Princeton Plasma Physics Laboratory

NSTX Experimental Proposal

Title: **LLD Characterization**		
OP-XP-1059	Revision: **0**	Effective Date: **6/11/2010** *(Approval date unless otherwise stipulated)* Expiration Date: **6/11/2012** *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

Responsible Author: H. W. Kugel	Date
ATI – ET Group Leader: C. H. Skinner	Date
RLM - Run Coordinator: E. D. Fredrickson (S. A. Sabbagh)	Date
Responsible Division: Experimental Research Operations	

RESTRICTIONS or MINOR MODIFICATIONS

(Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL

TITLE: **LLD Characterization** No. **OP-XP-1059**

AUTHORS: **H. Kugel, R. Maingi, V. Soukhanovskii** DATE: **6/11/2010**

---

1. Overview of planned experiment

Although the LLD was above Li melting temperature, initial XP1000 results are consistent with pumping by solid coatings. Saturation of the solid coating on the nearby graphite has not been tested.

Core Pumping was indicated by:

- Required increase in integrated gas puffing ~x2
- Required front-end startup adjustments in fueling and heating power
- Reduction in flux consumption early in the discharge
- HeGDC not required to remove fuel gas from previous discharge

Edge pumping was indicated by:

- Edge Ne and Te profiles very similar to extensive operation with solid lithium coatings
- Characteristic improvements in confinement relative to no Li
- Absence of ELMS

During XP1000, LLD fill was ~5%. For this low initial fill, analysis is complicated by several interleaved issues. XP1059 will test filling the LLD to >40-50% Li capacity. This decreases the physical to geometric area ratio and bypasses or minimizes 6 issues:

- desorption of deuterium exacerbated by the high surface area of the porous Mo
- mass-limited diffusion into the Li
- mass-limited retention
- effective range uncertainty
- impurity strata due to repeated hot-cold-hot cycles
- Li to impurity ratio higher

2. Theoretical/ empirical justification

Recent NSTX high power divertor experiments have shown significant and recurring benefits of solid lithium coatings on plasma facing components to the performance of divertor plasmas in both L- and H- mode confinement regimes heated by high-power neutral beams. The next step in this work is the 2009 installation of a Liquid Lithium Divertor (LLD) and its characterization during the 2010 Experimental Campaign.

3. Experimental run plan

3.1 Prerequisites.

3.1.1 Perform OP-XMP-64, "NSTX Start-up Commissioning and Evaluation Using Lithiumization" until the required Reference Discharges achieve research grade, defined as 4MW NBI, 600ms Ip flattop, $\tau_e \geq 50$ms, Se=200kJ.

3.1.2 The LLD has a capacity of 37g. The estimated LITER coating efficiency is 5-7%. This requires a total LITER evaporation of 265-370g for a 50% fill. Operate the LLD at a temperature of 220°C. Using the LITER system at a rate of 70mg/min, fill the LLD to about 50% full using a total LITER evaporation of about 265g.

3.1.3 Operate the LLD at a temperature of 220°C until the Day-1 work described in 3.3 below is completed.

3.2 Guidelines, Decision Points, Contingency.

3.2.1 During the NBI power scans, stacking of the early beams shall be applied if necessary to ensure constant front-end evolution, and reproducible H-mode transitions.

3.2.2 During the NBI power scans, the pulse length and power shall be adjusted slowly to keep the LLD front-face temperature during discharges below 380-400°C to minimize evaporation.

3.3 Day-1:

3.3.1 Reference Discharges:

XP 1000 Initial Reference Discharges:

- R = 0.35m, 0.5m: Candidate Reference shots: 129061, 132582.
- R= 0.65m, 0.75m: Same Candidate Reference shots: 129061, 132582 but with OSP extended to higher R for pumping demonstration. Candidate Reference shots from 2008-09 database,129015-19, 129038.

- R= 0.63m Kallman Shots 134986 - HFS, 134991 - SGI PF2L current ~ 3.5 kA (the value that strike point control approaches)

XP 1000 Tested Reference Discharges

- 137487 (R=35cm), 137564 (R=50cm), 137536 (R=63cm)
- 137610-137623 (EFIT01 = 69.8-71 cm)
- The adopted discharge for OSP R=71cm may benefit from XP1003 (X-pt Cntrl)

3.3.2 At this point, the LLD will have been operating at 220°C during the filling. On the morning of Day-1 turn-on LITER at 20-40 mg/min.

3.3.3 Take R=35cm fiducial [2]

3.3.4 Take R=50cm, R=63cm, R=70cm reference discharges. [2]

3.3.5 When ELM-free, and characteristic Li-edge conditions are confirmed at R=70cm, turn off LITER and allow cold Li coating to saturate. [3]

3.3.6 If R=70cm Li-edge conditions persist due to LLD pumping, measure the number of shots until Li-edge conditions cease (e.g, ELMy, non-Li profiles). [6]

3.3.7 If R=70cm Li-edge conditions persist, vary HFS and SGI fueling to minimize central density. [6]

3.3.8 Let LLD cool from liquid (220°C) to below solidification (<180°C) and characterize rate at which LLD Li saturates and Li-edge conditions cease.

