.63					2	100	2
		0.75>0.63					2	100	2
		0.75>0.63					2	100	2
		0.75					2	100	2
							2	100	2
							2	150	2
							2	150	2
							2	200	2
							2	200	2
							2	250	2
							2	250	2

a) Same Candidate Reference shots: 129061, 132582 but with OSP extended to higher R for pumping demonstration.

b) Candidate Reference shots from 2008-09 database,129015-19, 129038.

XP1000: LLD Characterization, Day 5

Repeat Day-4 Reference Shots

DAY	State of LLD	Outer Strike Pt R (m)	LLD °C	LITER 20-40 mg/min	Li g Deposited	Fueling	Pnbi MW	No. of Shots
5	cold	0.63	Rm temp	NO/YES			2	2
							2	2
							2	2
							2	2
							2	2
							2	2
		0.75					2	2
							2	2
							2	2
							2	2
							2	2
							2	2

a) Same Candidate Reference shots: 129061, 132582 but with OSP extended to higher R for pumping demonstration.

b) Candidate Reference shots from 2008-09 database,129015-19, 129038.

XP1000: LLD Characterization, Day 6

1) LLD lithium maintenance.

2) Need nLi (0) measurement.

DAY	State of LLD	Outer Strike Pt R (m)	LLD °C	LITER 20 mg/min	Li g Deposited	Fueling	Pnbi MW	No. of Shots
6	warm	0.75	210	NO/YES			2	2
							2	2
							2	2
							2	2
							2	2
							2	2
							2	2
							2	2
							2	2

a) Same Candidate Reference shots: 129061, 132582 but with OSP extended to higher R for pumping demonstration.

b) Candidate Reference shots from 2008-09 database,129015-19, 129038.

Diagnostics for LLD Characterization

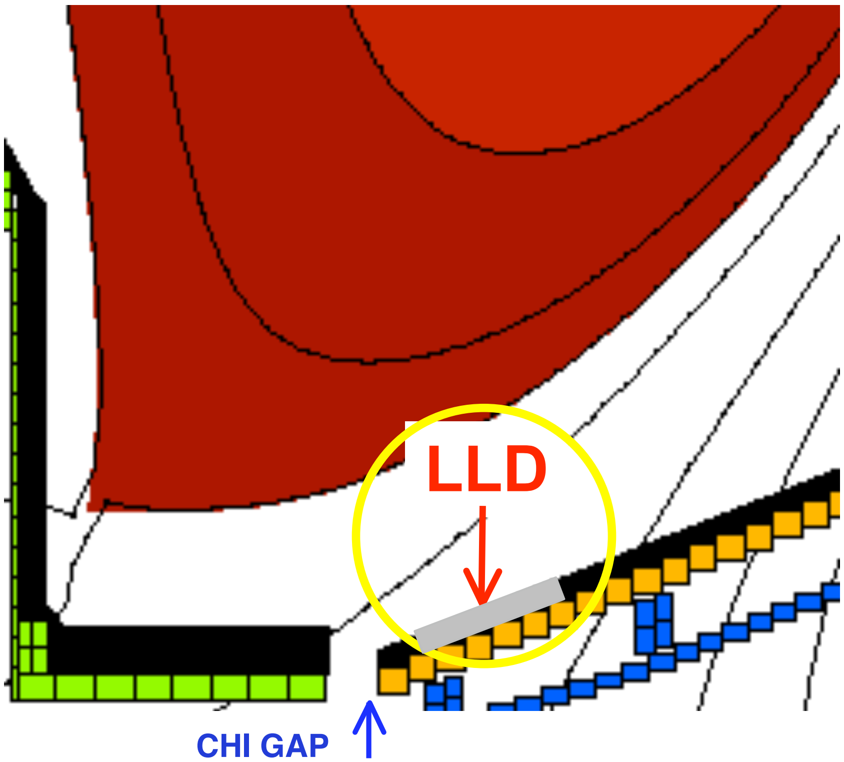
- Visible Cameras (unfiltered/filtered)
  - Phantom-V710, Bay-E, Top re-entrant window
  - Phantom-V7.3, Bay-J, Top re-entrant window
- IR Cameras
  - Fast IR Camera, Bay-H Top
  - Slow IR Camera, Bay-I Top
  - Slow IR Camera, Bay-G Bottom
- Divertor Spectrometer
- Lyman-α Diode Array
- Divertor Region Sample Probe
- 3 Quartz Deposition Monitors

