Princeton Plasma Physics Laboratory
NSTX Experimental Proposal

Profile of Fast Ions that are accelerated by HHFW

OP-XP-832	Revision:	Effective Date: *(Approval date unless otherwise stipulated)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

Responsible Author: W. Heidbrink	Date
ATI – ET Group Leader:	Date
RLM - Run Coordinator:	Date

Responsible Division: Experimental Research Operations

Chit Review Board (designated by Run Coordinator)

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL

TITLE: **Profile of Fast Ions that are Accelerated by HHFW** No. **OP-XP-832**
AUTHORS: **W. Heidbrink, M. Podesta, R. Pinsker,** DATE: **3/28/2008**
J. Hosea, P. Ryan, R. Harvey, S. Medley

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1. Overview of planned experiment

The goal of this experiment is to use the new FIDA diagnostic to measure the spatial profile of beam ions that are accelerated above the injection energy by HHFW heating.

2. Theoretical/ empirical justification

NSTX operates in a novel regime for high harmonic ion cyclotron heating. Because the field is low, beam ions are super-Alfvenic and the ratio of the gyroradius to the perpendicular wavelength is very large. Because it is a spherical tokamak, significant absorption at multiple cyclotron harmonics is expected. These differences from conventional tokamaks motivate a careful comparison between theory and experiment in this unusual regime.

For his Ph.D. thesis, Adam Rosenberg used neutron and neutral particle analyzer (NPA) measurements to study fast-ion acceleration by HHFW [1]. Although acceleration was observed by both of these diagnostics, no information on the spatial profile of the absorption was obtained. With the installation of the NSTX FIDA diagnostic, spatially-resolved measurements of the profile are now possible. FIDA measurements of accelerated beam ions in DIII-D were recently published [2]. The purpose of this experiment is to obtain similar data in NSTX.

L-mode plasmas were studied in both Rosenberg’s thesis and in more recent data with strong fast-ion acceleration [3]. Because the RF works well in this regime and because the FIDA data is of higher quality in low-density plasmas, the target plasma for this experiment is an L-mode plasma.

[1] A. Rosenberg et al., Phys. Plasmas **11** (2004) 2441.

[2] W.W. Heidbrink et al., Plasma Phys. Cont. Fusion **49** (2007) 1457.

[3] W.W. Heidbrink et al., Plasma Phys., Cont. Fusion **48** (2006) 1347.

3. Experimental run plan

The primary goal is to thoroughly document one case with significant fast-ion acceleration for eventual comparison with code calculations. The target plasma is similar to the ones in Ref. [3] except that the toroidal field is higher, i.e., 0.8 MA, 3-4 cm outer gap (for good HHFW coupling), toroidal field of ~ 0.55 T, central density below 4e13 cm^{-3}. We will use a deuterium plasma if we can keep it in L-mode; otherwise, we will use helium. The primary beam is Source C at 65 kV. (The low voltage is selected both to minimize fast-ion driven instabilities, which complicate the interpretation of the profiles, and because strong absorption is anticipated and observed at 65 kV.) Source C will be on steadily throughout the discharge (except for a single 10-ms beam-notch as a diagnostic validity check for the FIDA and NPA measurements). Source A at full voltage will be used to obtain MSE data at two times during the discharge; ordinarily, this will be at the end of the time of interest. The RF phasing is the value that produced the strongest acceleration in Rosenberg's work (14 m^{-1}). The HHFW will also be on continuously during the time of interest; the primary goal is to diagnose the accelerated fast-ion distribution function in approximate steady-state. The NPA will measure the distribution function after the RF turns off at a tangency radius of 50 cm (where strong acceleration was observed in Ref. [3]).

1a) Establish target condition with Source C and HHFW at > 2 MW.

1b) Substitute Source A for Source C to obtain MSE data at beginning of time period of interest; also study variation of acceleration with injection velocity (1 shot).

1c) NPA vertical scan in #1a condition (4 shots).

1d) If not already achieved through faults, no HHFW baseline shot (1 shot).

