**Princeton Plasma Physics Laboratory**

# NSTX Experimental Proposal

Title: **Development and characterization of an intermediate δ discharge with lithium PFC coatings**

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|---|---|---|
| **OP-XP-919** | Revision: | Effective Date: **6/8/09**<br>*(Approval date unless otherwise stipulated)*<br>Expiration Date: **6/8/11**<br>*(2 yrs. unless otherwise stipulated)* |

## PROPOSAL APPROVALS

| | |
|---|---|
| **Responsible Author: J. Kallman** | Date 6/8/09 |
| **ATI – ET Group Leader: D. Gates** | Date 6/8/09 |
| **RLM - Run Coordinator: R. Raman** | Date 6/8/09 |

**Responsible Division: Experimental Research Operations**

## Chit Review Board (designated by Run Coordinator)

Note: Step 2 – 10mg/min and 12.5min clock cycle repeated 2-3 times should be able to produce the target ELM-free discharge. The lower level of LFS gas loaded from a fiducial is most likely preferred over the higher levels of initial gas used during high levels of Li evaporation.

Note: Step 5 – use SGI (5000 Torr), pulse durations loaded from shot 134134

SGI ON for 10ms pulses at 50, 63, 90, 125 and 165ms.

## MINOR MODIFICATIONS (Approved by Experimental Research Operations)

# NSTX EXPERIMENTAL PROPOSAL

TITLE: **Development and characterization of an intermediate δ discharge with lithium PFC coatings** No. **OP-XP-919**

AUTHORS: **Josh Kallman** DATE: **6/5/09**

## 1. Overview of planned experiment

In order to study the effect of the LLD on particle pumping in NSTX and to utilize advanced control capabilities such as ELM triggering, an intermediate triangularity discharge will be developed. The discharge will run the strike point on the bull-nose tiles just outboard of the CHI gap and inboard of the LLD. In the FY09 stage of the experiment, the robustness of strike point control under varying plasma parameters (beam power, Ip, fueling) and deposition will be studied. The key figure of merit will be strike point position, with impurity, radiation, temperature, and density profiles obtained for reference during the discharges. This shape will be studied under baseline pre-Li, LITER, and then LLD conditions. The development and study of such a discharge will allow a controlled characterization of how lithium PFCs affect the plasma and what benefits they can provide.

## 2. Theoretical/ empirical justification

Solid lithium coatings have shown many performance benefits in NSTX, but the rises in hydrogenic and impurity density remain problematic. New diagnostics will provide the capability to better diagnose these phenomena and the LLD will later provide a more powerful tool for using lithium in NSTX. Characterization of heat fluxes will show how lithium modifies the SOL properties in this plasma shape. As an intermediate step, strike point control is necessary to avoid placing too much energy on either the CHI gap or the LLD itself.

## 3. Experimental run plan

All discharges will be run with the strike point at R~0.63m for the duration of the shot. This will utilize the strike point control developed in XP 904 and will start from a modified version of 133988 from that XP.

1. Pre-Li baseline (3-4 discharges)

Deuterium glow for 30s will be performed prior to 8 min He GDC before the first two shots. Discharge will be loaded from 133988 (or subsequently developed discharge). If modification has not been made already, shape will be optimized by adding 5 kA spike in PF1AL current and 2 kA spike in PF1AU current to raise bottom gap. PF1AL will also run at 2 kA higher current to keep flux off of bull nose tiles surrounding CHI gap.

NB sources as below. 1 discharge at each configuration. No Li evap. 4 MW power discharge is desired.

| Source A | Source B | Source C | Total |
|---|---|---|---|
| 2 MW – 60 ms on | 2 MW – 80 ms on | 2 MW – 130 ms on | 6 MW |
| 2 MW – 60 ms on | 2 MW – 80 ms on | 2 MW – 130 -150 ms | 6 → 4 MW |

If H-mode not achieved in discharge 2, extend source C time to 180 ms. If successful, repeat once before Li.

CS gas steady at 1200 Torr-L.

2. Lithium evaporation at sufficient rate to establish ELM-suppressed discharge with fueling to prevent discharge collapse due to Li pumping (8 discharges)

Keeping 4 MW power configuration from best shot above, begin with 10 mg/min lithium evaporation and increase until stable, ELM free discharge has been achieved. If unable to reach H-mode, adjust beam timing in similar manner as above, keeping Source C on longer until H-mode is reached. If beta limits are hit, try to decrease or eliminate Source C on-time. If necessary, drop Source C power to 1 MW and cut source B once H-mode reached. Start with CS gas at 1200, but increase in 100 Torr-L increments in order to maintain discharge. Increase lithium in 5 mg/min increments as necessary in order to suppress ELMS. If any change fails to produce a stable discharge, return to last successful shot and repeat before changing again. Once stable discharge achieved, repeat once.