Backup

Pumping by an LLD-I 15 cm Wide on Outer Divertor Will Provide Density Control for Inner Divertor Broad SOL Dα Profile High δ Plasmas

- Density reduction will depend on proximity of outer strike point to LLD-I

High δ : reduce n_e by >25%



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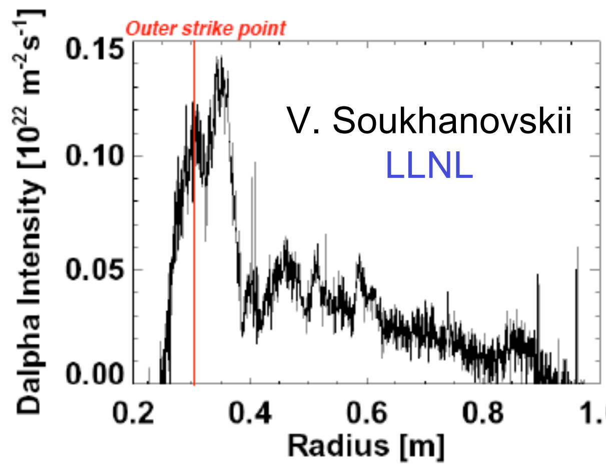
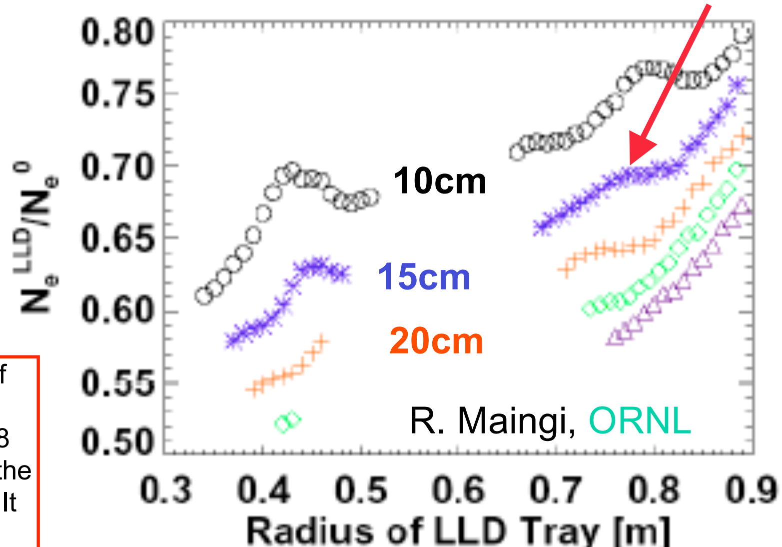


