Princeton Plasma Physics Laboratory **NSTX Experimental Proposal**		
Title: Scrape-off layer flows and plasma configuration		
OP-XP-447	**Revision: Version 2**	Effective Date: *(Ref. OP-AD-97)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS	
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ATI – ET Group Leader: H. Kugel	Date
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Responsible Division: Experimental Research Operations	
Chit Review Board (designated by Run Coordinator)	
MINOR MODIFICATIONS (Approved by Experimental Research Operations)	

1. Overview of planned experiment

Recent results[1,2,3] from Alcator C-MOD have shown that the rotation direction of ICRF heated plasma (i.e. no momentum input) can be reversed by varying the plasma configuration from lower single null (LSN), through double null diverted (DND), to upper single null (USN.) This rotation change can be readily measured on NSTX in a 1/2-day experiment, given its favorable diagnostic coverage, through a similar scan. This will yield a check of the C-Mod results at different aspect ratio.

An existing, stable, DND configuration for NSTX (shot 113039) will be used, eliminating the need for scenario development discharges. From a "balanced" DND configuration, (Drsep=0), we will use rtEFIT to control the shape of the plasma, smoothly varying the target Drsep in multiple discharges, achieving the values of –2, -1, -0.5 cm, (i.e. LSN configurations), and +0.5, +1, +2 cm (i.e. USN configurations). Two or three discharges will be made for each Drsep target.

In the later flattop portion of each of the above discharges, HHFW power (2 MW, 14 m^{-1}, heating phased) will be applied. HHFW induced, DND H-mode plasmas have been observed in the past on NSTX at these power levels (shot 113034). It is the contention of the C-MOD group that the power threshold for L-H transition is reduced by establishing a favorable plasma rotation direction, which depends on the configuration. For example, USN has a higher power threshold than LSN. This portion of the experiment will test this notion on NSTX.

2. Theoretical/ empirical justification

As outlined above, recent results from Alcator C-MOD indicate a change in direction of the SOL plasma flow when the plasma configuration is varied from USN through DND to LSN. This change in SOL rotation on C-MOD is correlated with a change in the core rotation of ICRF heated plasma. Since the ICRF does not impart momentum to the plasma, a mechanism to induce plasma flow in both the edge and core is needed to account for the observed rotation.

The mechanism that imparts momentum is related to the spontaneous flow of plasma along magnetic field lines in the scrape-off layer (SOL) of C-MOD. In the DND configuration, there are X-points at the top and bottom of the machine. Plasma flows in the scrape off layer from the midplane towards the strike points along magnetic field lines. As it flows, this SOL plasma imparts momentum, possibly through charge exchange, across the separatrix to the edge plasma. In the DND configuration, there is as much plasma flowing "upwards" as "downwards" towards the srike-points, and hence the net momentum input is near zero.

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[1] M. Greenwald, et. Al., "SOL flows coupled to the core as an explanation for the Up-Down Asymmetry in the L/H Threshold," presented at the Transport Task Force Meeting, April 2004.
[2] B. LaBombard, et. Al., "Scrape-off layer flows, magnetic topology and influence on the L-H threshold in a tokamak," submitted to PRL, Jan. 2004.
[3] B. LaBombard, et. Al., "Transport-Driven Scrape-off layer flows and the boundary conditions imposed at the magnetic separatrix in a tokamak plasma," submitted to Nuc. Fusion, May 2004.

In the USN or LSN configuration there is a single X-point on either the top or bottom of the device. For example, in the LSN configuration there is a strike-point on the bottom of the machine. Plasma flowing along field lines in the SOL (from the outboard midplane) can follow two paths: either up over the top of the plasma then to the strike-point, or down to the strike-point directly. The connection length to the strike-point is much longer on one of these paths, and hence more momentum can be imparted. This path length difference leads to a preferential momentum deposition direction, and hence a particular direction of rotation for the edge plasma, which is configuration dependant. By changing from USN to LSN, the direction of SOL toroidal (~parallel) rotation changes. This has been observed in C-MOD discharges. Moreover, the change in SOL rotation direction has been linked to a change in the core rotation. These overall changes in rotation have been identified at C-MOD as a likely explanation for the apparent L-H power threshold difference for ICRF heated plasmas in different magnetic configurations (USN v. LSN).

