Princeton Plasma Physics Laboratory

NSTX Experimental Proposal

Title: LSN development for very early HHFW heating and H-mode		
OP-XP-451	**Revision:**	Effective Date: *(Ref. OP-AD-97)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS	
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RLM - Run Coordinator: S. Kaye	Date 6/22/2004
Responsible Division: Experimental Research Operations	

Chit Review Board (designated by Run Coordinator)

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

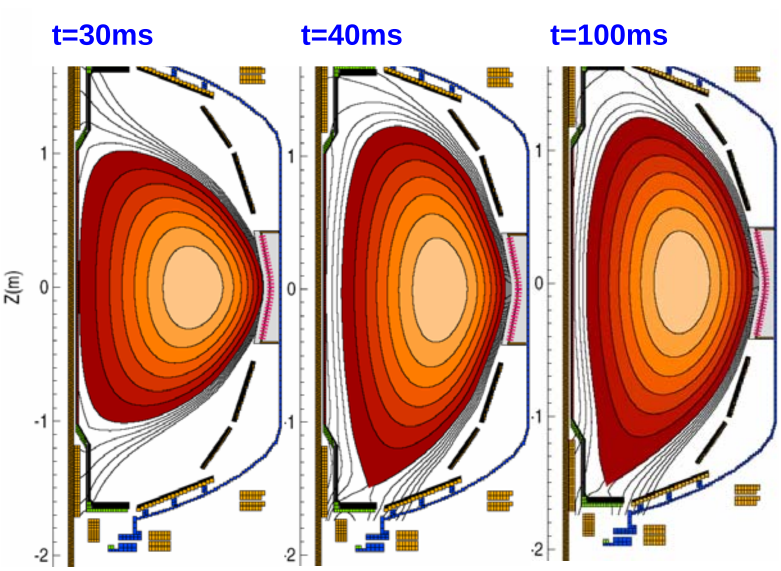
1. Overview of planned experiment

This experiment will attempt to generate a high elongation (κ = 2.2) PF1B LSN diverted discharge very early ($t \leq$ 40ms) during the plasma current ramp-up. This plasma will be used as a target for two purposes. First, utilizing a small outer gap < 5cm, HHFW heating will be applied during the I_P ramp-up from t=40 to 100ms to raise T_e, lower l_i, and reduce the OH flux consumption. Previous attempts at early HHFW heating in CS-limited discharges exhibited irreproducible heating, so this experiment will test if diverted plasmas improve early heating. Second, we will attempt to induce an H-mode transition before t=50ms using HHFW and/or NBI power. Using whichever method(s) result in the largest l_i and flux consumption reductions, TF scans will be performed to assess beta limits and pulse-length improvements at lower l_i and elevated safety factor.

2. Theoretical / empirical justification

Early H-mode access was optimized in XP-440 and utilized in XP-432 to produce very long (Δt up to 1.1s) pulse-length discharges with currents ranging from 0.8-1.2MA at 4.5kG. At the highest I_P values or with lower TF, OH I^2t limits and/or low central q MHD instabilities limit performance and pulse-length. To improve performance further, we will attempt to divert with a high elongation LSN shape very early in the plasma current ramp to lower l_i, raise q, and reduce flux consumption and possible impurity influx. This discharge will then be used as a target for early HHFW heating. If heating is successful, further reductions in l_i and flux consumption should occur. Further, if H-mode can be induced shortly after the plasma is diverted, this will also contribute to flux savings and pulse-length.

3. Experimental run plan - 30 shots total



The desired discharge shape evolution is shown to the left. As seen in the figure, the plasma elongation just after breakdown and hand-off to the plasma control system (at t=20ms) is quite low (< 1.6) and can be increased significantly to 2.2 for the l_i values typical of this time in the discharge (l_i = 0.6). The passive structure current is computed from the original lower-κ plasma evolution and is included in this analysis. Desired coil currents are given in the operations request list.

