Princeton Plasma Physics Laboratory
NSTX Experimental Proposal

Title: **Effect of the active stabilization of RWMs on the background plasma**

OP-XP-931	Revision:	Effective Date: **5/12/09** *(Approval date unless otherwise stipulated)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

Responsible Author: Luis F. Delgado-Aparicio *et al.*	Date 5/12/09
ATI – ET Group Leader: S. Sabbagh	Date 5/12/09
RLM - Run Coordinator: Roger Raman	Date 5/12/09

Responsible Division: Experimental Research Operations

Chit Review Board (designated by Run Coordinator)

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL

TITLE: Effect of the active stabilization of RWMs on the background plasma

No. **OP-XP-931**

AUTHORS: **L. Delgado-Aparicio, S. A. Sabbagh, K. Tritz, D. Stutman, R. Bell, J. Berkery, M. Finkenthal, S. P. Gerhardt, B. LeBlanc, J. Levesque, J. Manickam and J-K. Park**

DATE: **05/04/2009**

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1. Overview of planned experiment

The main motivation of the present experimental proposal is to contribute to addressing the 2009 research milestone on understanding the physics of RWM stabilization and control, especially on the effects of the actively stabilized RWMs on the background plasma. The two research targets to study are, a) the role of the resonant field amplification and its kinetic response near the marginal stability and, b) the modification of the kinetic plasma profiles by the use of the (*n=3* braking and the *n=1* active feedback) external fields .

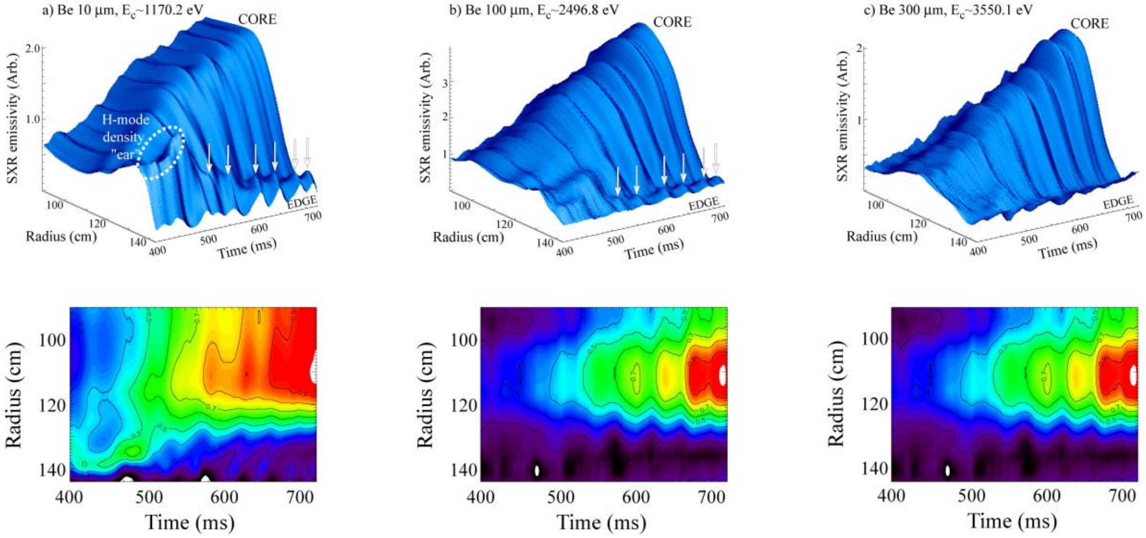


Fig. 1. ME-SXR characterization of actively stabilized RWM plasmas.