The diagnostic suite of NSTX is well suited to make the type of rotation measurements that would support the existence of this momentum coupling mechanism. Specifically, the edge rotation diagnostic (ERD) can provide both poloidal and toroidal rotation measurements across the separatrix and into the SOL of NSTX. While in the core, the 51-channel CHERS diagnostic can provide toroidal rotation profiles at high spatial resolution, when NBI "blips" are added. NSTX also has a large degree of flexibility, in terms of the plasma configurations that can be attained. All three relevant configurations (USN, DND, and LSN) have been demonstrated, and rtEFIT can be pre-programmed to provide a high degree of systematic shape control.

Examination of an existing HHFW plasma (i.e. no momentum input) database of NSTX discharges gives a preliminary indication that the measured plasma edge flow does change in the expected manner, comparing LSN to DND configured plasmas. This database is assembled over many days (even years) though, and a systematic study, including USN plasmas, is necessary to gather convincing data.

3. Experimental run plan

0. Fidutial
1. Establish shot 113039, (600 kA, .42 T, 4×10^{19}, CS fueled, D_2)
   a. config: DND, dRsep=0
   b. RF: 14 m-1, 1MW from 200-500 ms
   c. NBI: Source C, 70 kV, blip from 150-160, 250-260, 350-360, 450-460
2. Repeat w/increasing RF power
   a. Config: same
   b. RF: 1MW 200-300, 2 MW 300-400, 3MW 400-500
   c. NBI: same as condition #1
3. Repeat conditon #2
4. Repeat condition #2

5. dRsep variation within a shot (LSN start)
   a. config: program rtEFIT for dRsep: 0 (120-150), -2 (150-200), -2 (200-250), -1 (250-300), -.5 (300-350), 0 (350-400), +0.5 (400-450), +1 (450-500), +2 (500-550)
   b. RF: 2MW from 200-550

   c. NBI: no blips
6. dRsep variation within a shot (USN start)
   a. config: program rtEFIT for dRsep: 0 (120-150), +2 (150-200), +2 (200-250), +1 (250-300), +.5 (300-350), 0 (350-400), -0.5 (400-450), -1 (450-500), -2 (500-550)
   b. RF: 2MW from 200-550
   c. NBI: no blips

7. LSN
   a. Config: LSN, dRsep=-2 cm
   b. RF: 1MW 200-300, 2 MW 300-400, 3MW 400-500
   c. NBI: blips as per condition #1
8. Repeat condition #7
9. Repeat condition #7
10. USN
    a. Config: USN, dRsep=+2 cm
    b. RF: 1MW 200-300, 2 MW 300-400, 3MW 400-500
    c. NBI: blips as per condition #1
11. Repeat condition #10
12. Repeat condition #10

Decision point: Either continue w/ finer scan in dRsep (cond. 13-20) or vary NBI blip time (cond. 21-22) or vary gas and puffing (cond. 23-24)

13. USN
    a. Config: USN, dRsep=+1 cm
    b. RF: 1MW 200-300, 2 MW 300-400, 3MW 400-500
    c. NBI: blips as per condition #1
14. Repeat condition #13
15. USN
    a. Config: USN, dRsep=+0.5 cm
    b. RF: 1MW 200-300, 2 MW 300-400, 3MW 400-500
    c. NBI: blips as per condition #1
16. Repeat condition #15
17. LSN
    a. Config: LSN, dRsep=-0.5 cm
    b. RF: 1MW 200-300, 2 MW 300-400, 3MW 400-500
    c. NBI: blips as per condition #1
18. Repeat condition #17
19. LSN
    a. Config: LSN, dRsep=-1 cm
    b. RF: 1MW 200-300, 2 MW 300-400, 3MW 400-500
    c. NBI: blips as per condition #1
20. Repeat condition #19

21. vary NBI blip time
    a. Config:

    b. RF: 1MW 200-300, 2 MW 300-400, 3MW 400-500
    c. NBI: blip from 130-140, 230-240, 330-340, 430-440
22. vary NBI blip time
    a. Config:
    b. RF: 1MW 200-300, 2 MW 300-400, 3MW 400-500
    c. NBI: blip from 110-120, 210-220, 310-320, 410-420

23. outboard midplane gas injection of D2
    a. Config:
    b. RF: 1MW 200-300, 2 MW 300-400, 3MW 400-500
    c. NBI: blips as per condition #1
24. outboard midplane gas injection of He
    a. Config:
    b. RF: 1MW 200-300, 2 MW 300-400, 3MW 400-500
    c. NBI: blips as per condition #1

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

HHFW: 1-3 MW of RF power will be needed on each discharge from t=200 to t=500 ms. The antenna should be phased for heating at14 m^{-1}. (R. Wilson)