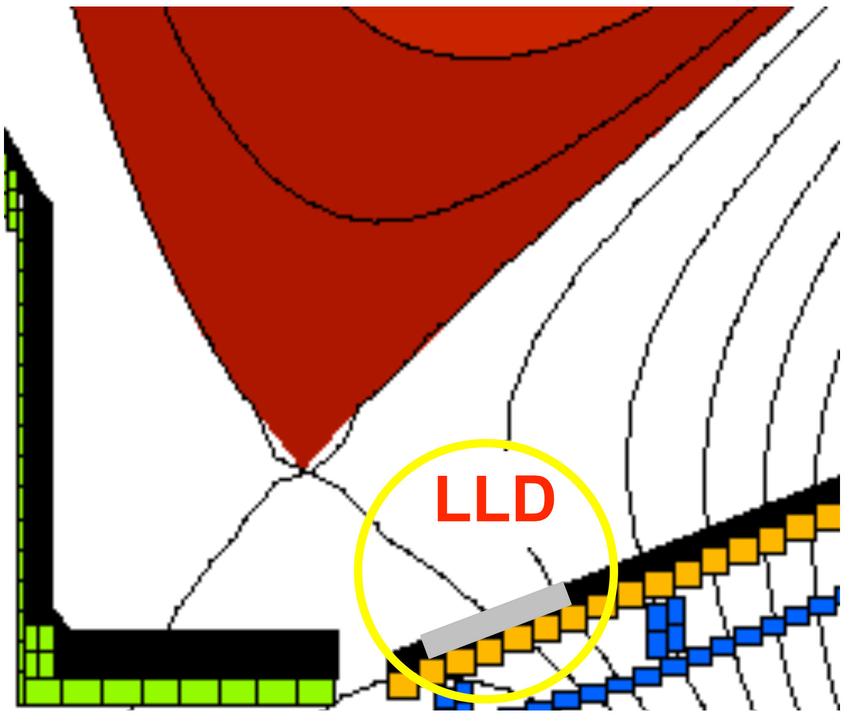


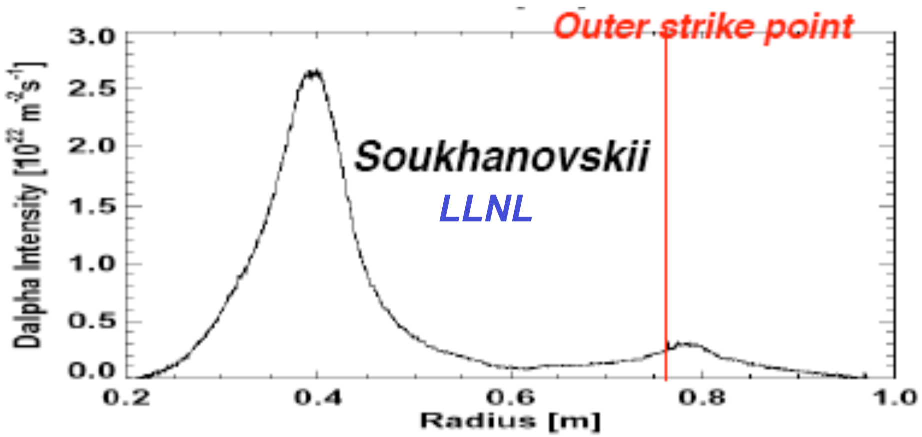
Shown for different LLD-I widths

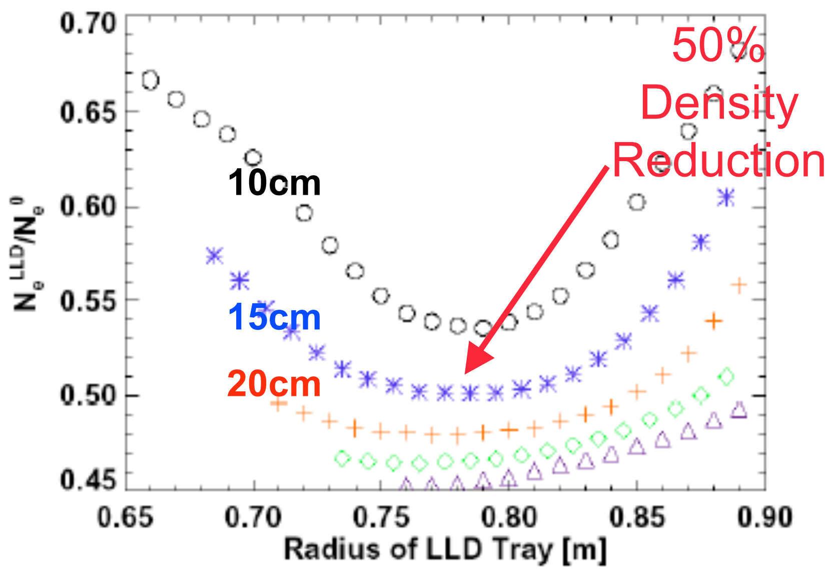
- The heat flux in our standard non-lithium fiducials increases with time because of the increasing li that causes an increasing OSP radius. The peak quasi-steady value is ~ 1 MW/m2, dropping to 0.6 MW/m2 at the outer edge of the tray, i.e. 0.8 MW/m2 average. It is lower by 50% early in the shot.In post-Li ELM-free cases, the contraction of the profile into the near SOL means the far SOL peak goes down. It is typically 0.5 MW/m2 average, assuming the lithium doesn't change the magnitude too much.Pre-li: 129013, 129014Post-li: 129064

