Princeton Plasma Physics Laboratory

NSTX Experimental Proposal

Title: ELM Mitigation Using Resonant Magnetic Perturbations		
OP-XP-525	**Revision:**	Effective Date: *(Ref. OP-AD-97)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

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Responsible Division: Experimental Research Operations		

Chit Review Board (designated by Run Coordinator)

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

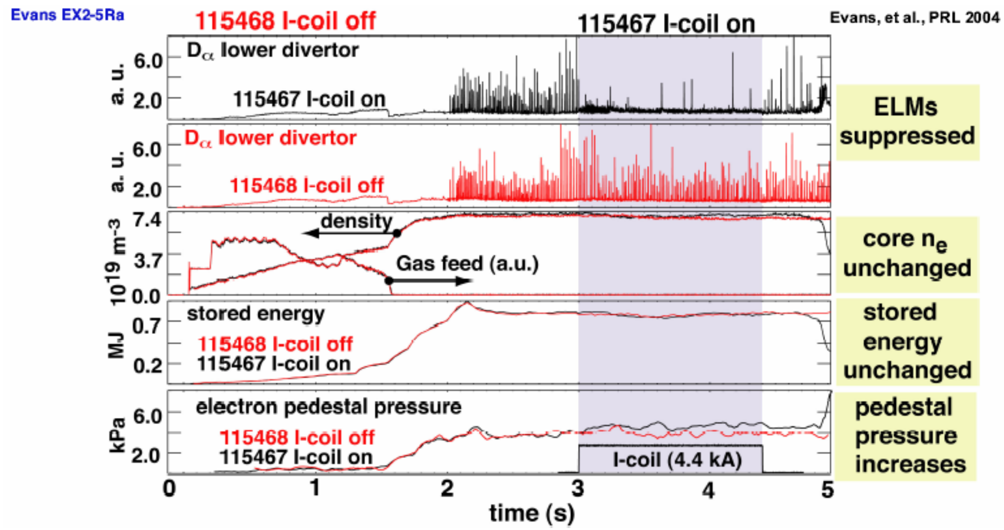
NSTX EXPERIMENTAL PROPOSAL

1. Overview of planned experiment

The objective of this experiment is to control periodic large bursts of power to PFCs due to Type I ELMs. This means replacing large, impulsive bursts of power with steady, but instantaneously small, releases of energy from edge. This will help establish a “steady-state” scenario with minimal impact on core confinement. A further objective is to disburse the escaping power flux to divertor region over an area larger than that associated with giant ELMs in order to maintain plasma purity. This will be done by applying n=1 and n=3 resonant magnetic field perturbations at the plasma edge using the set of EF/RWM compensation coils.

2. Theoretical/ empirical justification

This technique used successfully on DIII-D using both their C- and I-coils (Evans et al., 2003, 2004, 2005). While most of the DIII-D investigations used the (internal) I-coil, their early experiments used the (external) C-coil, which is obviously more related to the NSTX approach. The idea behind the approach is to use the I, C-coils to produce a stochastic boundary serving as “relief valve” for edge pressure buildup. It was found that the best ELM suppression came about when weak stochastic layer formed across most of pedestal, and that the I-coil gave finer control of edge perturbations. In fact, Type I ELMs were suppressed with I-coil (see figure below), and the discharge was left with coherent oscillations punctuated by isolated events. The energy loss at each ELM was reduced by a factor of 2 to 3, and there were no significant peaks in divertor power flux with I-coil on. The ELM behavior was found to be sensitive to toroidal phase of perturbation, which indicates importance of externally applied field perturbations relative to the intrinsic error field (something to investigate on NSTX). While ELMS were not suppressed with the C-coil, their frequency and amplitude were seen to be modified.



JET has a particular interest in the results of this experiment, as they are planning to put in ex-vessel coils for 2008 ops, and they want to determine if this is best approach (or is in-vessel needed). NSTX will provide an important data point for this decision, as NSTX will perform this experiment with a shape similar to that of JET (and ITER).

Recent use of the EF/RWM control coils on NSTX has shown an effect on ELMs in both AC and DC modes of operation. Also important is the observation of locked mode growth even at modest current levels (<1 kA, lower for n=1). The precise time that a specific current level is applied also appears to be quite important in terms of when the locked modes appear in the discharge. These locked modes will have to be avoided by operating the control coils at low current.

