Princeton Plasma Physics Laboratory
NSTX Experimental Proposal

Title: **n=2 Intrinsic Error Fields and RWM Critical Rotation From Even Parity Magnetic Braking in NSTX**

OP-XP-805	Revision: **4**	Effective Date: Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

Responsible Author: Stefan Gerhardt	Date
ATI – ET Group Leader: Steve Sabbagh	Date
RLM - Run Coordinator: Mike Bell	Date
Responsible Division: Experimental Research Operations	

Chit Review Board (designated by Run Coordinator)

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL

TITLE: **n=2 Intrinsic Error Fields and RWM Critical Rotation From Even Parity Magnetic Braking in NSTX** No. **OP-XP-805**
AUTHORS: **S. P. Gerhardt, J.E. Menard, J.W. Berkery** DATE: **3/3/2008**

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1. Overview of planned experiment

This experiment will attempt to infer the residual n=2 error fields in NSTX and study the RWM critical rotation profile with even-parity magnetic braking. The Error Field Correction (EFC) coils will be used to apply n=2 error fields of varying phases and magnitudes. The response of the plasma flow damping and pulse length to the applied field will be used to infer the presence of the error field. In particular, the present EFC coils allow an n=2 applied EF. After developing a reference discharge based on shot 124411, a scan of the n=2 applied field, with six directions, and two magnitudes per direction, will be conducted. This will allow a determination of the optimal "direction" for n=2 EF correction. Once an optimal direction is established, an optimization of the EFC coil current magnitude will be done to determine if n=2 EF correction allows a significant improvement in pulse length. The magnitude of the EFC current in the optimal "direction" will then be increased until the intrinsic EF is overcompensated, the rotation damping increases, and an n=1 RWM grows. A continued increase of the n=2 applied field will then be used to asses the critical rotation profile for the RWM with n=2 braking of various strengths.

The EFC coil configuration for this XP allows a configuration with an n=6 perturbation. If time allows, this n=6 configuration will be utilized as a further measure of the RWM critical rotation profile. The optimal n=2 correction from the previous section will be applied, with an n=6 perturbation added on top. The n=6 level will be increased until the associated magnetic braking induces a rotation collapse and RWM. The rotation profiles when the RWM grows will be added to the database of critical rotation profiles.

2. Theoretical/ empirical justification

While the importance of resonant n=1 error fields is well known, most present tokamaks do not consider the role of non-resonant error fields. These error fields can provide a source of plasma rotation braking, slowing the plasma and resulting in eventual mode destabilization (NTM or RWM). Experiments during the CY2007 campaign revealed the existence of an asymmetric response (in the plasma rotation and pulse length) to an applied n=3 field. This implies that there is an intrinsic n=3 error field in NSTX, possibly related to known deformation of PF5. Correction of this n=3 field, when combined with n=1 DEFC, resulted in the longest ever 900 kA pulse in NSTX (shot 125329). These results motivate the present search for n=2 error fields in NSTX. If a significant n=2 EF is inferred, it would strongly motivate an effort to either reduce the EF source or correct it with an additional SPA.

Note additionally that the n=6 portion of the experiment provides an interesting opportunity for additional RWM studies. The mode spectrum is strongly edge peaked compared to the other cases, and is fairly pure. However, the ion temperature multiplication in the NTV expressions may cause the actual damping to be quite low. This configuration is also an important candidate for ELM suppression via RMP, so it is important to assess how n=6 applied fields might impact RWM physics.

3. Experimental run plan

A) Preparation:

i) Take SPA compensation shots for the even EFC Coil Configuration: **(3 shots)**

Shot To Reload	Shot Taken
126917	
126918	
126920	

ii) Reproduce target plasma: Shot 124411 **(2-5 shots)**
800kA, 4.5kG LSN NBI heating discharge, H-mode at 113 msec.
Shot should suffer rotation collapse and RWM at ~.9 sec.
Note: the inner gap is sensitive to the CS gas plenum pressure for this shot. Need to watch this variable carefully. Optimum for last year was 900 T.
Target to be repeated twice in order to verify reproducibility.

