Princeton Plasma Physics Laboratory
NSTX Experimental Proposal

Title: Parametric dependence of low-density locked-mode threshold		
OP-XP-415	**Revision: 0.0**	Effective Date: 1/12/2004 *(Ref. OP-AD-97)* Expiration Date: 1/12/2006 *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

Author:	**J. Menard**	Date 1/12/2004
ATI - Task Force Leader:	**S. Sabbagh**	Date
RLM - Run Coordinator:	**S. Kaye**	Date
Responsible Division: Experimental Research Operations		

Chit Review Board (designated by Run Coordinator)

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

Parametric dependence of low-density locked-mode threshold

1. **Overview of planned experiment:**

The goal of this experiment is obtain a more detailed understanding of the parametric dependence of the mode-locking threshold in low aspect ratio plasmas such as NSTX. Theoretically, for fixed applied vacuum error field, it is expected that the critical rotation frequency for mode locking should scale as the inverse of the square root of the electron density. For ohmic plasmas with only diamagnetic rotation (assumed to scale as T_e/B_T), this implies that the critical density for mode locking should scale very roughly as $(B_T / T_e)^2$. If T_e scales less than linearly with B_T, the density threshold for locking should increase with applied toroidal field. If the natural rotation is increased with beam injection, the critical density is expected to decrease. As the no-wall beta limit is approached, error field amplification may again raise the critical density for locking. However, error field amplification may only be observable if the confinement is sufficiently good at low density allowing the no-wall beta limit to be approached with reduced momentum input. In short, this experiment will test these theoretical scalings by systematically varying the plasma density, toroidal field, and momentum input in operating conditions prone to the generation of locked modes.

2. **Justification:**

Several FY2002 NSTX experiments have shown that the correction of the PF5 coil has led to a significantly reduced error field. Experimental proposal 207 empirically assessed the impact of error field reduction on NSTX plasma performance by determining the maximum achievable plasma current flat-top duration for ohmic and beam-heated LSN discharges as a function of plasma current and density. This experiment allowed a direct comparison of results to similar data taken prior to error-field reduction. This experiment also showed that locked modes could still be generated at sufficiently low density, and that locking often occurred at several preferred toroidal positions. However, in general, there is little detailed knowledge of the mode locking threshold for present NSTX plasmas for operating conditions without strong NBI heating and at low density. Thus, this experiment will provide data for better understanding mode locking physics in ST geometry and should provide a more complete picture of which operating scenarios in NSTX are potentially prone to locked modes.

3. **Plan:**

The locking threshold will be determined by observing when the locked-mode detector shows a persistent mode exceeding 1 Gauss prior to discharge termination due to OH solenoid limits. The dependence of the onset of locking will be determined as a function of electron density, applied toroidal field, and neutral beam induced rotation. H-mode should be systematically avoided through modifications of inner gap or gas fueling as needed. The experiment will be performed as follows:

1. Recreate low-density ohmic locked-mode shot similar to shots 106954-106956 with line-average density of $0.7\text{-}1.1\times10^{19}m^{-3}$ at 800kA, 4.5kG, κ=1.8, δ=0.35. Locked-mode onset time was typically t=240ms. **(4 shots)**
2. Increase plasma rotation and beta with NBI **(10 shots)**

a. Add source A NBI at 80kV for 20ms starting at t=220ms to document rotation.
    i. If mode is no longer observed following 20ms beam pulse, move pulse 20ms earlier in 20ms steps until mode is again observed. Alternatively, use source B at 60kV to lower rotation if CHERs data is not compromised.
    ii. If mode is still observed, double beam pulse width and decrease beam turn-on time until mode is stabilized by rotation.

b. Once mode has been stabilized with sufficient rotation:
    i. Increase beam power such that beta limit (rapid disruption) is reached just prior to nominal locked-mode turn-on time.
    ii. Decrease NBI power to just avoid rapid disruption in attempt to excite locked mode near beta limit.

c. Obtain rotation profile data for determination of critical v_ϕ values versus β. Operate CHERs with 10ms sampling window so long as diagnostic is not compromised.

3. Decrease field to 3.5kGauss and repeat 2 above. **(8 shots)**

4. Systematically increase density for 4.5kGauss and 3.5kGauss shots **(8 shots)**
    a. Perform without long duration NBI heating to find ohmic critical n_e.
    b. Then, add 20ms beam blips just before mode turn-on time just above critical electron density to measure rotation profiles of ohmic discharges.

<u>Day #1 Number of shots = 30</u>

5. Use internal RWM/error-field sensor array to compare locked-mode amplitude and toroidal phase on both the ex-vessel and in-vessel sensors, and measure mode helicity with new internal sensors. Repeat Scans 3 and 4 above to obtain threshold data with both sensor sets.

<u>Day #2 number of shots = ½ day (15 shots)</u>

4. **Required machine, beam, ICRF and diagnostic capabilities:**

Machine:	3.5 - 4.5 kG
Beams:	80keV deuterium, source A
ICRF:	None
Diagnostics:	Toroidal mirnov array, locked mode coils, full kinetic profiles of electrons, ions, and impurities are essential.

5. **Planned analysis:**

Data will be used to determine critical density for mode locking and for comparison to theoretical scaling expectations.

6. **Planned publication of results:**

An article based on these results is expected within one year of completion of the experiment.

PHYSICS OPERATIONS REQUEST

Title: Parametric dependence of low-density locked-mode threshold **XP No.: 415**

Machine conditions (specify ranges as appropriate)

I_{TF} (kA): **42, 53kA** Flattop start/stop (s): **0 / 0.4**

I_P (MA): **0.8-1.2MA** Flattop start/stop (s): **0.18 / 0.3**

Configuration: **LSN**

Outer gap (m): **0.05**, Inner gap (m): **0.06**

Elongation κ: **1.8**, Triangularity δ: **0.35**

Z position (m): **0.00**

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

NBI - Species: **D**, Sources: **A**, Voltage (kV): **80**, Duration (s): **0.2**

ICRF – Power (MW): **0**, Phasing: **Heating / CD**, Duration (s): **0**

CHI: **Off**

Either: List previous shot numbers for setup: **106954**

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

Title: Parametric dependence of low-density locked-mode threshold **No. 415**

Diagnostic system	**Need**	**Desire**	**Requirements** (timing, view, etc.)
Bolometer – tangential array		✓	
Bolometer array - divertor		✓	
CHERS	✓		Measure rotation profile during NBI blips
Divertor fast camera		✓	
Dust detector		✓	
EBW radiometers		✓	
Edge deposition monitor		✓	
Edge pressure gauges		✓	
Edge rotation spectroscopy	✓		Measure edge rotation profile
Fast lost ion probes - IFLIP		✓	
Fast lost ion probes - SFLIP		✓	
Filtered 1D cameras		✓	
Filterscopes		✓	
FIReTIP	✓		Need for line-density evolution
Gas puff imaging		✓	
Infrared cameras		✓	
Interferometer - 1 mm		✓	
Langmuir probe array		✓	
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 measurements		✓	
Plasma TV	✓		
Reciprocating probe		✓	
Reflectometer – core		✓	
Reflectometer - SOL		✓	
RF antenna camera		✓	
RF antenna probe		✓	
SPRED		✓	
Thomson scattering	✓		
Ultra-soft X-ray arrays	✓		
Visible bremsstrahlung detector		✓	
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		✓	