Princeton Plasma Physics Laboratory **NSTX Experimental Proposal**		
Title: Non-solenoidal Ip Rampup with HHFW		
XP-521	**Revision:**	Effective Date: *(Ref. OP-AD-97)* Expiration Date: *(2 yrs. unless otherwise stipulated)*
PROPOSAL APPROVALS		
Author: C. E. Kessel, O. Mitarai, R. Maingi, RF Group		Date
ATI – ET Group Leader: R. Maingi and C. E. Kessel (deputy)		Date
RLM - Run Coordinator: J. Menard (S. Sabbagh)		Date
Responsible Division: Experimental Research Operations		
Chit Review Board (designated by Run Coordinator)		
MINOR MODIFICATIONS (Approved by Experimental Research Operations)		

NSTX EXPERIMENTAL PROPOSAL

Non-solenoidal Ip Rampup with HHFW **XP521**

1. Overview of planned experiment

Use the solenoid to ramp up the plasma current to various values, then flattop the OH coil current, and inject HHFW power to observe the heating/CD effectiveness in sustaining the plasma current. Starting from 400 kA at $t_{flattop}$ = 80 ms, the plasma current values will be progressively reduced. A few NBI heating cases will be done first to setup various turn on times for rtEFIT/isoflux, OH current clamping, and heating.

2. Theoretical/ empirical justification

The goal of non-solenoidal current startup and rampup can be broken into 3 phases; the breakdown and early startup, the RF plasma current rampup, and the RF+NBI plasma current rampup. These can be separated and developed independently. At low plasma currents which we expect CHI or PF coil startup to provide, say 50-200 kA the NBI confinement is poor, and an RF method for heating and driving current is preferable. The HHFW system is suited to this purpose, and efforts to develop this capability should be pursued. In the 2004 run campaign, routine heating was established at 7 m^{-1} and 14 m^{-1} in deuterium plasmas, along with transition into H-mode. This requires the plasma to be close to the antenna for sufficient coupling. The challenge here is to establish this coupling (location of R+a relative to the antenna) at earlier times, at lower plasma currents and lower electron temperatures. The approach taken here is to start with a successful HHFW H-mode discharge from the 2004 run campaign, and terminate the plasma current rampup at lower currents, but otherwise apply a similar timing for position control and heating/CD. Simulations showed under various conditions that heating or heating with CD could sustain the plasma current at 400 kA, and drive the plasma current up from 200 kA, with 3 MW of HHFW power, and reasonable transport assumptions.

3. Experimental run plan

Reference discharge for HHFW is 112283, an rtEFIT/isoflux controlled HHFW experiment, with I_P = 700 kA, B_T = 0.45 T, k|| = 14 m^{-1}, HOWEVER, we will be cutting the I_P rampup short.

0) establish that OH coil current can be clamped at its present value, at a given time. **(2 shots)**

NBI heating/CD cases:

1) use solenoid to rampup plasma current up to 500 kA, at t = 80 ms, flattop I_P = 500 kA, apply rtEFIT/isoflux at 110 ms, clamp OH current at its value at 140 ms, and apply 2 (A at 90 keV, B at 70 keV), and 3 (A at 90 keV, B at 70 keV, C at 70 keV) NBI sources at 150 ms, respectively. Maintain 10 cm outer gap. **(5 shots)**

HHFW heating cases:

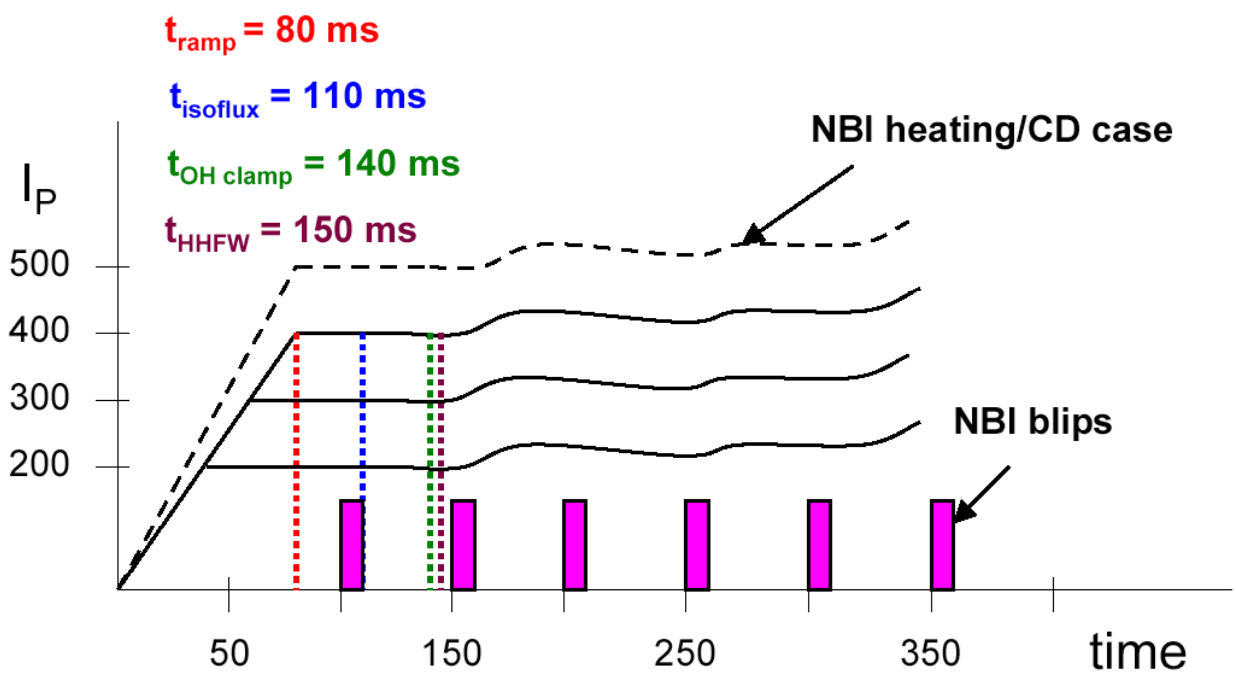
2) Use solenoid to ramp plasma current up to 400 kA, at t = 80 ms. Flattop I_P at 400 kA, apply rtEFIT/isoflux at 110 ms, clamp OH current at its value at 140 ms, apply > 3 MW of HHFW with 14 m^{-1} heating phasing at 150 ms. Maintain < 5 cm outer gap. **(5 shots)**

3) Use solenoid to ramp plasma current up to 300 kA, at t = 60 ms. Flattop I_P at 300 kA, apply rtEFIT/isoflux at 110 ms, clamp OH current at its value at 140 ms, apply > 3 MW of HHFW with 14 m^{-1} heating phasing at 150 ms. Maintain < 5 cm outer gap. **(5 shots)**

4) Use solenoid to ramp plasma current up to 200 kA, at t = 40 ms. Flattop I_P at 200 kA, apply rtEFIT/isoflux at 110 ms, clamp OH current at its value at 140 ms, apply > 3 MW of HHFW with 14 m^{-1} heating phasing at 150 ms. Maintain < 5 cm outer gap. **(5 shots)**

5) choose best shots and do references: apply HHFW with no OH current clamping, and clamp OH current with no HHFW. (**8 shots)**

Total shots: 30



6) if difficulties getting OH to clamp at its present value at a specified time, then use following procedure at each I_P: rampup to 400 kA, t = 80 ms, flattop I_P at 400 kA, apply rtEFIT/isoflux at 110 ms, NO OH clamping and NO HHFW, record I_{OH} at 140 ms.

7) if difficulties with early timing, shift entire timing sequence out by 20 ms; I_P = 400 kA at 100 ms, I_P = 300 kA at 75 ms, I_P = 200 kA at 50 ms.

6) if difficulties with plasma reconnections during $V_{loop} = 0$, then leave discharge in I_P feedback control, and examine loop voltages to determine HHFW effects. May also try to apply HHFW power before OH clamp to see if it improves.

13) if difficulties with isoflux control at lowest I_P values, use Thomson data to identify plasma outboard location, and request artificial outer gap (i.e. request R+a to be on antenna limiter) in isoflux to achieve desired plasma-antenna distance. Another option is to switch to the old controller, however, the setup time would be long.