3. Experimental run plan

This initial experiment will be an exploratory one, to be run in a Lower Single Null configuration with κ=2 and δ=0.5. The baseline shot is 111554, which is a shot with mixed Type I and Type V ELMs. The objective will be to eliminate the Type I ELMs in favor of the more innocuous Type V ELMs. This baseline shot will be replaced with a better one (i.e., more Type I ELMs) should one be developed in this configuration during the present run.

Both n=1 and n=3 RMPs will be investigated with the node positions and current levels for each mode and node position also varied. Observations on NSTX have indicated that the plasma is very sensitive to the timing and current levels for DC n=1 and n=3 perturbations. Limits appear to be up to 1 kA for n=3 and 0.5 kA for n=1; beyond those, locked modes appear and the plasma settles into distress. Therefore, the coil current levels will be kept relative low (see shot list table on the next page). A total of 25 shots is requested (one run day). The focus will be on the applied n=3 perturbation, and flexibility will be retained to either increase or decrease the maximum current levels, depending on observations of effect on ELMs and discharge quality.

The experiment will last 1 ½ days. The first half day will be demo of the effect on a long pulse, highly shaped discharge using 116206 as a baseline shot. Two phases of n=3 will be used, and EF/RWM coil current level increments of 0.2 kA (with the coil current starting at 0.35 sec, lasting until 0.75 sec). Two baseline shots will be taken to check reproducibility of ELMs and several shots at the condition that shows an effect will also be taken to show consistency.

Additional EF corrections to compensate for intrinsic n=1 error fields will be incorporated in Day 0.5-1.5 if more information is known. The compensated n=1 error field condition would be used as a baseline for both the n=1 and n=3 scans.

Day 0-0.5

Case	Phase (arb)	EF/RWM Current
1-Baseline (116206)	0	0
A.1	0	0.2 kA
A.2	0	0.4 kA
A.3+	0	As needed in 0.2 kA increments
B.1-B.x	60	Similar to A

Day 0.5-1.5

Shot	Toroidal Mode #	Phase (deg) (arbitrary)	EF/RWM Coil Current
1 – Baseline (112503)	0	0	0
2	3	0	0.2 kA
3	3	0	0.4 kA
4	3	0	0.6 kA
5	3	0	0.8 kA
6-9	3	60	As in 2-5
10	1	0	0.3 kA
11	1	0	0.2 kA
12	1	0	0.1 kA
13-15	1	60	As in 10-12
16-18	1	120	As in 10-12
19-21	1	180	As in 10-12
22-24	1	240	As in 10-12
25-27	1	300	As in 10-12

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

No prerequisite XPs are needed.

5. Planned analysis

T. Evans to compute RMP spectra for various toroidal mode numbers/node positions for NSTX EF/RWM coil set using TRIP3D

6. Planned publication of results

Results will be presented at various conferences and published in a refereed journal when the analysis is complete.

PHYSICS OPERATIONS REQUEST

ELM Mitigation Using Resonant Magnetic Field Perturbations **OP-XP-525**

Machine conditions (specify ranges as appropriate)

I_{TF} (kA): **53 kA** Flattop start/stop (s): **0/1**

I_P (MA): **0.8-1.0 MA** Flattop start/stop (s): _____/_____

Configuration: **Double Null/ Lower Single Null**

Outer gap (m): _____, Inner gap (m): _____

Elongation κ: **1.9-2.2**, Triangularity δ: **0.5-0.7**

Z position (m): **0.00**

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

NBI - Species: **D**, Sources: **A/B/C**, Voltage (kV): **90**, Duration (s): _____

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

CHI: **Off**

Either: List previous shot numbers for setup: **116206/112503; EF/RWM coil current on from 0.35 to 0.75 s (constant with time)**

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! Reference source not found. **OP-XP-525**

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		✓	Only available by special request of T. Biewer @ MIT
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	✓		For Day 0.5-1.5
Neutral particle analyzer		✓	
Neutron Rate (2 fission, 4 scint)			
Neutron collimator			
Plasma TV	✓		
Reciprocating probe		✓	
Reflectometer - FM/CW			
Reflectometer - fixed frequency homodyne	✓		For profile information
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			