2. Theoretical/ empirical justification

A fast and compact multi-energy soft X-ray (ME-SXR) array has been used for the determination of time and space-resolved SXR emissivity in different energy ranges during active stabilization of resistive wall modes (RWM) in NSTX (see Figure 1). The insensitivity of ME-SXR to stray fields helps to discriminate between the RWM and parasitic perturbations. At high $\beta_N > \beta_N^{No-wall}$, *n=1* perturbations with a characteristic frequency of ~20-30 Hz appear in the ME-SXR emissivity profiles that have been correlated with density and temperature fluctuations in both the edge and core regions (see Figure 1). Fast T_e measurements are obtained from ratios of the emissivity profiles by modeling the slope of the continuum radiation. The amplitude of the core and mid-radius T_e modulations associated with actively-stabilized resistive RWMs is of the order of 50-100 eV (~10%). Their time history is also in good agreement with the slow evolution of the $n=1$ magnetic perturbation measured by the poloidal and radial RWM coils. The ME-SXR data shows that during RWM active stabilization there is a strong coupling between the edge and core activity. Similar observations have also been made during experimental campaigns both at DIII-D and JT-60U [e.g. a) Investigation of Resistive Wall Mode internal structure (I. N. Bogatu, APS-DPP-2006) and b) Dynamics and Stability of Resistive Wall Mode in the JT-60U High-β Plasmas (Matsunaga, 22nd IAEA-2008)]. This result suggests the presence of a stable resistive wall mode (RWM) near the natural resonant field amplification (RFA) resonance. The implications of the latter are important because we should be able to conclude whether an unstable RWM grows from the stable RFA, or indeed from another $n = 1$ mode denoting multi-mode behavior.

3. Experimental run plan

a) First part.-

The goal of the first part of this XP is to study the role of the resonant field amplification near marginal stability (see details in Figure 2). Both the $n=1$ active feedback and the $n=3$ error field correction will increase the β_n close to marginal stability on the early part of the discharges; the error filed correction and the active feedback will turn onto an $n=3$ magnetic braking and a single frequency (20-30 Hz) $n=1$ waveform at approximately t_1~600 ms. We will then scan the Pk-Pk n=1 amplitude to look for the *kinetic response* of the RFA; neon injection (as prescribed in Figure 2) will also be used to test this dependence. Total time: ½ day (maximum of 12-15 shots).

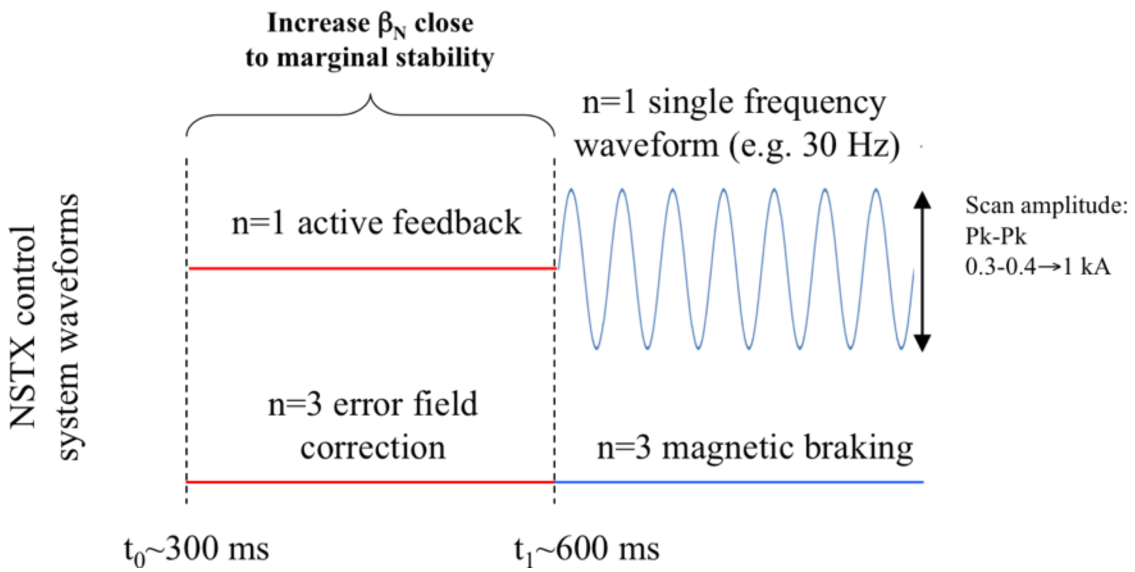
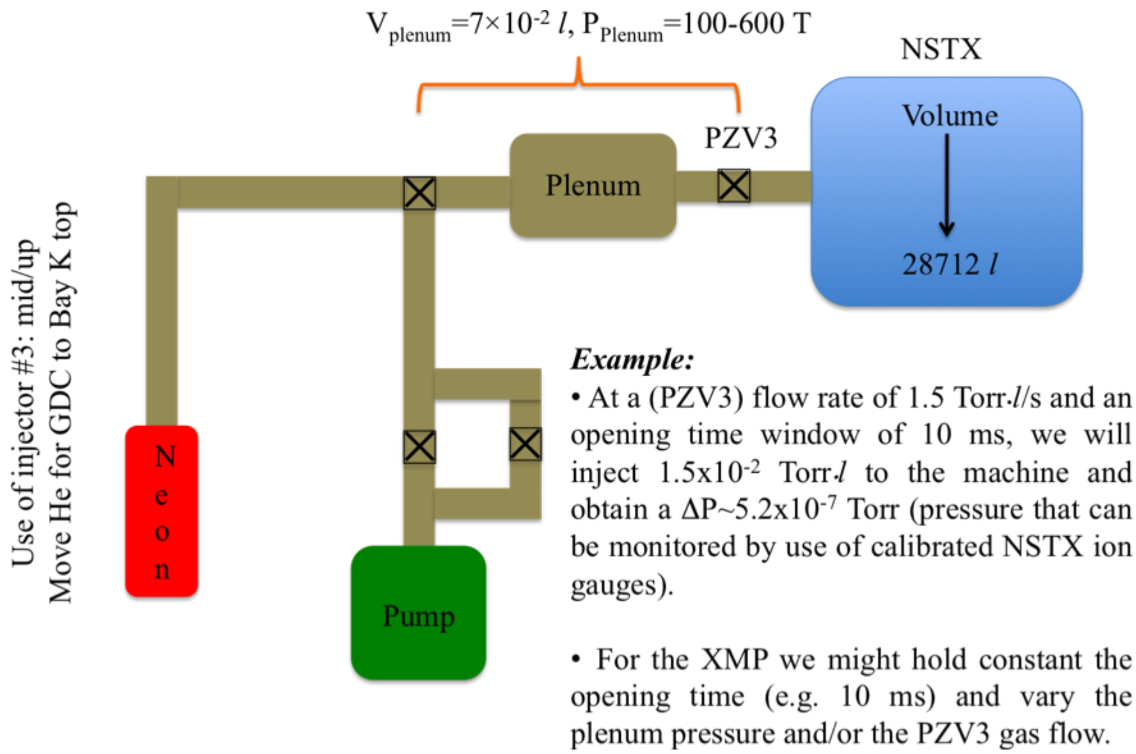


