Princeton Plasma Physics Laboratory
NSTX Experimental Proposal

Title: **LLD Characterization**		
OP-XP-1000	Revision: **0**	Effective Date: **3/22/2010** *(Approval date unless otherwise stipulated)* Expiration Date: **3/22/2012** *(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)

Prerequisite for XP1000:
Complete XMP064, "NSTX Start-up Commissioning and Evaluation Using Lithium Coating Only"

- After ISTP-001 and NB Alignment are completed, apply 2hrs HeGDC. Record RGA spectra before, during, and after this HeGDC.

- With the LLD at room temperature (TBD) perform a LITER deposition at 20 mg/min for at least 600min (10hrs). This will deposit 12g total of which 0.84g is incident on the LLD (7% of 12g) yielding a Li coating thickness over its estimated physical area (8x its geometric area) of ~200nm ([0.84g/(0.534g/cm^3 x 8 x 9.3 x 10^{3}cm^3)] x10^{7}nm/cm). Record initial and final RGA spectra.

- Complete the startup checklist.

- Continue to perform shots until the required reference discharges achieve research grade, defined as;
  4MW NBI, 600ms I_p flattop, $t_e \geq$ 50ms, Se $\geq$200kJ

XP1000 Has Parts: A and B

- Part A: Inner Divertor, R = 0.5m, 0.63m.
- Part B: Outer divertor, R=0.75m.
- 3 Options for scheduling Part A & B, either:
  - Schedule both for one, 3 day session
  - Or, schedule A for 2 days following XMP-064, and then later, 1 day for B
  - Or, schedule 2 days for A following XMP-064, and leave 3rd day as an administrative decision pending results of the first 2 days
- Note: Delaying Part B also delays XPs dependent on the results of Part B.

NSTX EXPERIMENTAL PROPOSAL

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

AUTHORS: **H. Kugel, R. Maingi, V. Soukhanovskii** DATE: **3/4/2010**

1. Overview of planned experiment

1. 1 The first purpose of this experiment is characterization of the Liquid Lithium Divertor (LLD) pumping capability and its effects on plasma performance as compared with solid lithium coatings.

1.2 The second purpose of this experiment is to qualify LLD-1 for use as an operational tool to support XPs for the duration of the 2010 Run.

1.3 The third purpose of this experiment is to achieve the LLD Milestone as follows:

- Install LLD-1.
- Determine the relationship between lithiated surface conditions and edge and core plasma conditions.
- Understand LLD-1 pumping, by a study of D retention as function of surface conditions such as Li coverage and LLD surface temperature, and plasma exhaust parameters such as: scrape-off layer density, temperature, strike-point location, and flux expansion.

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 Depending on the results of OP-XMP-64, do or do not use strike point controls.

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.

3.2.3 The R=0.35m case shall not be tested unless the R=0.63m case exhibits pumping.

3.3 Perform the discharges (cold, R=0.5m, 0.63m) listed in Part 1A.

DECISION POINT: If administratively approved, proceed to Part 2A (cold R=0.75m). If not approved, proceed to Part 1B (warm, R=0.5m, 0.63m).

3.4 If Parts 1A and 1B completed (cold and warm R = 0.5m, 0.63m) and if administratively approved, proceed to complete Part 2A and 2B (cold and warm R = 0.75m).

Part 1A. Do Reference Shots Using <u>Cold LLD</u> (To = 30-50°C).

Day	State of LLD	Outer Strike Pt R (m)	LLD °C	LITER 20 mg/min	Li g Deposited	Fueling	Pnbi MW /msec	No. of Shots
1	cold	0.50m	Rm temp	20mg/min		HFS	3	2
							5	2
						SGI	3	2
							5	2
		0.63m				HFS	2 /100	2
							2/TBD	
						SGI	2/100	2
							2/TBD	
Select best of HFS and SGI, and Test persistence of pumping effect								
				OFF				5

If administratively approved proceed to Part 2A. If not proceed to Part 1B.

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)

Part 1B. Do Reference Shots Using <u>Warm LLD</u> (To = 210-230°C).

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.

2	warm	0.50m	210°C	20mg/min		HFS	3	2
							5	2
						SGI	3	2
							5	2
		0.63m				HFS	2 /100	2
							2/TBD	
						SGI	2/100	2
							2/TBD	
Select best of HFS and SGI, and Test persistence of pumping effect								
				OFF		TBD		5

- 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)

If administratively approved, proceed to Part 2A. If not, wait until scheduled.

Part 2A. Do Reference Shots Using Cold LLD (To = 30-50°C).

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.

3		0.75m		20mg/min		HFS	2/100	2
							2/TBD	2
						SGI	2/100	2
							2/TBD	2
Select best of HFS and SGI, and Test persistence of pumping effect								
				OFF		TBD		5

Part 2B. Do Reference Shots Using Warm LLD (To = 210-230°C).

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.

3		0.75m		20mg/min		HFS	2/100	2
							2/TBD	2
						SGI	2/100	2
							2/TBD	2
Select best of HFS and SGI, and Test persistence of pumping effect								
				OFF		TBD		5

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

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-1000**
AUTHORS: **H. Kugel, R. Maingi, V. Soukhanovskii** DATE: **3/04/10**

(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, $\tau_s \geq 50$ms, Se=200kJ.

- 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.
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PF2L current ~ 3.5 kA (the value that strike point control approaches)

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: <u>**LSN**</u>

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

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Note special diagnostic requirements in Sec. 4

Diagnostic	Need	Want
Bolometer – tangential array	√	
Bolometer – divertor	√	
CHERS – toroidal	√	
CHERS – poloidal	√	
2 Divertor fast cameras	√	
Dust detector	√	
EBW radiometers		
Edge deposition monitors	√	
Edge neutral density diag.	√	
Edge pressure gauges	√	
Edge rotation diagnostic	√	
Fast ion D_alpha - FIDA		√
Fast lost ion probes - IFLIP		√
Fast lost ion probes - SFLIP		√
Filterscopes	√	
FIReTIP	√	
Gas puff imaging		
Hα camera - 1D	√	
High-k scattering	√	
Infrared cameras	√	
Interferometer - 1 mm	√	
Langmuir probes – divertor	√	
Langmuir probes – BEaP		√
Langmuir probes – RF ant.		√
Magnetics – Diamagnetism	√	
Magnetics – Flux loops	√	
Magnetics – Locked modes	√	
Magnetics – Pickup coils	√	
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.	√	

Note special diagnostic requirements in Sec. 4

Diagnostic	Need	Want
MSE	√	
NPA – ExB scanning		
NPA – solid state		
Neutron measurements	√	
Plasma TV	√	
Reciprocating probe		
Reflectometer – 65GHz	√	
Reflectometer – correlation	√	
Reflectometer – FM/CW	√	
Reflectometer – fixed f	√	
Reflectometer – SOL	√	
RF edge probes		
Spectrometer – SPRED	√	
Spectrometer – VIPS	√	
SWIFT – 2D flow	√	
Thomson scattering	√	
Ultrasoft X-ray 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 fast pinhole camera		
X-ray spectrometer - XEUS	√	