Princeton Plasma Physics Laboratory **NSTX Experimental Proposal**			
Title: “Snowflake” divertor configuration in NSTX			
OP-XP-1045	Revision:	Effective Date: *(Approval date unless otherwise stipulated)* Expiration Date: *(2 yrs. unless otherwise stipulated)*	
PROPOSAL APPROVALS			
Responsible Author: V. A. Soukhanovskii			Date **1 August 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: "Snowflake" divertor configuration in NSTX No. **OP-XP-1045**
AUTHORS: **V. A. Soukhanovskii et al.** DATE:

1. Overview of planned experiment

The goal of the experiment is to obtain and study the "snowflake" divertor (SFD) configuration in NSTX. In the first part, configuration scoping studies will be performed to obtain the SFD configuration 1) using the developed strike point PCS control; 2) using pre-programmed divertor coil currents and the new reversed PF1B coil configuration. Once stable SfD configurations are obtained, we will characterize their transport, turbulence and radiative properties in the second part of the XP, by scanning plasma current, input power, lithium evaporation rate, and divertor gas injection rate.

2. Theoretical/ empirical justification

The "snowflake" divertor configuration has been recently proposed by Dr. D. D. Ryutov [1-5]. The concept has been evaluated using analytic and numerical modeling [1-5], and first results have been obtained in the TCV tokamak [6] and NSTX. In the "snowflake" divertor configuration, a second-order null is created in the divertor region by placing two X-points in close proximity to each other. In NSTX, two divertor coils PF1A and PF2L will be used to obtain the "snowflake" configuration. The initial results obtained on NSTX in XP 924 in 2009 were very encouraging: the "snowflake" configuration was obtained using the strike point control capability in PCS, and significant reductions in divertor peak heat flux and core impurities were demonstrated [7 - 9].

3. Experimental run plan

3.1 "Snowflake" divertor configuration with PF1A and PF2L coils

- Obtain a reference discharge, 2-4 MW NBI, medium triangularity shape w/ PF1A and PF2L, LITER rate 10-20 mg/min (100-200 mg), R_{OSP}=0.50-0.60 m, both ISP and OSP under PCS control. Use shots 137983, 139391 as a starting point
- Use OSP position and lower squareness adjustments to obtain "snowflake" configurations
- Criteria for "snowflake" divertor configuration – lower null-point separation d < 20 cm, as well as clear proximity of secondary null to the primary lower X-point in EFIT02 reconstructions

3.2 "Snowflake" divertor configuration with reversed PF1B, PF1A and PF2L coils

- Use isoflux controlled shot 139121 as a starting point
- Introduce PF1B in flattop (ramp starting at 0.25-0.3 over 50-100 ms) at 1, 2, 3 kA levels

3.3 “Snowflake” divertor configuration properties

Document conditions in the “snowflake” divertor configuration discharges developed above by changing plasma current, input power, divertor pumping, and divertor radiated power as follows:

- Obtain discharges in a range of plasma currents (0.7 – 1.2 MA)
- Obtain discharges in a range of NBI power (1 – 5 MW)
- Obtain discharges in a range of LITER rates (100 – 400 mg / shot)
- Study impact of divertor gas injection by using Bay E divertor gas injector at several rates (plenum pressure range 1000-4000 Torr using deuterium)
- Study impact of divertor impurity gas injection by using Bay E divertor gas injector at several rates (plenum pressure range 500-1000 Torr using deuterated methane).

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] M.V. Umansky, R.H. Bulmer, R.H. Cohen, T.D. Rognlien and D.D. Ryutov, Analysis of geometric variations in high-power tokamak divertors, Nucl. Fusion 49 (2009) 075005

[2] D.D. Ryutov, R.H. Bulmer, R.H. Cohen, D.N. Hill, L. Lao, J.E. Menard, T.W. Petrie, L.D. Pearlstein, T.D. Rognlien, P.B. Snyder, V. Soukhanovskii, M.V. Umansky, A Snowflake Divertor: a Possible Way of Improving the Power Handling in Future Fusion Facilities, Paper IC/P4-8, 22st IAEA Fusion Energy Conference, Geneva, Switzerland, 10/2008.

[3] Ryutov, D.D., Cohen, R.H.; Rognlien, T.D.; Umansky, M.V., The magnetic field structure of a snowflake divertor, Physics of Plasmas, v 15, n 9, p 092501 (13 pp.), Sept. 2008

[4] D.D. Ryutov, A “SNOWFLAKE” DIVERTOR AND ITS PROPERTIES, 34th EPS Conference on Plasma Phys. Warsaw, 2 - 6 July 2007 ECA Vol.31F, D-1.002 (2007)

[5] Ryutov, D.D. , Geometrical properties of a "snowflake" divertor, Physics of Plasmas, v 14, n 6, p 64502/1-4, June 2007