Figure 2. Waveforms for $n=1, 3$ active feedback, error field correction, magnetic braking and single frequency Pk-Pk scan.



Example:

- At a (PZV3) flow rate of 1.5 Torr·l/s and an opening time window of 10 ms, we will inject 1.5x10^{-2} Torr·l to the machine and obtain a $\Delta P \sim 5.2\text{x}10^{-7}$ Torr (pressure that can be monitored by use of calibrated NSTX ion gauges).

- For the XMP we might hold constant the opening time (e.g. 10 ms) and vary the plenum pressure and/or the PZV3 gas flow.

Fig 3.- Basic gas/pump diagram for neon tests during neon injection XMP and XP931.

A detailed plan of the shot list is as follows:

1) *Fiducial (e.g. 133078): 1-2 shots*

- I_p=0.9 MA, B_t=4.5 kG, P_{NBI}=6 MW
- $n=1$ active feedback and $n=3$ correcting phase (~-200 A) for all the shot.

2) *Add: 3 shots*

- Turn off n=1 active feedback @ ~500 ms and maintain n=3 correction (1 shot)
- Stop $n=3$ error field correction from 300ms to 400 ms (1 shot).
- Ramp up $n=3$ braking from -200 A → 700 A in the interval: 300→500 ms (1 shot)

3) *Focus on n=3 braking: 2 shots*

- Delay t_1 (the time at which n=3 breaking starts) if rotation is too low
- If beta is too high (due to Lithium) reduce NBI power

4) *AC field: 6-8 shots*

- OPTION: Consider using n=1 active feedback, but with a longer time constant of ~ 100 ms
- Look for reproducibility @ sufficiently high $\beta \sim 5.5$
- Use spreadsheet for PCS values: 20-40 Hz of $n=1$
- Change amplitude of n=1 waveform from 0.3→1.0 kA and use neon for lower and higher case!

