## Princeton Plasma Physics Laboratory
# NSTX Experimental Proposal

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| **Title:** **Error-field studies using tearing modes and mode control coils** | | |
| **OP-XP-455** | **Revision:** | Effective Date: 7/12/04<br>*(Ref. OP-AD-97)*<br>Expiration Date: 7/12/06<br>*(2 yrs. unless otherwise stipulated)* |

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| **PROPOSAL APPROVALS** | |
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| **ATI – ET Group 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)

## 1. Overview of planned experiment

This experiment will attempt to infer any residual vacuum error fields in NSTX from the response of locked and rotating tearing modes to external non-axisymmetric field perturbations. The amplitude and (static) toroidal phase angle of externally applied n=1 mid-plane field will be scanned to minimize tearing and locking activity in a reference discharge. In this condition with minimized error field, the experiment will then attempt to determine the error-field penetration threshold scaling to compare to conventional aspect ratio scalings. During the initial phase of execution of this experiment, only 2 external mode control coils ($EMC^2$) with a single toroidal phase angle will be available. Thus, the scan of toroidal phase angle in this experiment cannot be conducted this run year.

## 2. Theoretical / empirical justification

Resonant error fields can destabilize tearing modes by increasing the mode $\Delta'$ and cause the mode to lock from the induced electromagnetic braking torque at the resonant mode rational surface. Thus, vacuum error field reduction could potentially reduce tearing and locked mode activity in NSTX. Further, if some confidence can be gained that error fields have been minimized in NSTX, the penetration threshold for error fields can be systematically determined and compared to standard tokamak results. The results of this research should also contribute to developing both pre-programmed and feedback-driven compensation algorithms for correcting any residual error fields.

## 3. Experimental run plan - 48 shots total

A. Study low-density ramp-up locked-mode **(18 shots)**
   a. Start with 1MA, $B_T$=3kG PF1B LSN 113266 from XP-415
   b. NBI programming: Source B at 100ms, Source C at 130ms
      i. This beam timing will be kept fixed unless otherwise noted
   c. Scan MC coil current in 500A steps to minimize locking during ramp **(6 shots)**
      i. Ramp active coil current from 0 to full current with trapezoidal waveform
         1. Start 20ms ramp at 100ms, ramp down at 180ms to zero current
      ii. Change polarity of active coil and repeat scan **(6 shots)**
      iii. Document current amplitude and direction that minimizes locking
   d. Scan early gas fueling/density to determine modified locking threshold **(6 shots)**

B. Study low-density flat-top locked-mode **(10 shots)**
   a. Starting from reduced-locking waveform from (A) above, extend waveform in time 200ms to apply external field during flat-top locked phase **(6 shots)**
      i. Scan control coil current after t=200ms in 500A steps to minimize locking
      ii. Document current amplitude that minimizes locking
   b. Scan early gas fueling/density to determine modified locking threshold (**4 shots)**

C. Study rotating tearing mode locking at higher density **(20 shots)**

   a. Increase density to just above threshold for early locking
   b. Starting from reduced-locking coil waveform from (B) above, extend waveform in time 220ms to apply field during flat-top phase until t=600ms **(6 shots)**
      i. Scan active coil current after t=400ms in 500A steps to minimize locking
      ii. Document current amplitude that minimizes locking
   c. Scan late momentum input to determine modified locking threshold **(8 shots)**
      i. Reduced momentum: turn off source C at 300ms
         1. Delay turn-off time in 50ms increments to scan locking time
      ii. Increased momentum: turn on source A at 300ms
         1. Delay turn-on time in 50ms increments to scan locking time
   d. In discharge with longest duration of no mode locking, change mode control coil currents in 20% increments/decrements to find error-field threshold **(6 shots)**

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

The usual NBI and diagnostic capabilities are required.

## 5. Planned analysis

EFIT, TRANSP, MPTS, CHERS, and internal magnetic sensor analysis will be performed.

## 6. Planned publication of results

Results will be published in conference proceedings and/or journal such as Nuclear Fusion or Physics of Plasmas within one year of experiment.

# PHYSICS OPERATIONS REQUEST

**Error-field studies using tearing modes and mode control coils** **OP-XP-455**

Machine conditions (specify ranges as appropriate)

$I_{TF}$ (kA): **36-40kA** Flattop start/stop (s): **-0.010s/0.5s**

$I_P$ (MA): **0.8-1.0MA** Flattop start/stop (s): **0.18s/0.5s**

Configuration: **Lower Single Null**

Outer gap (m): **10cm**, Inner gap (m): **2-10cm**

Elongation κ: **2.0-2.5**, Triangularity δ: **0.55-0.75 (lower x-point)**

Z position (m): **0.00**

Gas Species: **D**, Injector: **Midplane + Inner wall**

NBI - Species: **D**, Sources: **A,B,C** Voltage (kV): **up to 90kV** Duration (s): **0.5s**

ICRF – Power (MW): **0** Phasing: N/A Duration (s):

CHI: **Off**

*Either:* List previous shot numbers for setup: **113262-113266 from XP 415**

*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

## Error-field studies using tearing modes and mode control coils OP-XP-455

| Diagnostic | Need | Desire | Instructions |
|---|---|---|---|
| Bolometer – tangential array | | X | |
| Bolometer array - divertor | | X | |
| CHERS | X | | |
| Divertor fast camera | | X | |
| Dust detector | | X | |
| EBW radiometers | | X | |
| Edge deposition monitor | | X | |
| Edge pressure gauges | | X | |
| Edge rotation spectroscopy | | X | |
| Fast lost ion probes - IFLIP | | X | |
| Fast lost ion probes - SFLIP | | X | |
| Filtered 1D cameras | | X | |
| Filterscopes | X | | |
| FIReTIP | X | | |
| Gas puff imaging | | X | |
| Infrared cameras | | X | |
| Interferometer - 1 mm | | X | |
| Langmuir probe array | | X | |
| Magnetics - Diamagnetism | X | | |
| Magnetics - Flux loops | X | | |
| Magnetics - Locked modes | X | | |
| Magnetics - Pickup coils | X | | |
| Magnetics - Rogowski coils | X | | |
| 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 measurements | X | | |
| Plasma TV | X | | |
| Reciprocating probe | | X | |
| Reflectometer – core | | X | |
| Reflectometer - SOL | | X | |
| RF antenna camera | X | | |
| RF antenna probe | | X | |
| SPRED | | X | |
| Thomson scattering | X | | |
| Ultrasoft X-ray arrays | X | | |
| Visible bremsstrahlung det. | | | |
| Visible spectrometers (VIPS) | | | |
| X-ray crystal spectrometer - H | | X | |
| X-ray crystal spectrometer - V | | X | |
| X-ray PIXCS (GEM) camera | | | |
| X-ray pinhole camera | X | | |
| X-ray TG spectrometer | | X | |