1e) If not already achieved through faults, 60% HHFW power shot (1 shot).

2) Reduce toroidal field to 4.0 kG. Repeat previous steps as time permits.

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

This is a ½ day experiment. It is desirable to complete this experiment prior to the introduction of lithium into the machine.

NBI: Source C @ 65 kV; Source B @ 65 kV (backup for C); Source A @ 90 kV. Beam modulation of Source C required.

HHFW: Over 2 MW coupled, 14 m^{-1} phasing.

Essential Diagnostics: FIDA, SSNPA, NPA, neutrons, Thomson.

Highly Desirable: CHERS, Mirnov.

5. Planned analysis

In addition to the usual equilibrium and TRANSP analysis by the experimentalists, analysis of the primary condition by RF SciDAC codes is anticipated. The distribution functions predicted by these codes are input to the FIDA simulation code, as in Ref. [2].

6. Planned publication of results

A journal article like Ref. [2] is anticipated.

PHYSICS OPERATIONS REQUEST

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Machine conditions (specify ranges as appropriate)

I_{TF} (kA): **50-max** Flattop start/stop (s): **0/0.75**

I_P (MA): **0.8** Flattop start/stop (s): **0.25/0.5**

Configuration: **Inner Wall Limiter**

Outer gap (m): **0.04** Inner gap (m): **0**

Elongation κ: **1.9** Upper/lower triangularity δ: 0.4

Z position (m): **0**

Gas Species: **D/He** Injector(s): Midplane/Inner wall/Lower dome

HELIUM VALVE AT 700 TORR (rather than standard 1700 Torr)

NBI Species: **D** Sources: **A/B/C** Voltage (kV): **90/65/65** Duration (s): **0.4**

ICRF Power (MW): **>2** Phasing: **14 m^{-1}** Duration (s): **0.3**

CHI: **Off** Bank capacitance (mF):

LITER: Off

Either: List previous shot numbers for setup: **127043**

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

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Note special diagnostic requirements in Sec. 4

Diagnostic	**Need**	**Want**
Bolometer – tangential array		x
Bolometer – divertor		
CHERS – toroidal		x
CHERS – poloidal		
Divertor fast camera		
Dust detector		
EBW radiometers		
Edge deposition monitors		
Edge neutral density diag.		
Edge pressure gauges		
Edge rotation diagnostic		
Fast ion D_alpha - FIDA	x	
Fast lost ion probes - IFLIP		x
Fast lost ion probes - SFLIP		x
Filterscopes		x
FIReTIP		
Gas puff imaging		
Hα camera - 1D		
High-k scattering		
Infrared cameras		
Interferometer - 1 mm		x
Langmuir probes – divertor		
Langmuir probes – BEaP		
Langmuir probes – RF ant.		
Magnetics – Diamagnetism		
Magnetics – Flux loops	√	
Magnetics – Locked modes		
Magnetics – Pickup coils	√	
Magnetics – Rogowski coils	√	
Magnetics – Halo currents		
Magnetics – RWM sensors		
Mirnov coils – high f.		x
Mirnov coils – poloidal array		x
Mirnov coils – toroidal array		x
Mirnov coils – 3-axis proto.		x

Note special diagnostic requirements in Sec. 4

Diagnostic	**Need**	**Want**
MSE		x
NPA – ExB scanning	x	
NPA – solid state	x	
Neutron measurements	x	
Plasma TV		
Reciprocating probe		
Reflectometer – 65GHz		x
Reflectometer – correlation		
Reflectometer – FM/CW		
Reflectometer – fixed f		x
Reflectometer – SOL		
RF edge probes		x
Spectrometer – SPRED		
Spectrometer – VIPS		
SWIFT – 2D flow		
Thomson scattering	x	
Ultrasoft X-ray arrays		x
Ultrasoft X-rays – bicolor		
Ultrasoft X-rays – TG spectr.		
Visible bremsstrahlung det.		x
X-ray crystal spectrom. - H		
X-ray crystal spectrom. - V		
X-ray fast pinhole camera		
X-ray spectrometer - XEUS		x