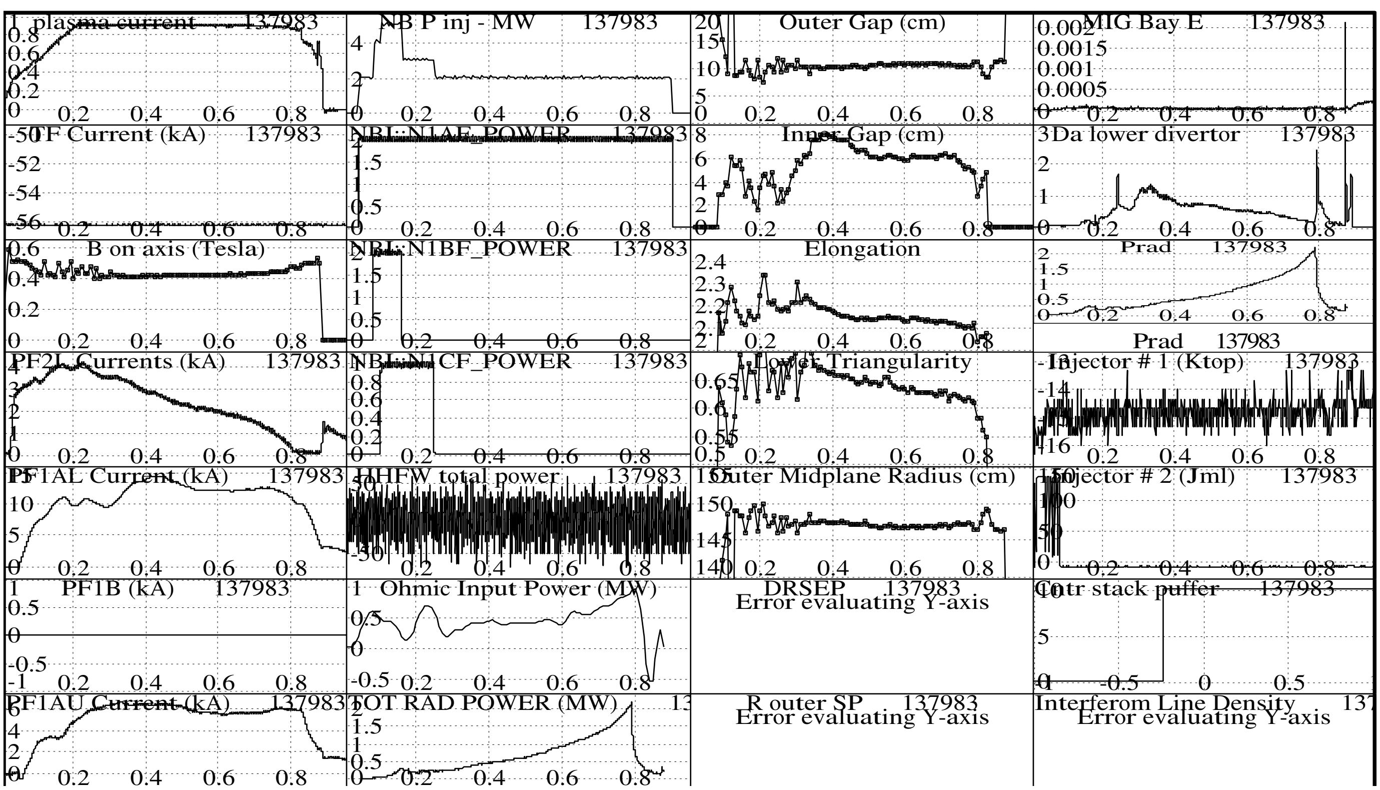
[6] F Piras, S Coda, I Furno, J-M Moret, R A Pitts, O Sauter, B Tal, G Turri, A Bencze, B P Duval, F Felici, A Pochelon and C Zucca, Snowflake divertor plasmas on TCV, Plasma Phys. Control. Fusion 51 (2009) 055009

[7] V. A. Soukhanovskii *et al.,* Taming the Plasma Material Interface with the “Snowflake” divertor in NSTX, U.S. Burning Plasma Organization eNews, March 17, 2010, http://burningplasma.org/enews031710.html

[8] US DOE OFES Joint Facilities Res. Milestone 2010, 2nd Quarter Report, http://www.science.doe.gov/ofes/Performance_Targets/FY_2010/FY2010_JRT_Q2report_final.pdf

[9] V. A. Soukhanovskii *et al.,* “Snowflake” divertor configuration in NSTX, accepted for publication in JNM, 2011

XP-scope-2



PHYSICS OPERATIONS REQUEST

TITLE: "Snowflake" divertor configuration in NSTX   No. **OP-XP-1045**
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Brief description of the most important operational plasma conditions required:

NBI, LITER, PCS (isoflux and strike point control), PF1B in reversed polarity

1) Develop "snowflake" divertor configuration

2) Scan plasma parameters

Previous shot(s) which can be repeated: 137983

Previous shot(s) which can be modified: 135498

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 1300-1400 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): **10-30**

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		