3.4 Day-2:

3.4.1 Start with LLD at room temperature and LITER 20-40mg/min

3.4.2 With LLD cold, take R=35cm fiducial [2]

3.4.3 With LLD cold, take R=50cm, R=63cm, R=70cm reference discharges [2]

3.4.4 Start heating LLD from cold to 220°C [6]

3.4.5 If at 220°C, ELM-free, characteristic Li-edge conditions are confirmed at R=70cm, turn off LITER and allow cold Li coating to saturate [3]

3.4.6 Restart LITER and restore Li-edge conditions. [3]

3.4.7 If Li-edge conditions restored, start XP1001.

3.48 If Li-edge conditions not restored, increase LITER to 50-60mg/min and raise LLD temp and continue coating until Li-edge conditions are restored. [5]

4. Required machine, NBI, RF, CHI and diagnostic capabilities

Perform OP-XMP-64, "NSTX Start-up Commissioning and Evaluation Using Lithiumization" until the required Reference Discharges achieve research grade, defined as 4MW NBI, 600ms Ip flattop, $\tau_e \geq$ 50ms, Se=200kJ.

5. Planned analysis

UEDGE, TRANSP, etc.

6. Planned publication of results

PSI2010, Nucl. Fusion, IAEA2010

PHYSICS OPERATIONS REQUEST

TITLE: **LLD Characterization** No. **OP-XP-1059**
AUTHORS: **H. Kugel, R. Maingi, V. Soukhanovskii** DATE: **6/11/10**

(use additional sheets and attach waveform diagrams if necessary)

Brief description of the most important operational plasma conditions required:

1.) Perform OP-XMP-64, "NSTX Start-up Commissioning and Evaluation Using Lithiumization" until the required Reference Discharges achieve research grade, defined as 4MW NBI, 600ms Ip flattop, $\tau_e \geq$ 50ms, Se=200kJ.

XP 1000 Initial Reference Discharges:

- R = 0.35m, 0.5m: Candidate Reference shots: 129061, 132582.
- R= 0.65m, 0.75m: Same Candidate Reference shots: 129061, 132582 but with OSP extended to higher R for pumping demonstration. Candidate Reference shots from 2008-09 database,129015-19, 129038.

- R= 0.63m Kallman Shots 134986 - HFS, 134991 - SGI PF2L current ~ 3.5 kA (the value that strike point control approaches)

XP 1000 Tested Reference Discharges

- 137487 (R=35cm), 137564 (R=50cm), 137536 (R=63cm)
- 137610-137623 (EFIT01 = 69.8-71 cm)
- The adopted discharge for OSP R=71cm may benefit from XP1003 (X-pt Cntrl)

Previous shot(s) which can be repeated: Refer to Shot tables
Previous shot(s) which can be modified: Ibid. Refer to Shot tables

Machine conditions: Ibid,

I_{TF} (kA): Flattop start/stop (s):

I_P (MA): Flattop start/stop (s):

Configuration: **LSN**

Equilibrium Control: **Outer gap / Isoflux** (rtEFIT) **/ Strike-point control** (rtEFIT)

Outer gap (m): Inner gap (m): Z position (m):

Elongation: Triangularity (U/L): OSP radius (m):

Gas Species: Injector(s):

NBI Species: **D** Voltage (kV) **A: B: C:** Duration (s):

ICRF Power (MW): Phase between straps (°): Duration (s):

LITERs: Off / On Total deposition rate (mg/min):

LLD: Temperature (°C): **a) cold (30-50°C, b) warm (210-230°C)**

EFC coils: Off/On Configuration: **Odd / Even / Other**

DIAGNOSTIC CHECKLIST

TITLE: **LLD Characterization** No. **OP-XP-1000**

AUTHORS: H. Kugel, R. Maingi, V. Soukhanovskii DATE: **6/11/10**

Note special diagnostic requirements in Sec. 4 *Note special diagnostic requirements in Sec. 4*

Diagnostic	Need	Want
Beam Emission Spectroscopy		
Bolometer – divertor		√
Bolometer – midplane array	√	
CHERS – poloidal		√
CHERS – toroidal		√
Dust detector		√
Edge deposition monitors	√	
Edge neutral density diag.		√
Edge pressure gauges	√	
Edge rotation diagnostic		√
Fast cameras – divertor/LLD	√	
Fast ion D_alpha - FIDA		
Fast lost ion probes - IFLIP		
Fast lost ion probes - SFLIP		
Filterscopes	√	
FIReTIP		√
Gas puff imaging – divertor		√
Gas puff imaging – midplane		√
Hα camera - 1D		√
High-k scattering		√
Infrared cameras	√	
Interferometer - 1 mm		√
Langmuir probes – divertor		√
Langmuir probes – LLD		√
Langmuir probes – bias tile		√
Langmuir probes – RF ant.		√
Magnetics – B coils	√	
Magnetics – Diamagnetism	√	
Magnetics – Flux loops	√	
Magnetics – Locked modes	√	
Magnetics – Rogowski coils	√	
Magnetics – Halo currents		√
Magnetics – RWM sensors	√	
Mirnov coils – high f.		√
Mirnov coils – poloidal array		√
Mirnov coils – toroidal array		√
Mirnov coils – 3-axis proto.		√

Diagnostic	Need	Want
MSE		
NPA – E‖B scanning		
NPA – solid state		
Neutron detectors		√
Plasma TV	√	
Reflectometer – 65GHz		√
Reflectometer – correlation		√
Reflectometer – FM/CW		√
Reflectometer – fixed f		√
Reflectometer – SOL		√
RF edge probes		
Spectrometer – divertor		√
Spectrometer – SPRED		√
Spectrometer – VIPS		√
Spectrometer – LOWEUS		√
Spectrometer – XEUS		√
SWIFT – 2D flow		√
Thomson scattering	√	
Ultrasoft X-ray – pol. arrays		√
Ultrasoft X-rays – bicolor		√
Ultrasoft X-rays – TG spectr.		√
Visible bremsstrahlung det.	√	
X-ray crystal spectrom. - H		√
X-ray crystal spectrom. - V		√
X-ray tang. pinhole camera		√