14) OH coil I^2t limit is 265 kA^2-s/turn^2; this allows I_{OH} at 20 kA/turn (where I_P = 200 kA in 112283) for more than 600 ms, which is considered OK

15) for successful runs, attempt some cases with 7 m^{-1} heating phasing, and 7 m^{-1} co-CD and cntr-CD phasing

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

HHFW system, P_{HHFW} > 3 MW, 7 m^{-1} and 14 m^{-1}, heating phasing and possibly co-CD and cntr-CD phasing

CHERS NBI blips of source A 90 keV and B at 70 keV, 10 ms duration, separated by 40 ms, starting at 100 ms

MSE diagnostic, NBI blips, appears to require 100 ms blips, which is too long, due to beam voltage transient. (ONLY USE IN NBI SHOTS)

B_T = 0.45 T

I_P ramp, HHFW with rtEFIT/isoflux control, 14 m^{-1} reference is 112283 (700 kA), t_{raamp} = 175 ms, $t_{isoflux}$ = 200 ms, t_{HHFW} = 250 ms.

rtEFIT/isoflux controller

NBI 3 sources, A at 90 keV, B at 70 keV, C at 70 keV

Gas should be same as reference shot 112283 for all cases

5. Planned analysis

EFIT

CURRAY

TRANSP

TSC

6. Planned publication of results

Results would be presented at the APS meeting and subsequently submitted to Nuc. Fusion or Phys. of Plasmas

PHYSICS OPERATIONS REQUEST

Non-solenoidal Ip Rampup with HHFW **XP521**

Machine conditions (specify ranges as appropriate)

I_{TF} (kA): **54 (4.5kG)** Flattop start/stop (s): **0/1.5**

I_P (MA): **0.2-0.5** Flattop start/stop (s): **0.08/0.6**

Configuration: **Double Null, diverted**

Outer gap (m): <**0.05**, Inner gap (m):

Elongation κ: ≈**2.0**, Triangularity δ: **0.5**

Z position (m): **0.0**

Gas Species: **D**, Injector: **Inner**, **same as 112283**

NBI - Species:**D**, Sources: **A/B/C**, Voltage (kV): **90/70/70**, Duration (s): **0.8**

ICRF – Power (MW): >**3.0**, Phasing: **Heating/CD**, Duration (s): **0.5**

CHI: **OFF**

Either: List previous shot numbers for setup: **112283**

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

Non-solenoidal Ip Rampup with HHFW **XP521**

Diagnostic	**Need**	**Desire**	**Instructions**
Bolometer - tangential array	X		
Bolometer array - divertor			
CHERS	X		
Divertor fast camera			
Dust detector			
EBW radiometers			
Edge deposition monitor			
Edge pressure gauges			
Edge rotation spectroscopy		X	
Fast lost ion probes – IFLIP	X		
Fast lost ion probes – SFLIP	X		
Filtered 1D cameras			
Filterscopes	X		
FIReTIP	X		
Gas puff imaging			
High-k scattering			
Infrared cameras			
Interferometer – 1 mm			
Langmuir probes - PFC tiles			
Langmuir probes - RF antenna			
Magnetics – Diamagnetism	X		
Magnetics – Flux loops	✓		
Magnetics – Locked modes	X		
Magnetics – Pickup coils	✓		
Magnetics - Rogowski coils	✓		
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 Rate (2 fission, 4 scint)			
Neutron collimator			
Plasma TV		X	
Reciprocating probe			
Reflectometer - FM/CW			
Reflectometer - fixed frequency homodyne			
Reflectometer - homodyne correlation			
Reflectometer - HHFW/SOL	X		
RF antenna camera	X		
RF antenna probe	X		
Solid State NPA			
SPRED			
Thomson scattering - 20 channel	✓		
Thomson scattering - 30 channel		X	
Ultrasoft X-ray arrays	X		
Ultrasoft X-ray arrays - 2 color			
Visible bremsstrahlung det.	X		
Visible spectrometers (VIPS)	X		
X-ray crystal spectrometer - H			
X-ray crystal spectrometer - V			
X-ray PIXCS (GEM) camera			
X-ray pinhole camera			
X-ray TG spectrometer			