Princeton Plasma Physics Laboratory
NSTX Experimental Proposal

Title: Comparison of error field correction techniques at high beta-N		
OP-XP-614	**Revision:**	Effective Date: 3/15/2006 *(Ref. OP-AD-97)* Expiration Date: 3/15/2008 *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

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RLM - Run Coordinator:	**R. Raman/S. Sabbagh**	Date

Responsible Division: Experimental Research Operations

Chit Review Board (designated by Run Coordinator)

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL

Comparison of error field correction techniques at high beta-N OP-XP-614

1. Overview of planned experiment

This experiment will compare the performance of three error field correction (EFC) techniques. Pre-programmed EFC and proportional EFC (assuming the error field is *proportional* to the product of the OH and TF currents) will be tested first. "Dynamic" EFC will then be attempted by using the RWM/EF feedback control system to minimize the total residual error field from resonant field amplification from the rotationally stabilized RWM.

2. Theoretical / empirical justification

Several long-pulse scenarios in NSTX are evidently limited by rotation decay near the plasma edge which then propagates to the plasma core leading to locked island formation and/or RWM destabilization and plasma disruption. The addition of n=1 field to such plasmas resulted in maintenance of the plasma rotation and extended pulse durations for a particular applied field phase. This result implies the existence of a residual intrinsic error field. Results from 2005 also indicate the presence of a time-dependent error field resulting from an interaction between the OH and TF coils. The error field appears to be most consistent with TF coil motion induced by the OH. If the TF coil displacement is linear in the product of the OH and TF coil currents, the actual TF-generated error field will be proportional to I_{OH} x I_{TF}^2, and this scaling will also be tested. This experiment will develop several EFC algorithms and attempt to improve plasma performance for a wider range of operating conditions.

3. Experimental run plan

Day 1 – 30 shots

1. Reproduce 800kA target plasma with edge locking **(2 shots)**
2. Add n=1 corrective field – try to reduce flow damping and mode locking
    a. Apply linear "corrective" n=1 ramp after I_{OH} zero crossing **(8 shots)**
        i. Scan ramp-rate to find optimal correction coefficient for longest shot
        ii. Fine-scan EF phase once optimal coefficient has been determined
    b. Use same proportionality coefficient in EFC algorithm: **(8 shots)**
        i. EFC algorithm $B_{n=1} = a_1 \times \mathrm{LPF}\{I_{OH}\times I_{TF}\} + a_2 \times |\mathrm{LPF}\{I_{OH}\times I_{TF}\}|$
            1. Use only a_1 term initially, τ_{LPF} = 90ms, then add a_2 term
        ii. Compare EFC algorithm result to pre-programmed for 800kA discharge
3. If EFC algorithm improves discharge, test at other plasma current and B_T **(12 shots)**
    a. Compare plasma performance with and w/o EFC for 3 scenarios:
    b. (1) 1.0MA & 4.5kG, (2) 0.7MA and 3.5kG (3) 1.0MA and 3.5kG

Day 2 – 30 shots

4. Use RWM/EF feedback control system for "dynamic" EFC
   a. Verify feedback system readiness **(2 shots)**
      i. Turn on mode-identification (MID) algorithm in PCS
      ii. Verify real-time MID signals are same as post-shot analysis
      iii. Apply baseline zeroing after OH crossing (or smallest EF)
      iv. Verify MID exhibits ramping amplitude vs. time
         1. OH×TF field is not removed in present version of MID
   b. Test DEFC – use optimal RWM gain and phase if data is available
      i. Set phase shift δ between MID and feedback currents to 180º, or best available value from analysis of previous EFC results.
      ii. Use in-vessel sensor array (U vs. L) with most working sensors
      iii. Scan feedback proportional gain – observe effect on plasma **(8 shots)**
      iv. Scan phase difference δ with ± 15º increments **(12 shots)**
      v. Repeat gain scan with optimal δ **(4 shots)**
   c. Switch to other sensor array – re-scan δ – compare performance **(4 shots)**
5. Compare performance (shot duration, ELMs, β_N, etc.) to EFC results
6. Determine if <u>average</u> time evolution of optimal DEFC SPA currents is similar to evolution of pre-programmed EFC SPA currents.

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

The usual diagnostic coverage is required.

5. Planned analysis

EFIT/LRDFIT, 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

Comparison of error field correction techniques at high beta-N **OP-XP-614**

Machine conditions (specify ranges as appropriate)

I_{TF} (kA): **36kA, 53kA** Flattop start/stop (s): **_-0.050_/_1.5__**

I_P (MA): **0.5-1.2** Flattop start/stop (s): **0.16-1.5**

Configuration: **PF1B LSN**

Outer gap (m): **__10cm___**, Inner gap (m): **_4cm__**

Elongation κ: **__2.2-2.4__**, Triangularity δ: **0.25-0.8**

Z position (m): **0.00**

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

NBI - Species: **D**, Sources: **A,B,C** Voltage (kV): **__90kV___**, Duration (s): **_1.5_**

ICRF – Power (MW): **__0__**, Phasing: **N/A**, Duration (s): _____

CHI: **Off**

Either: List previous shot numbers for setup: **119312**

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

Comparison of error field correction techniques at high beta-N OP-XP-614

Diagnostic	Need	Desire	Instructions
Bolometer - tangential array		✓	
Bolometer array - divertor		✓	
CHERS	✓		
Divertor fast camera	✓		
Dust detector		✓	
EBW radiometers		✓	
Edge deposition monitor		✓	
Edge pressure gauges		✓	
Edge rotation spectroscopy		✓	
Fast lost ion probes – IFLIP		✓	
Fast lost ion probes – SFLIP		✓	
Filtered 1D cameras		✓	
Filterscopes	✓		
FIReTIP	✓		
Gas puff imaging		✓	
High-k scattering		✓	
Infrared cameras		✓	
Interferometer – 1 mm		✓	
Langmuir probes - PFC tiles		✓	
Langmuir probes - RF antenna		✓	
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 Rate (2 fission, 4 scint)	✓		
Neutron collimator		✓	
Plasma TV	✓		
Reciprocating probe		✓	
Reflectometer - FM/CW		✓	
Reflectometer - fixed frequency homodyne		✓	
Reflectometer - homodyne correlation		✓	
Reflectometer - HHFW/SOL		✓	
RF antenna camera		✓	
RF antenna probe		✓	
Solid State NPA		✓	
SPRED		✓	
Thomson scattering - 20 channel	✓		
Thomson scattering - 30 channel		✓	
Ultrasoft X-ray arrays	✓		
Ultrasoft X-ray arrays - 2 color	✓		
Visible bremsstrahlung det.		✓	
Visible spectrometers (VIPS)		✓	
X-ray crystal spectrometer - H		✓	
X-ray crystal spectrometer - V		✓	
X-ray pinhole camera		✓	