B) Scan of n=2 applied field phase/magnitude **(15 shots)**

Six phases with two magnitudes each. SPA Currents turning on at .35, ramping to full value by 0.4 seconds, on for remainder of shot (100 msec earlier than in 701, timing may be modified).

Note that these are the currents leaving the SPA Units, which are connected so that positive SPA current makes field into NSTX, i.e. negative EFC field for the physics convention.

Target to be repeated in order to verify reproducibility of the condition.

i)

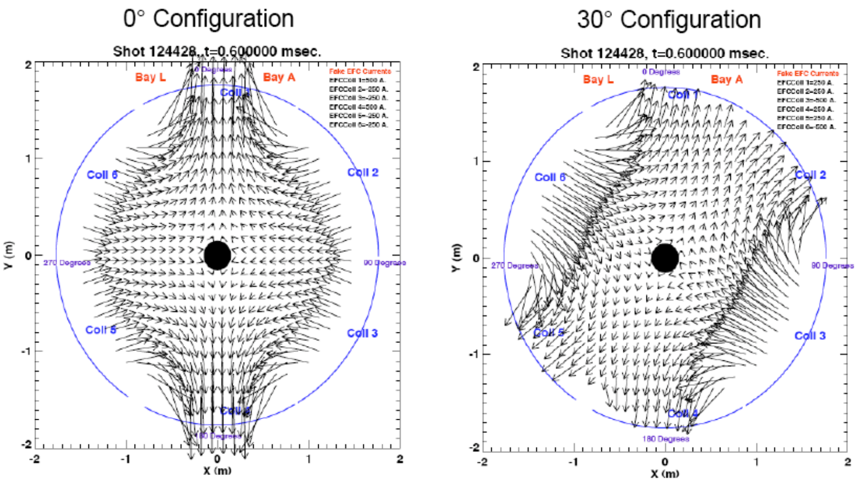
Phase	SPA 2 (A)	SPA 3 (A)	SPA 1 (A)	Shot
90	250	-125	-125	
90	500	-250	-250	
0	-250	125	125	
0	-500	250	250	
target	0	0	0	

ii)

Phase	SPA 2 (A)	SPA 3 (A)	SPA 1 (A)	Shot
150	-125	250	-125	
150	-250	500	-250	
60	125	-250	125	
60	250	-500	250	
target	0	0	0	

iii)

Phase	SPA 2 (A)	SPA 3 (A)	SPA 1 (A)	Shot
30	-125	-125	250	
30	-250	-250	500	
120	125	125	-250	
120	250	250	-500	
target	0	0	0	



- "Engineering" Toroidal Angle Increasing CW As Viewed From Top.
- Positive RWM Current Pointing OUT of the vessel.

C) Optimization of n=2 EF correction for long pulse discharges **(up to 5 shots)**

i) Determine phase of optimal n=2 correction data collected in step B). Optimal direction will have best sustained rotation, longest pulse length. <u>If no asymmetry was observed in step B, then skip to part D.</u>

ii) Increase/Decrease EFC coil current in 250 A increments in order to optimize the discharge (i.e. maximum rotation and pulse length)

Optimal Phase	SPA 2 (A)	SPA 3 (A)	SPA 1 (A)	Shot

D) RWM Critical Rotation Profile with n=2 braking **(5 shots)**

i) If step C was executed (n=2 EF was identified), then: the baseline for this step is the optimal discharge from step C.
If step C was not executed (no n=2 EF), then: of the configurations from B can be utilized as the baseline.

Record shot number for baseline discharge in this step:__________

ii) Further increase the EFC coil current in the optimal direction, so that EF braking is over compensated and a collapse occurs. Repeat this step with 200A increments of the EFC coil current.

Optimal Phase	SPA 2 (A)	SPA 3 (A)	SPA 3 (A)	Shot

E) Addition of n=6 braking to optimized n=2 correction **(up to 7 shots)**

i) If step C was executed (n=2 EF was identified), then utilize the optimum discharge from Step C as the baseline discharge for this step.
If step C was not executed (no n=2 EF), then utilize reference discharge for this step.
Record shot number for baseline discharge in this step:__________

ii) Add an n=6 perturbation to the baseline discharge in 500A increments until rotation collapse and RWM is induced. SPA waveform to be same as in step B. Once damping is strong enough, cease to add additional field and move to part iii).

