## Princeton Plasma Physics Laboratory
# NSTX Experimental Proposal

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|---|---|---|
| Title: **HHFW Heating & Current Drive Phase Scans in D L-mode Plasmas** | | |
| **OP-XP-825** | Revision: | Effective Date: *(Approval date unless otherwise stipulated)* Expiration Date: *(2 yrs. unless otherwise stipulated)* |

## PROPOSAL APPROVALS

| | |
|---|---|
| **Responsible Author:** | 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: **HHFW Heating & Current Drive Phase Scans in D L-mode Plasmas** No. **OP-XP-825**

AUTHORS: **P. Ryan, J. Hosea, R. Bell, L. Delgado-Aparicio, S. Kubota, B. LeBlanc, F. Levinton, C.K. Phillips, S. Sabbagh, G. Taylor, K. Tritz, J. Wilgen, J.R. Wilson** DATE: **Apr 1, 2008**

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## 1. Overview of planned experiment

Goal: Study heating and CD in deuterium L mode plasmas and compare results to those obtained in helium under XPs 712 and 717.

– **Heating in $D_2$ L mode:**

- Determine if density in deuterium can be held below onset for wave propagation at the wall.
- Show how efficiency depends on wavelength in deuterium
- Need to establish behavior in deuterium L mode to optimize current drive for startup and in preparation for H mode studies

– **CD in $D_2$ L mode:**

- Phase scan for HHFW CD with time-resolved MSE; compare with loop voltage differences.
- MSE beam blip at end of HHFW pulse and progressively move it forward in time upon succeeding shots to determine the current relaxation time

## 2. Theoretical/ empirical justification

This XP is a continuation of XPs 712 and 717 which established HHFW heating efficiency and CD properties in helium L mode plasmas. HHFW heating and CD properties in deuterium plasmas are to be determined and compared to those in helium plasmas and analyzed with advanced RF modeling codes. It is important to establish behavior in deuterium L mode to permit optimization of current drive for startup and in preparation for H mode studies. The approach used in these experiments and further justification of these experiments can be found in XPs 712 and 717.

## 3. Experimental run plan

This experiment has two parts:

a. Heating of L mode deuterium plasma
   - dependence on edge density and wavenumber
b. Phase scan for HHFW CD with time-resolved MSE

# A. Heating of L mode deuterium plasma
## - dependence on edge density and wavenumber

- Setup conditions as for XP712 at B = 5.5 kG but with deuterium plasma:
- LSN, deuterium L-mode, gap ~ 4 - 5 cm (same conditions as for shot 123435, -90 degrees)
- Apply $P_{RF}$ as for ~ 200 ms (at full 0.55 Tesla field) with $k_{||} = -8m^{-1}$
- Apply 90 kV NB pulse at end of RF pulse - use 70 kV beam to measure $T_i$ and rotation
  - 3 shots

**I Perform wavenumber scan at ~ 4 cm**

Scan vs phase is limited by need to complete it in 1/2 day

**i. With plasma settings as for shot 123435 but with deuterium - Gap at ~ 4 cm:**

- 1 shot @ 14 $m^{-1}$ (180º)
- 1 shot @ -12 $m^{-1}$ (-150º)
- 1 shot @ -8 $m^{-1}$ (-90º)
- 1 shot @ -3 $m^{-1}$ (-30º)
- 1 no RF shot

(Additional shots may be required to set matching for each $k_{||}$. NB should be added 20 ms before end of RF pulse)

**ii. Scan with RF pulse modulated to determine tau (10 Hz modulation)**

- 1 shot @ 14 $m^{-1}$ (180º)
- 1 shot @ -12 $m^{-1}$ (-150º)
- 1 shot @ -8 $m^{-1}$ (-90º)
- 1 no RF shot

# B. Phase scan for HHFW CD with time-resolved MSE

- Increase HHFW power to 3-4 MW range, or as high as achievable, for 300-400 ms pulses.
- Run similar conditions to where loop voltage differences have been seen in the past upon phase change (107899, 107907) but also at higher B (.55 T); or the conditions of part A if loop voltage response is adequate.
- Start MSE beam blip at end of HHFW pulse and progressively move it forward in time upon succeeding shots to determine the current relaxation time (3 steps)

**II Phase scan for HHFW CD with time-resolved MSE**

Scan for CD is limited to ½ day

**i. With NB pulse near end of RF pulse:**

- 1 shot @ 14 $m^{-1}$ (180º)
- 1 shot @ -8 $m^{-1}$ (-90º)
- 1 shot @ +8 $m^{-1}$ (+90º)
- ❖ Check that voltage is responding to phase. If not change conditions (lower density)

**ii. With NB stepped in toward start of RF pulse**

- 2 shots @ +8 $m^{-1}$ (+90º)
- 2 shot @ -8 $m^{-1}$ (-90º)
- 1 no RF shot

(Additional shots may be required to set matching for each $k_{||}$.)

