Princeton Plasma Physics Laboratory **NSTX Experimental Proposal**		
Title: Radiative divertor with impurity seeding and lithium coatings in NSTX		
OP-XP-1050	Revision:	Effective Date: *(Approval date unless otherwise stipulated)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS	
Responsible Author: V. A. Soukhanovskii	Date **1 September 2010**
ATI – ET Group Leader: R. Maingi	Date
RLM - Run Coordinator: E. Fredrickson	Date
Responsible Division: Experimental Research Operations	

RESTRICTIONS or MINOR MODIFICATIONS
(Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL

TITLE: Radiative divertor with impurity seeding in NSTX No. **OP-XP-1050**
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1. Overview of planned experiment

The goal of this experiment is to study a steady-state partially detached divertor (PDD) regime with impurity seeding. This will be done in NBI-heated H-mode discharges in a higher-end elongation / triangularity lower single null (LSN) and double null (DN) shapes with κ=2.3–2.4 and δ=0.5-0.7. Gaseous impurity (e.g., deuterated methane CD_4) will be injected in increased quantities to increase divertor P_{rad} to obtain the outer target detachment. Divertor measurements, such as the D_α, D_β, D_γ brightness profiles, heat flux profiles from two-color IR cameras, core and divertor radiated power, divertor Langmuir probe I_{sat} and neutral pressure will be measured and analyzed for signs of heat flux reduction, recombination, power and momentum loss, and an X-point MARFE formation. The goal is to determine the injected gas quantity necessary to establish PDD conditions, simultaneously retaining good core plasma quantities (MHD, confinement, impurity level). Another goal is to study the operational space of the impurity-seeded radiative divertor, changing input power and divertor pumping (with LITERs or LLD).

2. Theoretical/ empirical justification

Presently, divertor geometry and radiative (detached) divertors are considered candidate techniques for steady-state mitigation of divertor heat flux and erosion of divertor material in NSTX and NSTX-U. Recent experiments conducted with a high flux expansion divertor demonstrated significant divertor peak heat flux reduction and access to partial detachment using additional D_2 injection at $\Gamma < 9.8 \times 10^{21}$ s^{-1} and divertor radiation from intrinsic impurities (lithium helium, carbon) [1, 2]. The proposed experiment will attempt to reproduce these results using extrinsic impurity seeding in LSN and DN configurations.

3. Experimental run plan

Part 1. Heat flux reduction and detachment in high elongation / triangularity LSN plasmas with impurity seeding (10-15 shots)

1. Setup a HFS-fueled discharge with elongation κ = 2.2 – 2.4, triangularity δ < 0.75, and -5>*drsep*>-10 mm with highest possible I_p (0.9-1.2 MA) and highest NBI power (5-6 MW) for highest divertor peak heat flux (2-3 shots)
   - Wall conditions should permit reproducible H-mode access with 2 NBI sources
   - rtEFIT control will be used
   - Use 140560 (0.8 MA / 4 kG / 6 MW) as a template shot, or some more recent 1 MA shot
   - Configuration will be adjusted to obtain *drsep* ~ -1.0 cm, outer gap ~ 10 cm, R_{OSP} ~ 35 – 45 cm

2. Perform a scan of gas injection rate and/or times (5 shots).
   - Inject CD_4 from Bay E lower divertor gas injector in increasing quantities until partial detachment is observed. If the gas injector plenum pressure is 1000-2000 Torr, a pulse of 10 ms and higher would contain about 5-10 % of the total carbon discharge inventory.

- Use Supersonic gas injector (SGI) instead of divertor gas injector to study dependence on gas poloidal location and carbon transport
- As a backup option, may use Branch 5 injector and the PZV4/4a valve to inject gas in the outer SOL close to outer strike point

3. Overview of desirable data
   - Obtain data in a range of NBI input powers (2-5 MW)
   - Obtain data in a range of LITER rates (100-400 mg/shot)
     - Use best PDD discharge from above with doubled LITER rate as a starting point
   - In one high density discharge, turn off NBI at the time when n_e is high (> 5 x 10^{19} m^{-3}) to obtain high density low input power condition for ~ 200 ms
   - Use GPI diagnostic to obtain edge turbulence data in some shots (pitch angle permitting)
   - Optional, time permitting: Obtain PDD with D_2 gas injection at similar discharge parameters for comparison

Part 2. Heat flux reduction and detachment in high elongation / triangularity DN plasmas (10 shots)

Repeat the best gas injection scenario in DN shots. Optional, time permitting - scan down gas injection rate using plenum pressure increments of 100-150 Torr.

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

NBI, good wall conditions, LITER, diagnostic set as in attachment

5. Planned analysis

EFIT, LRDFIT, TRANSP, UEDGE

6. Planned publication of results

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

References

[1] SOUKHANOVSKII, V. A. et al., Phys. Plasmas 16 (2009) 022501.
[2] SOUKHANOVSKII, V. A. et al., Nucl. Fusion 49 (2009) 095025.

PHYSICS OPERATIONS REQUEST

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Brief description of the most important operational plasma conditions required:

NBI, LITER, PCS, Bay E divertor gas injector

1) Demonstrate impurity-seeded radiative divertor

2) Study divertor radiated power, peak divertor heat flux and core confinement and performance as functions of SOL power, impurity seeding rate and lithium deposition rate

Previous shot(s) which can be repeated: 140560

Previous shot(s) which can be modified: 140560

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

I_{TF} (kA): **56.2** Flattop start/stop (s):

I_P (MA): **0.9** Flattop start/stop (s):

Configuration: **LSN**

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

Outer gap (m): **10 cm** Inner gap (m): Z position (m): **0.00**

Elongation: Triangularity (U/L): OSP radius (m): **0.4-0.55**

Gas Species: **D2** Injector(s): **HFS at 1600-1900 Torr, 2, 3, Bay E divertor**

NBI Species: **D** Voltage (kV) **A: 90** **B: 90** **C:** 65 Duration (s):

ICRF Power (MW): **0** Phase between straps (°): Duration (s):

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

LITERs: On Total deposition rate (mg/min): **10-40**

LLD: Temperature (°C): **room, no heating applied**

EFC coils: On Configuration: **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		