Princeton Plasma Physics Laboratory **NSTX Experimental Proposal**		
Title: **Liquid Lithium Divertor recycling and pumping studies**		
OP-XP-1001	Revision:	Effective Date: *(Approval date unless otherwise stipulated)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS	
Responsible Author: V. A. Soukhanovskii	Date
ATI – ET Group Leader: C. H. Skinner	Date
RLM - Run Coordinator:	Date
Responsible Division: Experimental Research Operations	

RESTRICTIONS or MINOR MODIFICATIONS

(Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL

TITLE: **LLD recycling and pumping studies** No. **OP-XP-1001**
AUTHORS: **V. A. Soukhanovskii, M. Jaworski, J. Kallman, H. W. Kugel, R. Maingi, R. Raman, and NSTX Team** DATE:

1. Overview of planned experiment

This XP is a part of a series of experiments that aim at characterizing the liquid lithium divertor (LLD) performance. In this experiment, pumping and recycling characteristics of the LLD and the surrounding lower divertor surfaces will be studied as functions of the steady-state core ion density, divertor density, and LLD temperature regime. Additionally, particle containment times (τ_p*) characterizing pump-out of the edge and SOL density will be measured or inferred using measurements-based particle balance models.

2. Theoretical/ empirical justification

Laboratory measurements (e.g., R. Doerner et al., Nucl. Fusion 42, 1318 (2002)) showed that liquid lithium retention of incident ions is a function of both liquid lithium temperature and ion fluence. This experiment aims at measuring the LLD pumping (i.e. dynamic retention) and recycling processes under a variety of temperature and incident ion flux conditions. A prerequisite to this experiment is XP 1000 by H. W. Kugel et al. The latter XP is expected to address the following points:

- Demonstration of reduced ion density / inventory with "warm" LLD (T=215-240 C) (i.e., pumping vs distance to strike point)
- Operational scenario for proper LLD thermal regime (i.e., temperature vs distance to strike point, NBI power)
- Impurity influx and core content with cold and warm LLD
- LITER evaporation requirements such as evaporation rate and evaporation frequency

3. Experimental run plan

1. Steady-state ion density scan and Density pump-out (τ_p*) measurements

   1.1. Establish a long-pulse H-mode discharge with SGI fueling and "cold" LLD (2-3 shots)

   - Use SGI scenarios from shots 134134, 134136, 134991 as guidance. If shots do not go through, use 200-400 Torr in high field side injector. SGI regime: R=158 cm, 5000 Torr, 10 ms pulses.
   - Use highest P_{NBI} possible while avoiding β-limiting instabilities (from XP 1000, e.g., 3 MW or 5 MW)
   - Use shaping similar to the best discharges with LLD pumping from XP 1000, e.g. high-triangularity with R_{OSP}=0.45 m, or medium triangularity with R_{OSP}=0.63 m. Use isoflux control for GAPOUT=10 cm
   - Use best LITER scenario established in XP 1000

1.2. Obtain several reference discharges with cold LLD and several core ion density (ion inventory) values by adding or removing SGI pulses in the fueling scenario (up to 10 shots)

- Expected range of steady-state ion densities 1-6 x 10^{19} m^{-3}
- Obtain core, edge, SOL, and divertor ion and electron densities from multiple diagnostics for particle balance analysis
- Add 1-3 SGI pulses after 0.4-0.5 s for "pump-out" characterization

1.3. Repeat best discharges from 1.2 with "warm" LLD to document density behavior (up to 10-15 shots)

- Use LDGIS gas injection in flat-top phase in 1-3 shots to document divertor density pump-out. LDGIS setup: plenum pressure 200-400 Torr.

2 (Optional, time permitting) LLD pumping as function of LLD temperature (up to 15 shots). If technically possible and administratively allowed, characterize pumping and recycling with LLD at higher temperature.

- Desirable range of LLD temperatures 200-320 C
- Repeat best discharges from 1.2 and 1.3 with LLD at higher temperature
- If LLD higher temperature is obtained as a result of plasma heating during a discharge, assure that best SGI pulse scenarios were used for pump-out characterization (parts
- Optional, time-permitting – repeat 1.3.1 for divertor pump-out characterization

3. (Optional, time-permitting) Density pumping and pump-out (τ_p*) measurements with warm LLD without fresh LITER coatings.

   - Establish "no-LITER" conditions by running up to 4 discharges without depositing fresh lithium coatings from LITERs. Note divertor recycling and lithium emission changes. Keep the LLD at room temperature for in discharges.
   - Repeat best discharges from 1.2 and 1.3 with "warm" LLD (220-250 C).

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

Prerequisite: XP 1000 as described in Section 2.

5. Planned analysis

EFIT, TRANSP, particle balance equations, UEDGE, SOLPS, DEGAS 2

6. Planned publication of results

Results will be presented in upcoming fusion meetings and major refereed publications.

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PHYSICS OPERATIONS REQUEST

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Brief description of the most important operational plasma conditions required:

Section 1.1

Previous shot(s) which can be repeated:

Previous shot(s) which can be modified: 134134, 134136, 134991 and shots from XP 1000

Machine conditions *(specify ranges as appropriate, strike out inapplicable cases)*

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

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

Configuration: **Limiter / DN / LSN / USN**

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):

CHI: **Off / On** Bank capacitance (mF):

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

LLD: Temperature (°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**
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.		

Note special diagnostic requirements in Sec. 4

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		