### iii. Put on long NB pulse and see if reaction depends on phase

- 1 shot @ -8 $m^{-1}$ (-90º)
- 1 shot @ +8 $m^{-1}$ (+90º)
- 1 shot @ 14 $m^{-1}$ (180º)

These shots are intended to see if we can drive current (or even operate) in the presence of high power NBI. May also go into H-mode. May need to go to 70 kV beams.

Some of this may be accomplished during the time-resolved MSE measurements.

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

Stable or at least reproducible plasma conditions are required for the quantitative comparisons of this XP.

NB pulses are needed at 90 kV for MSE measurements

Critical diagnostics include:

- EFIT with high time resolution
- Reflectometry for edge density and PDI
- Reflectometry for wave measurements for opposite side from antenna
- Edge probe for PDI
- Gap RF probes for leakage
- 4 RF probe(s) for edge RF field
- MSE for some shots for effects on current

# 5. Planned analysis

**Expected results:**

- Heating efficiency in deuterium L mode vs wavenumber: 14 $m^{-1}$, -8 $m^{-1}$ (co CD), -3$m^{-1}$, -11$m^{-1}$, etc.
  - – Core heating from EFIT W
  - – Core electron heating from Thomson scattering
  - – Ion heating and core rotation from Chers
- Edge heating/power loss
  - – Edge ion heating from edge rotation diagnostic
  - – Edge electron heating from Thomson scattering
  - – Rotation effects
- MSE measurements of current drive
  - –Co vs counter for conditions where loop voltage is reduced for co
- Plasma profiles, core and edge, for permitting predictions of wave propagation damping and CD characteristics

**Planned analysis:**

- Compare efficiencies vs wavenumber to those for helium
- Determine CD profile vs time in RF pulse
- Determine if stability with NB is dependent of antenna phase
- Analysis of wave propagation, damping and CD characteristics from onset density into the core of plasma - along field and perpendicular directions of the ray path, and including collisions - for predicting CD and surface losses
- Benchmarking of RF codes that include surface losses

## 6. Planned publication of results

The results will be submitted for publication.

# PHYSICS OPERATIONS REQUEST

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Machine conditions (specify ranges as appropriate)

$I_{TF}$ (kA): **-53 – -65** Flattop start/stop (s): **-0.02 – 0.7**

$I_P$ (MA): **0.4 – 0.9** Flattop start/stop (s): **0.1 /0.6**

Configuration: **LSN**

Outer gap (m): **0.04 – 0.08** Inner gap (m): **~0.04**

Elongation κ: Upper/lower triangularity δ:

Z position (m):

Gas Species: **D and He** Injector(s): **Inner wall to start**

**NBI** Species: **D** Sources: **A, C** Voltage (kV): **90, 70** Duration (s): **0.04 - 0.4**

**ICRF** Power (MW): **≤ 3** Phasing: **Various** Duration (s): **0.2 – 0.4 modulated**

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

**LITER: Off**

Previous shot numbers for setup: **123435, or 127449, but with deuterium**

## DIAGNOSTIC CHECKLIST

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*Note special diagnostic requirements in Sec. 4*

| Diagnostic | Need | Want |
|---|---|---|
| Bolometer – tangential array | √ | |
| Bolometer – divertor | √ | |
| CHERS – toroidal | √ | |
| 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 | | √ |
| Fast lost ion probes - IFLIP | | √ |
| Fast lost ion probes - SFLIP | | √ |
| Filterscopes | √ | |
| FIReTIP | | √ |
| Gas puff imaging | | |
| Hα camera - 1D | | √ |
| High-k scattering | √ | |
| Infrared cameras | | √ |
| Interferometer - 1 mm | | |
| 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. | √ | |
| 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 – ExB scanning | √ | |
| NPA – solid state | | |
| Neutron measurements | √ | |
| Plasma TV | √ | |
| Reciprocating probe | | |
| Reflectometer – 65GHz | √ | |
| Reflectometer – correlation | √ | |
| Reflectometer – FM/CW | √ | |
| Reflectometer – fixed f | √ | |
| Reflectometer – SOL | √ | |
| RF edge probes | √ | |
| Spectrometer – SPRED | √ | |
| Spectrometer – VIPS | √ | |
| SWIFT – 2D flow | | |
| Thomson scattering | √ | |
| Ultrasoft X-ray 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 fast pinhole camera | | √ |
| X-ray spectrometer - XEUS | | √ |