SPA Current added to Reference Shot (all three SPA units) (A)	Shot
500	
1000	
1500	
2000	
2500	

iii) Repeat the shot in part ii) with sufficient n=6 damping and n=2 correction.

iv) If n=2 correction was applied, repeat shot in iii) without n=2 correction.

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

Most critical diagnostics are for this XP: CHERS, MPTS, MSE, Equilibrium Magnetics, Fast Mirnovs, RWM/LM sensors, USXR

NBI voltage on A,B,C = 90,90,80kV

No RF or CHI.

RWM coils will need to be in the “Even Connection” or “Series Connection” configuration. The mapping of the SPAs to coils will thus be:

Supply	Coils (Physics Sign Convention)
SPA 1	-3, -6
SPA 2	-1, -4
SPA 3	-2, -5

Note: The (physics) sign convention above is based up current being sourced into the physical “positive” lead of the RWM coils, such that positive current makes magnetic field pointing into the vessel, i.e. negative field.

In order to switch from the traditional anti-series connection, the following step must be taken inside the interface box in the NTC.

1: Remove all three plates labeled BB

2: Remove the following jumpers:

SU1P to 6A

SU2P to 4A

SU3P to 5A

3: To put coils 3 & 6 in the even configuration:

Add jumper between 3B and 6A

Add jumper between 6B and SU1P:

4: To put coils 2 & 5 in the even configuration:

Add jumper between 2B and 5A

Add jumper between 5B and SU3P:

5: To put coils 1 & 4 in the even configuration:

Add jumper between 1B and 4A

Add jumper between 4B and SU2P

A test shot should be taken to confirm this connection. A suggested set of waveforms for this shot is:

SPA 1: +500A from 0 to .1, -500A from .1 to .2

SPA 2: +900A from .4 to .5, -900A from .5 to .6

SPA 3: +1300A from .8 to .9, -1300A from .9 to 1.0

5. Planned analysis

Analysis of data from CHERS, MPTS, RWM/EF sensors, USXR emission, and Mirnov signals. EFIT/LRDFIT equilibrium analysis. Analysis of applied spectrum and comparison to that from known error field sources using local codes. Analysis of RWM critical rotation profile and comparison to the database from n=1 and n=3 braking.

6. Planned publication of results

Results complement previous n=3 EF results. Will be reported at APS/ITPA/IAEA meetings, and published in journal such as Nuclear Fusion or Phys. Plasmas within 1 year of conducting experiment.

PHYSICS OPERATIONS REQUEST

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Machine conditions (specify ranges as appropriate)

I_{TF} (kA): **53 kA** Flattop start/stop (s): **-.02 / 1.5 (s)**

I_P (MA): **0.8MA** Flattop start/stop (s): **.18 / 1.3 (s)**

Configuration: **LSN**

Outer gap (m): **0.12 (m)** Inner gap (m): **.05 (m)**

Elongation κ: 2.2 Upper/lower triangularity δ: .35 / .65

Z position (m): 0

Gas Species: **D** Injector(s): CS midplane, Outer Midplane

NBI Species: **D** Sources: A,B,C Voltage (kV): 90, 90, 80 Duration (s): **Full Shot**

ICRF Power (MW): **0 MW** Phasing: **NA** Duration (s): **NA**

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

LITER: On / Off

Previous shot numbers for setup: **124411**

DIAGNOSTIC CHECKLIST

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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 – RF ant.		
Magnetics – Diamagnetism	✓	
Magnetics - Flux loops	✓	
Magnetics - Locked modes	✓	
Magnetics - Pickup coils	✓	
Magnetics - Rogowski coils	✓	
Magnetics - RWM sensors	✓	

Diagnostic	**Need**	**Want**
Mirnov coils – high f.	✓	
Mirnov coils – poloidal array	✓	
Mirnov coils – toroidal array	✓	
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'r - H		
X-ray crystal spectrom'r - V		
X-ray fast pinhole camera		
X-ray spectrometer - XEUS		