NBI will be needed to provide "blips" for CHERS measurements on all shots. The most reliable source should be used. If no one source is better at the time of the experiment, then choose source C. Folklore is that source C has greater ion losses, i.e. less energy absorbed in the plasma, i.e. less perturbative to the Ohmic and/or HHFW plasma. We want to minimize specifically any momentum input from the NBI. To this end, de-rate the source to ~70 kV. Blip the beam on for 7.1 ms from t=253-260 and from t=353-360 ms. The CHERS system integrates for 7.1 ms (out of 10 ms), and so shortening the pulse to the relevant integration time will reduce the beam energy deposited. (T. Stevenson)

The Edge Rotation Diagnostic will be instrumental. (T. Biewer)

The fish-eye view camera should be on to provide ancillary confirmation of plasma shape (Charles Bush).

The IR camera, viewing the diverter will provide quantitative measurements of the heat flowing to the lower divertor in each configuration (Rajesh Maingi, Henry Kugel.)

Other diagnostics, which may glean useful information, are the Gas Puff Imaging system (Stewart Zweben) and the reciprocating probe (Jose Boedo).

5. Planned analysis

The DrSep parameter from EFIT will be used as the control variable, against which the measured edge and core toroidal rotation will be plotted. We expect to see a change in the direction of edge rotation as the plasma is shifted from USN through DND to LSN. There should be a corresponding change in the magnitude of the core rotation.

The presence or absence of HHFW H-mode will also be monitored, as the plasma configuration is varied.

6. Planned publication of results.

The results would be presented to the NSTX group at the physics meeting. If the results confirm the measurements made at C-MOD, then direct comparison between NSTX and C-MOD can be made. This will help steer experiments on both machines in next year's run campaigns, and the data will be used in "research forum" proposals this fall. Publication in a refereed journal of the results will follow.

PHYSICS OPERATIONS REQUEST

Machine conditions (specify ranges as appropriate)

I_{TF} (kA): **0.43 T** Flattop start/stop (s): _____/_____

I_P (MA): **0.6** Flattop start/stop (s): **0.150/0.4**

Configuration: **LSN, USN, DND**

Outer gap (m): **~4 cm**, Inner gap (m): **~4-6 cm**

Elongation κ: ~**1.9**, Triangularity δ: ~**0.40**

Z position (m): **0.00**

Gas Species: **D2**, Injector: **Outer Midplane**

NBI - Species:, Sources: C Voltage (kV): **75** Duration (s): **2x0.010**

ICRF – Power (MW): **2**, Phasing:14m-1 Duration (s): **0.100**

CHI: **Off**

Either: List previous shot numbers for setup: **113040 (600 kA), 113048 (800 kA)**

Or: Sketch the desired time profiles, including inner and outer gaps, κ, δ, heating, fuelling, etc. as appropriate. Accurately label the sketch with times and values.

Diagnostic	Need	Desire	Instructions
Bolometer – tangential array			
Bolometer array - divertor			
CHERS	✔		
Divertor fast camera		✔	
Dust detector			
EBW radiometers			
Edge deposition monitor			
Edge pressure gauges		✔	
Edge rotation spectroscopy	✔		
Fast lost ion probes - IFLIP			
Fast lost ion probes - SFLIP			
Filtered 1D cameras			
Filterscopes			
FIReTIP		✔	
Gas puff imaging		✔	
Infrared cameras		✔	
Interferometer - 1 mm		✔	
Langmuir probe array		✔	
Magnetics - Diamagnetism			
Magnetics - Flux loops	✔		
Magnetics - Locked modes			
Magnetics - Pickup coils	✔		
Magnetics - Rogowski coils	✔		
Magnetics - RWM sensors			
Mirnov coils – high frequency			
Mirnov coils – poloidal array		✔	
Mirnov coils – toroidal array		✔	
MSE			
Neutral particle analyzer			
Neutron measurements			
Plasma TV		✔	
Reciprocating probe		✔	
Reflectometer – core		✔	
Reflectometer - SOL		✔	
RF antenna camera			
RF antenna probe			
SPRED		✔	
Thomson scattering	✔		
Ultrasoft X-ray arrays			
Visible bremsstrahlung det.			
Visible spectrometers (VIPS)		✔	
X-ray crystal spectrometer - H			
X-ray crystal spectrometer - V			
X-ray PIXCS (GEM) camera			
X-ray pinhole camera			
X-ray TG spectrometer			