Princeton Plasma Physics Laboratory
NSTX Experimental Proposal

Title: **HHFW Heating of CHI-Only Discharges**		
OP-XP-1158	Revision: **2**	Effective Date: *(Approval date unless otherwise stipulated)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

Responsible Author: G. Taylor	Date
ATI – ET Group Leader: G. Taylor/R. Raman	Date
RLM - Run Coordinator: S. Sabbagh	Date
Responsible Division: Experimental Research Operations	

RESTRICTIONS or MINOR MODIFICATIONS
(Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL

TITLE: **HHFW Heating of CHI-Only Discharges** No. **OP-XP-1158**

AUTHORS: **G. Taylor, D. Mueller, B.A. Nelson, R. Raman, J.C. Hosea, B.P. LeBlanc, C.K. Phillips, P.M. Ryan**

DATE: **May 6, 2011**

1. Overview of planned experiment

This experiment aims to heat CHI-only discharges with 20 ms pulses of at least 1 MW of HHFW power. The experiment contributes to the NSTX research milestone R12-2. It will be run immediately following XP-1157, “CHI-only Discharges”. The experiment will assess the effectiveness of HHFW heating to increase T_e and the current persistence time. It will also study changes in the density profile, oxygen and carbon impurity levels when HHFW power is coupled to a CHI-only discharge.

2. Theoretical/ empirical justification

NSTX has a long-term goal of developing a plasma scenario that does not use the central solenoid. This non-inductive scenario includes heating a CHI-initiated discharge with sufficient HHFW power to ramp up I_p non-inductively to a level where NBI fast-ions can be confined. However, until now there has been no experiment that has had the explicit goal of heating CHI-only discharges with HHFW power. In the absence of HHFW heating NSTX CHI-only plasmas have $T_e < 50$ eV and pulse lengths that are only ~ 20 ms. If significant HHFW power (> 1 MW) can be coupled to a CHI-only plasma it has the potential to significantly increase T_e and the current persistence time. In 2008 a few attempts were made to couple $k_\phi = -8\ m^{-1}$ HHFW power into a CHI-initiated discharge that was coupled to induction. Thomson scattering data showed indications of electron heating ~ 20 ms after the start of the discharge when HHFW power was applied (shot 129612), but HHFW power tripped off after being on for only 10 ms. XP-1157, “CHI-only Discharges”, will be run in both FY11 and FY12. In FY11 XP-1157 aims to generate reproducible I_p = 350 kA CHI-only discharges with $T_e > 50$ eV, and may increase the pulse length to ~ 40 ms. In FY12 XP-1157 aims to generate reproducible I_p = 400 kA CHI-only discharges with $T_e > 70$ eV, and may increase the pulse length beyond 40 ms as a result of the higher T_e. XP-1158 will be run in FY11 and FY12 immediately following XP-1157 and will attempt to couple into the tail of the CHI discharge.

3. Experimental run plan

This experiment is expected to take a total of 1-1.5 run days, 0.5 days in FY11 and 0.5-1 day in FY12. It should be run during the morning following XP-1157, after HHFW vacuum conditioning the previous evening. It will start with one of the best discharges from XP-1157. While CHI-only discharges can be reproducible there is no position control system that can tailor the gap between the CHI plasma and the HHFW antenna, this will present a significant challenge for achieving and maintaining efficient HHFW coupling. Also, because the CHI plasma is relatively cold the fast waves will make many passes through the plasma before being absorbed. Since the HHFW power will be coupled into a very low density plasma HHFW antenna tuning will be set to close to vacuum loading settings on the stubs and stretchers. HHFW antenna phasing should be set to launch a low k_ϕ in order to start the perpendicular propagation of the fast wave at a low density, reducing the width of the evanescent region between the antenna and the CHI plasma. This experiment will start with -90° strap-to-strap antenna phasing, which launches $k_\phi = -8\ m^{-1}$, using stub and stretcher settings from shot 129612. It will then use -60° strap-to-strap antenna phasing, which launches a combination of $k_\phi = -8\ m^{-1}$ and $k_\phi = -3\ m^{-1}$. The $k_\phi = -8\ m^{-1}$ power will heat the plasma increasing absorption of the $k_\phi = -3\ m^{-1}$ power closer to the antenna.