3. Scan in late-discharge power, keeping fueling and Li rate fixed as determined in step 2 above (9 discharges)

Begin with 4 MW discharge from above and change beam power at 200 ms to demonstrate discharge and strike point control robustness. If a discharge fails, repeat last stable discharge before moving on to different power/timing.

| Source A | Source B | Source C | Total |
|---|---|---|---|
| 2 MW - 60 ms on | 2 MW – 80 – 200 ms | 2 MW – 130 – 150 ms | 6 → 4 → 2 MW |
| 2 MW – 60 ms on | 1 MW – 80 ms on | 2 MW – 130 – 150 ms | 5 → 3 MW |
| 2 MW – 60 ms on | 1 MW – 80 ms on | 2 MW – 130 ms on | 5 MW |
| 2 MW – 60 ms on | 2 MW – 80 ms on | 2 MW – 130 ms on | 6 MW (optional) |

4. Ip Scan using lowest-power stable discharge above (6 discharges)

Utilizing Li rate, fueling, and NB power from discharge as determined above, scan at 3 different Ip. 2 discharges at each of 850 kA, 950 kA, 1 MA. Verify strike point control and equilibrium stability/profiles. If strike point control fails, attempt to diagnose with Ege or move to different IP or next step.

5. Scan in fueling, beginning with optimum fueling/Li rate from lowest power/highest current discharge above (8 discharges)

Begin with CS rate as determined above and decrease in 100 T-L increments. 1 discharges at each rate, until shot fails to go through. Once down to minimum sustainable rate, begin adding SGI/shoulder gas at pressures and times as determined from Vlad XP. If possible, further decrease CS flow while adding more SGI to compensate.

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

Key prerequisite is development of intermediate triangularity discharge with controlled strike point location in XP by Koleman. NBI heating desired in order to reach H-mode. Diagnostics desired shown on attached.

## 5. Planned analysis

EFIT for equilibrium reconstruction, TRANSP for transport analysis, and edge modeling codes to determine effect of LLD on discharge parameters (R, T_e, etc)

## 6. Planned publication of results

Results will be published as thesis research, with incidental publications occurring as needed.

# PHYSICS OPERATIONS REQUEST

TITLE: **Development and characterization of an intermediate δ discharge with lithium PFC coatings** No. **OP-XP-919**

AUTHORS: **Josh Kallman** DATE: **6/2/09**

**Describe briefly the most important plasma conditions required for the XP:**

Desire is to establish an ELM-free discharge with lithium present and with the strike point remaining at R=~.63 m (intermediate triangularity). This is the baseline for LLD operation and the goal is to characterize the impurity, density, and heat flux properties of this discharge:

A) without lithium

B) with evaporated lithium

C) with the LLD

This XP will fulfill parts A+B and will attempt to establish a stable equilibrium under the new shape parameters.

**List any pre-existing shots:**

133988

**Equilibrium Control:** Gap Control / rtEFIT(isoflux control):

Machine conditions *(specify ranges as appropriate, use more than one sheet if necessary)*

$I_{TF}$ (kA): **50** Flattop start/stop (s): **0/1**

$I_P$ (MA): **.750** Flattop start/stop (s): **.2/.8**

Configuration: **~~Limiter~~ / ~~DN~~ / LSN / ~~USN~~** *(strike out inapplicable cases)*

Outer gap (m): **.08** Inner gap (m): **.13** Z position (m):

Elongation $\kappa$: 2.25 Upper/lower triangularity $\delta$: **.55**

Gas Species: **D** Injector(s): **CS, SGI** , Shoulder

**NBI** Species: **D** Voltages (kV or off) **A: 90** **B: 90** **C: 90** Duration (s):

**ICRF** Power (MW): Phasing: Duration (s):

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

**LITERs: ~~Off~~ / On** Total deposition rate (mg/min): variable, but as necessary for ELM suppression, up to maximum of 40 mg/min.

**EFC coils: Off/~~On~~** Configuration: **Odd / Even / Other** *(attach detailed sheet)*

## DIAGNOSTIC CHECKLIST

TITLE: **Development and characterization of an intermediate δ discharge with lithium PFC coatings** No. **OP-XP-919**

AUTHORS: **Josh Kallman** DATE: **6/2/09**

*Note special diagnostic requirements in Sec. 4*

| **Diagnostic** | **Need** | **Want** |
|---|---|---|
| Bolometer – tangential array | **X** | |
| Bolometer – divertor | | **x** |
| CHERS – toroidal | **X** | |
| CHERS – poloidal | | **x** |
| Divertor fast camera | **X** | |
| Dust detector | | **x** |
| EBW radiometers | | |
| Edge deposition monitors | **X** | |
| Edge neutral density diag. | **X** | |
| Edge pressure gauges | **X** | |
| Edge rotation diagnostic | | **X** |
| Fast ion D_alpha - FIDA | | |
| Fast lost ion probes - IFLIP | | |
| Fast lost ion probes - SFLIP | | |
| Filterscopes | **X** | |
| FIReTIP | **X** | |
| Gas puff imaging | | |
| Hα camera - 1D | **X** | |
| High-k scattering | | |
| Infrared cameras | **X** | |
| Interferometer - 1 mm | **X** | |
| Langmuir probes – divertor | **X** | |
| Langmuir probes – BEaP | | |
| Langmuir probes – RF ant. | | |
| Magnetics – Diamagnetism | **X** | |
| Magnetics – Flux loops | √ | |
| Magnetics – Locked modes | **X** | |
| Magnetics – Pickup coils | √ | |
| Magnetics – Rogowski coils | √ | |
| Magnetics – Halo currents | | |
| Magnetics – RWM sensors | **X** | |
| Mirnov coils – high f. | | |
| Mirnov coils – poloidal array | **X** | |
| Mirnov coils – toroidal array | **X** | |
| Mirnov coils – 3-axis proto. | | |

*Note special diagnostic requirements in Sec. 4*

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