NSTX Data Used to Enable Analysis of Expected Performance of LLD for Low δ Plasmas

Low δ : reduce n_e by 50%







R. Maingi, ORNL

Shown for different LLD-I widths

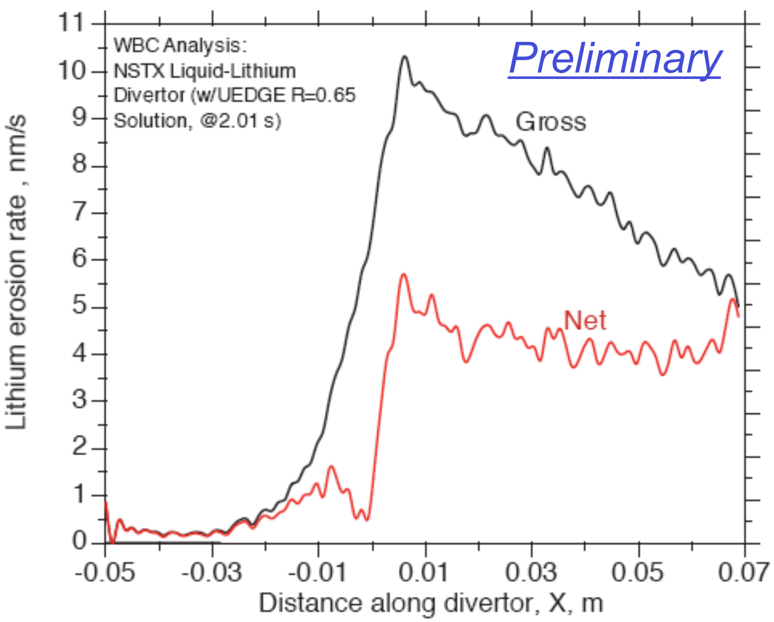
Automated IR Camera Calibrated Temperature Waveforms Needed Between Discharges

Li thermal conductivity is low. (~ W/m-°K 400 Cu, 140 Mo, 120 ATJ, 45 Li, 15 SS)

- **Power Handling: SNL thermal analysis for cases with the strike point on the LLD with peak Li temperature set at 400 °C,**
  - **can sustain a peak of ~2MW/m^2 for 10s and 4 MW/m^2 for ~3s.**
  - **Less Li, higher heat transfer.**
- **Lithium evaporation from LLD is very high above 400°C and D starts desorbing from LLD. Need to monitor temperature profiles during NBI.**
  - **LLD evap = LITER evap @ ~370°C**
- **Automated IR Camera calibrated temperature waveforms critical to monitoring LLD operation and benchmarking thermal simulations against initially short low, low power, NBI on LLD.**

