Princeton Plasma Physics Laboratory

NSTX Experimental Proposal

Solenoid-free inductive start-up with an outboard field-null and HHFW

OP-XP-510	**Revision: 0**	Effective Date: Feb-15-2005 *(Ref. OP-AD-97)* Expiration Date: Feb-15-2007 *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

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ATI – ET Group Leader: R. Raman	Date
RLM - Run Coordinator: J. Menard	Date February 24, 2005
Responsible Division: Experimental Research Operations	

Chit Review Board (designated by Run Coordinator)

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

1. Overview of planned experiment

The scientific goal of this experiment is to determine if it is possible to initiate a spherical tokamak discharge of 100kA using only the poloidal (and toroidal) field coils of NSTX with the OH coil completely inactive. This experiment will build on the results of XP 443 which generated 20kA plasmas with PF coil induction only. This experiment will focus on improving the radial position evolution of the plasma and increasing its elongation. Further, if the plasma can be held near the outboard limiter for a significant duration (10-15ms), we will assess whether HHFW heating can be used to further increase the plasma temperature and the inductively driven current by lowering the plasma resistivity.

2. Theoretical / empirical justification

The development of methods to generate toroidal plasma current without OH solenoid action is important for the ST concept. If HHFW power can be efficiently coupled into the achieved OH-free plasmas, there may be a path to higher plasma current using bootstrap current overdrive and fast wave current drive (FWCD) resulting in a start-up scenario completely free of the OH solenoid.

3. Experimental run plan

a. Reproduce shot 114405 which achieved 20kA plasma current with 400kW HHFW. Scan TF values from 3.0kG to 4.5kG, and use highest I_P discharge in scans below. Inject 50ms 3-source NBI pulse @ t=5ms into highest I_P discharge - turn off if deleterious. **(6 shots)**

b. Decrease PF3 current after t=-3ms to reduce dB_Z/dR and increase elongation. Adjust ratio of upper and lower currents to center plasma vertically from shot-to-shot. **(8 shots)**

Time (s)	Initial PF3U and PF3L PCS Current Request in kA				
-0.5	0.00				
-0.392	0.00				
-0.297	-1.52				
-0.292	-1.57				
-0.279	-1.62				
-0.021	-1.62				
-0.01	-1.45	Scanned PF3U and PF3L PCS Current Request in kA			
-0.003	0.00	INCREASING SHOT NUMBER →			
0.004	1.40	1.12	0.90	0.72	0.50
0.012	2.50	1.75	1.23	0.86	0.75
0.019	2.75	1.93	1.35	0.94	0.80

c. For discharge with highest current and longest period near antenna, increase HHFW power incrementally to measure plasma response to stronger heating. **(6 shots)**

   i. XMP to commission higher-power HHFW pre-ionization is a prerequisite.

   ii. Try 750kW, 1MW, 1.25MW, 1.5MW and adjust match accordingly.

d. Scan vertical field ramp-rate following improved position control and heating. **(6 shots)**

<table>
<tr><td>Time</td><td colspan="7">Initial PF5 PCS Current Request in kA</td></tr>
<tr><td>-0.5</td><td>0</td><td colspan="6" rowspan="4">Scanned PF5 PCS Current Request in kA

INCREASING SHOT NUMBER →</td></tr>
<tr><td>-0.018</td><td>0</td></tr>
<tr><td>-0.009</td><td>0.05</td></tr>
<tr><td>0.001</td><td>0.775</td></tr>
<tr><td>0.019</td><td>0.775</td><td>0.8</td><td>0.9</td><td>1.0</td><td>1.1</td><td>1.2</td><td>1.4</td></tr>
</table>

e. Assess impact of higher plasma elongation by adding PF2 current ramp **(4 shots)**

<table>
<tr><td>Time (s)</td><td colspan="5">Initial PF2U and PF2L PCS Current Request in kA</td></tr>
<tr><td>-0.40</td><td>0.00</td><td colspan="4" rowspan="2">Scanned PF2U and PF2L PCS Current Request in kA
INCREASING SHOT NUMBER →</td></tr>
<tr><td>0.00</td><td>0.00</td></tr>
<tr><td>0.02</td><td>0.00</td><td>-0.50</td><td>-1.00</td><td>-1.50</td><td>-2.00</td></tr>
</table>

f. Study null quality requirements for successful breakdown by reducing the field-null area consistent with expected null characteristics of other PF-only startup XPs. **(15 shots)**

   i. Scan TF in 0.25kG decrements until plasma initiation fails.
   ii. Starting at the TF value of the highest I_P discharge above, add stray field from DC PF2U and 2L currents in -0.5kA increments until plasma initiation fails.

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

Completion of XMP-030 - Development of HHFW assistance for plasma startup

5. Planned analysis

LRDFIT and EFIT will be used for reconstructions of the vacuum field patterns and flux surfaces of any plasma generated.

6. Planned publication of results

Results will be published in Nuclear Fusion, Physics of Plasmas, or other suitable journal depending on the success of the experiment within 1 year of experiment completion.

PHYSICS OPERATIONS REQUEST

Solenoid-free inductive start-up with an outboard field-null and HHFW **OP-XP-510**

Machine conditions (specify ranges as appropriate)

I_{TF} (kA): **24-53** Flattop start/stop (s): **0 / 0.2s**

I_P (MA): **100kA** Flattop start/stop (s): _____/_____

Configuration: **outer wall**

Outer gap (m): _____, Inner gap (m): _____

Elongation κ: _____, Triangularity δ: _____

Z position (m): **0.00**

Gas Species: **D** , Injector: **Midplane**

NBI - Species: **D**, Sources: **A/B/C**, Voltage (kV): **60kV**, Duration (s): **50ms**

ICRF – Power (MW): **Up to 2MW** Phasing: **0-0 and 0-PI**, Duration (s): **50ms**

CHI: **Off**

Either: List previous shot numbers for setup: _____**114405**________

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 CHECKLIST

Solenoid-free inductive start-up with an outboard field-null and HHFW **OP-XP-510**

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			
High-k scattering			
Infrared cameras			
Interferometer – 1 mm			
Langmuir probes - PFC tiles			
Langmuir probes - RF antenna			
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 Rate (2 fission, 4 scint)			
Neutron collimator			
Plasma TV	✓		
Reciprocating probe			
Reflectometer - FM/CW			
Reflectometer - fixed frequency homodyne			
Reflectometer - homodyne correlation			
Reflectometer - HHFW/SOL			
RF antenna camera			
RF antenna probe			
Solid State NPA			
SPRED			
Thomson scattering - 20 channel	✓		
Thomson scattering - 30 channel			
Ultrasoft X-ray arrays		✓	
Ultrasoft X-ray arrays - 2 color			
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			