A. Reproduce 1.2MA, B_T = 4.5kG discharge 112596 **(2 shots)**
   a. NBI programming: Source B at 70ms, Source A at 170ms, Source C at 320ms
      i. This beam timing will be kept fixed unless otherwise noted
   b. Extend programmed I_P flat-top period from 0.8 to t=1.0 second at 4.5kG

B. Change PF coil current programming between 30 to 100ms to divert early **(4 shots)**
   a. Current waveforms will ramp back to large outer gap shape after t=100ms
      i. This will avoid putting too much beam power on antenna due to small gap
   b. Document changes in inductance and flux consumption

C. If H-mode is not obtained ohmically during the early diverted phase, put 15ms current pause between 30 and 45ms to attempt to induce H-mode. **(2 shots)**
   a. If H-mode is achieved, remove later current pause near 90-100ms.

D. Apply HHFW from 30-100ms with 20ms ramp-time in heating phasing **(8 shots)**
   a. Adjust gap to achieve constant loading
   b. Scan HHFW power from 1-3 MW – document heating and changes in q and l_i
   c. Note that HHFW overlaps with beam for 30ms.
      i. If electron heating from HHFW is lost as beams turn on, delay NBI 30ms

E. If H-mode is still not obtained using current pause and HHFW power, turn off HHFW power and fire source B at 30ms to attempt to induce H-mode by 50ms. **(4 shots)**
   a. If H-mode is still not obtained by 50ms, try HHFW + NBI source B at 30ms

F. Starting with longest disruption-free flat-top shot at 4.5kG, perform TF scan **(10 shots)**
   a. Ramp TF down from 0.45 to 0.3T in 200ms scanning start time of ramp-down from 325-525ms in 50ms increments - document peak beta and duration (4 shots)
   b. Decrease flat-top TF to 0.40T and document MHD-stable pulse-length (2 shots)
   c. Decrease flat-top TF to 0.35T and document MHD-stable pulse-length (2 shots)
   d. Decrease flat-top TF to 0.30T and document MHD-stable pulse-length (2 shots)

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

Beams should be reliable at 95-100kV on sources A and B, and 90kV on source C.

5. Planned analysis

EFIT, TRANSP, MPTS, and CHERS are essential for subsequent analysis of current profile evolution and stability (both global and edge-localized).

6. Planned publication of results

Results will be published in conference proceedings and/or journal such as Nuclear Fusion or Physics of Plasmas within one year of experiment.

PHYSICS OPERATIONS REQUEST

LSN development for very early HHFW heating and H-mode **OP-XP-451**

Machine conditions (specify ranges as appropriate)

I_{TF} (kA): **36-53kA** Flattop start/stop (s): **-0.010s/1.0s**

I_P (MA): **0.8-1.2MA** Flattop start/stop (s): **0.18s/1.0s**

Configuration: **Lower Single Null**

Outer gap (m): **3-10cm**, Inner gap (m): **2-10cm**

Elongation κ: **2.0-2.5**, Triangularity δ: **0.55-0.75 (lower x-point)**

Z position (m): **0.00**

Gas Species: **D**, Injector: **Midplane + Inner wall**

NBI - Species: **D**, Sources: **A,B,C** Voltage (kV): **up to 100kV** Duration (s): **1s**

ICRF – Power (MW): **3MW**, Phasing: **Heating**, Duration (s): **0.1s**

CHI: **Off**

Either: List previous shot numbers for setup: **112596**

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.

	30ms	40ms	60ms	100ms
IP (MA)	0.2	0.28	0.4	0.6

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IP (MA)	0.2	0.28	0.4	0.6

Normalized Currents (kA/MA)

PF1AU	0	-2.5	-2.2	-2.1
PF2U	-2.5	-1.7	-1.3	-1
PF3U	11	2.9	3.6	3.9
PF5	7.9	10.6	10	7.7
PF3L	10.5	4.6	5	4.8
PF2L	-1	-2.1	-1.5	0
PF1AL	0	-0.3	-4.6	-5.2
PF1B	0	-14.2	-9.9	-7.4

Absolute Currents (kA)

PF1AU	0	-0.7	-0.9	-1.3
PF2U	-0.5	-0.5	-0.5	-0.6
PF3U	2.2	0.8	1.5	2.3
PF5	1.6	3	4	4.6
PF3L	2.1	1.3	2	2.9
PF2L	-0.2	-0.6	-0.6	0
PF1AL	0	-0.1	-1.8	-3.1
PF1B	0	-4	-4	-4.5

DIAGNOSTIC CHECKLIST
LSN development for very early HHFW heating and H-mode OP-XP-451

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