b) Second part.-

The second part of this experimental proposal attempts to study the effects of the applied external fields (*n=3* magnetic braking + *n=1* active feedback) on the plasma profiles. As is shown in Figure 1, it appears that either the braking or the active feedback can modify the kinetic profiles at early times, possibly affecting both the dynamics associated to the H-mode density ears (R~140 cm) and the impurity accumulation during active stabilization. The edge and core carbon densities, together with the neutrons and D_α (not shown here), also show the same ~20-30 Hz *n=1* activity. Two discharges per condition (with and without *n=1, 3* external fields) will be attempted, with and without neon injection. We will inject neon at a rate of 1.5 Torr·*l*/s (or less) for a short (e.g 5-10 ms) time window within [350-400] ms (see Figure 3 for details on neon injection). The external *n=3* braking and *n=1* active stabilization fields will begin at ~450 ms like in previous discharges (e.g. 120041-44-47, 120717). A matrix of shots is indicated in Figure 4. Total time: ½ day

		n=3 magnetic braking	
n=1 active feedback		***OFF***	***ON***
	OFF	w/o Neon (2 discharges)	w/o Neon (2 discharges)
	ON	w/o Neon (2 discharges)	w/o Neon (2 discharges)

Fig 4.- Shot matrix for first part of XP931.

A detailed plan of the shot list is as follows:

1) *Fiducial (e.g. 133078): 1-2 shots*

- I_p=0.9 MA, B_t=4.5 kG, P_{NBI}=6 MW
- *n=1* active feedback and *n=3* correcting phase (~-200 A) for all the shot.

2) *No fields: 2-3 shots*

- Turn off *n=1, 3* fields and try neon

3) *Just n=1: 2-3 shots*

- Turn ON ONLY *n=1* @ 450 ms and try neon

4) *Just n=3: 2-3 shots*

- Turn ON ONLY *n=3* @ 450 ms and try neon

5) *n=1, 3 together: 2-3 shots*

- Turn both ON @ 450 ms and try neon.

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

An important prerequisite for the development of our experimental proposal is an XMP, on the neon (gas-puff) injection within the lithium deposition framework. The tangential multi-energy OSXR array will operate in its 10, 100 and 300 μm capability meanwhile the USXR horizontal arrays should image the boundary plasma using the 5 μm Be foil.

5. Planned analysis

Data analysis planned: LRDFIT, MIST, TRANSP and NCLASS. Results from PEST, DCON and VALEN will be also required.

6. Planned publication of results

Presentations at the APS, EPS and IAEA meetings together with publications in major scientific journals (e.g. PRL, Nuclear Fusion, PoP, PPCF)

PHYSICS OPERATIONS REQUEST

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(use additional sheets and attach waveform diagrams if necessary)

Describe briefly the most important plasma conditions required for the experiment:

- Reproducibility of H-modes
- MHD free period from 350-400 ms onward
- Availability of neon injection
- n=1, 3 external fields

Previous shot(s) which can be repeated:

Previous shot(s) which can be modified:

Machine conditions *(specify ranges as appropriate, strike out inapplicable cases)*

I_{TF} (kA): Flattop start/stop (s):

I_P (MA): 0.9 MA Flattop start/stop (s):

Configuration: **Limiter / DN / LSN / USN**

Equilibrium Control: **Outer gap / Isoflux** (rtEFIT)

Outer gap (m): Inner gap (m): Z position (m):

Elongation κ: Upper/lower triangularity δ:

Gas Species: Injector(s):

NBI Species: **D** Voltage (kV) **A: 90** **B: 90** **C:** 90 Duration (s):

ICRF Power (MW): Phase between straps (°): Duration (s):

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

LITERs: Off and On Total deposition rate (mg/min): **10 mg/min**

EFC coils: Off and On Configuration: **As planned (see Figure 3 and 4)**

DIAGNOSTIC CHECKLIST

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Note special diagnostic requirements in Sec. 4

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 – BEaP		
Langmuir probes – RF ant.		
Magnetics – Diamagnetism		
Magnetics – Flux loops	√	
Magnetics – Locked modes		
Magnetics – Pickup coils	√	
Magnetics – Rogowski coils	√	
Magnetics – Halo currents		
Magnetics – RWM sensors	√	
Mirnov coils – high f.	√	
Mirnov coils – poloidal array	√	
Mirnov coils – toroidal array	√	
Mirnov coils – 3-axis proto.	√	

Note special diagnostic requirements in Sec. 4

Diagnostic	**Need**	**Want**
MSE	√	
NPA – E||B 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. - H		
X-ray crystal spectrom. - V		
X-ray fast pinhole camera		
X-ray spectrometer - XEUS		√