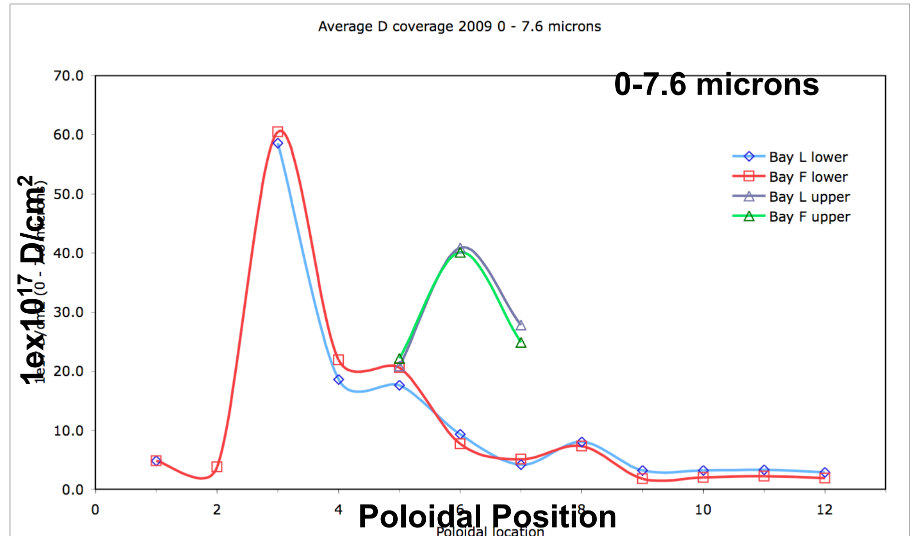
• Simulation Finds 50% of Li Sputtered from LLD Redeposited on Outer Divertor
• Ion Beam Analysis of NSTX 2009 Tiles Finds Li Redeposition on Outer Divertor

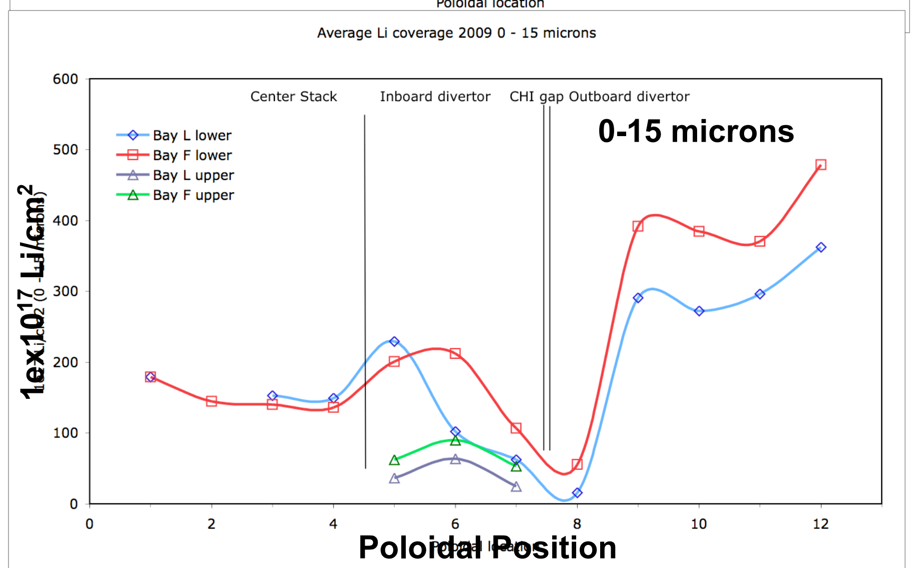
- 50.3% of sputtered (neutral) lithium is ionized within the computation zone (LLD and associated near-surface grid). 49.7% of sputtered lithium "escapes".



Gross and Net Erosion Rate Along LLD

- J.N. Brooks, J.P. Allain, Purdue Univ, PFC Meeting 7/09





IBA of NSTX 2009 Tiles

- W. R. Wampler, SNL, 11/09