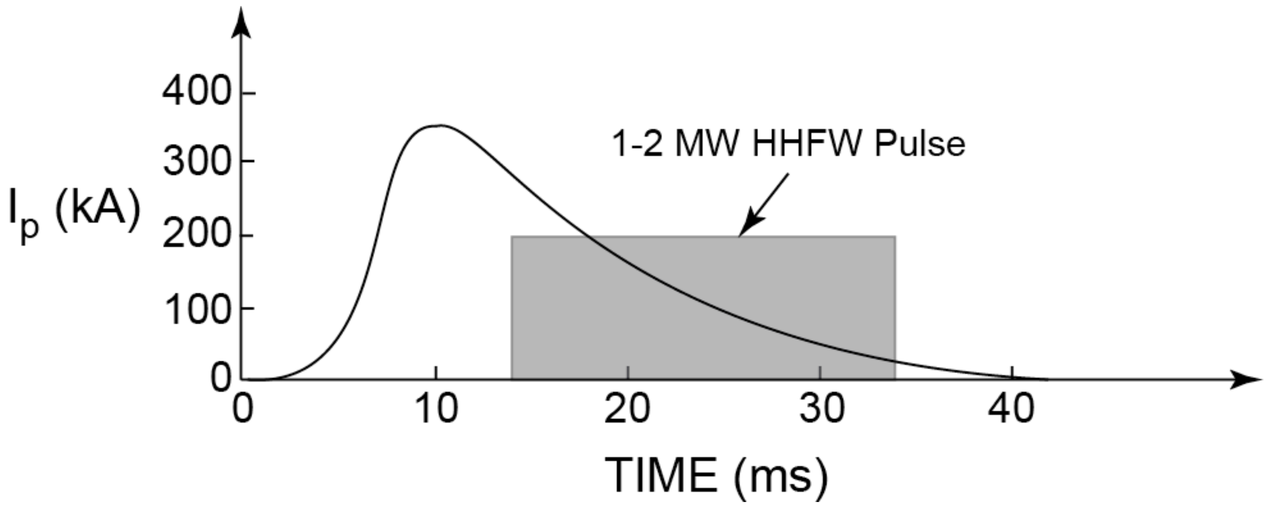

Figure 1: Schematic showing time of the 20 ms HHFW heating pulse relative to the time evolution of I_p.

The run plan is as follows:

1. Setup a CHI-only discharge from XP-1157. Once the time evolution of the pulse is reproducible, begin to add a 20 ms pulse of $k_\phi = -8\ m^{-1}$ HHFW power, as shown in Figure 1, using antenna settings from 129612. The HHFW power will be raised incrementally to ~1 MW and the antenna settings will be adjusted to optimize coupling. It may be necessary to adjust the timing of the start of the HHFW pulse, or the antenna tuning to improve coupling. Li conditioning evaporation rates may also be adjusted to change the density in front of the antenna. **(15 shots)**

2. If significant increases in T_e and pulse length are observed and the HHFW pulse stays on for 20 ms, the HHFW power will be incrementally increased to ~ 2 MW. CHI discharges without HHFW will be run after the HHFW-heated discharges to provide no RF comparison shots. **(5-10 shots)**

3. The antenna strap-to-strap phasing will be reduced from -90° to -60° to launch a combination of $k_\phi = -8\ m^{-1}$ and $k_\phi = -3\ m^{-1}$ and steps 1 and 2 will be repeated. **(20-25 shots)**

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

This experiment should follow the HHFW plasma conditioning XMP, and requires P_{RF} = 1-2 MW at strap-to-strap antenna phasings of -90° and -60°. Thomson scattering T_e and n_e are required for core and edge electron heating data. For analysis of edge power loss and coupling efficiency, the experiment also requires SOL reflectometry and edge ion heating data from the edge rotation diagnostic. Visible and IR camera imaging of the antenna and lower divertor are also required.

5. Planned analysis

Planned analysis includes calculation of rf deposition, bootstrap and rf–driven current profile with TRANSP-TORIC and GENRAY-ADJ modeling.

6. Planned publication of results

The results will be submitted for publication in *Nuclear Fusion* or *Physics of Plasmas*.

PHYSICS OPERATIONS REQUEST

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Brief description of the most important operational plasma conditions required:

These are transient CHI discharges they are not standard plasma discharges. HHFW antenna tuning should be initially set using antenna settings from shot 129612. The experiment should be run during the morning following XP-1157 and should be preceded by HHFW vacuum conditioning during the previous evening.

Previous shot(s) which can be repeated: 142161-3 or best from XP-1157

Previous shot(s) which can be modified:

Machine conditions *(specify ranges as appropriate, strike out inapplicable cases)*

I_{TF} (kA): **-41 to -65** Flattop start/stop (s): **-0.02/0.7**

I_P (MA): **0.3-0.5** Flattop start/stop (s): **N/A**

Configuration: **CHI transitioning to CS limited**

Equilibrium Control: **N/A**

Outer gap (m): **N/A** Inner gap (m): **N/A** Z position (m): **0.0**

Elongation: **N/A** Triangularity (U/L): **N/A** OSP radius (m): **N/A**

Gas Species: **D** Injector(s): **LDGIS, Inj. 2, Inj. 1, Inj. 3**

NBI Species: **D** Voltage (kV) **A: 40-60 B: C:** Duration (s): **0.02**

ICRF Power (MW): **2** Phase between straps (°):**-60, -90** Duration (s): **0.02**

CHI: **On** Bank capacitance (mF): **5-50**

LITERs: On Total deposition rate (mg/min): **5 to 30**

LLD: N/A Temperature (°C):

EFC coils: Off Configuration: **SPAs drive Absorber PF coils**

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		