Princeton Plasma Physics Laboratory

NSTX Experimental Proposal

Title: **Vertical Stability Physics and Performance Limits in Tokamaks with Highly Elongated Plasmas**		
OP-XP-811	Revision:	Effective Date: Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS	
Responsible Author: Egemen Kolemen	Date
ATI – ET Group Leader: David Gates	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)

1. Overview of planned experiment

Axisymmetric vertical stability control limitations for ITER is one of the major design criteria. Optimization of the ITER PF design requires information on the limits to axisymmetric stability control performance, as well as the safe margins in operation experienced in present-day devices with configurations relevant to ITER. To this aim, we propose to measure the major design parameters for the axisymmetric stability control for NSTX: maximum controllability threshold in elongation, κ_{max}, and maximum controllable displacement for κ just below threshold, ΔZ_{max}, in order to be able to compare with similar measurements on other machines and help design of ITER.

2. Theoretical/ empirical justification

The ability of the ITER vertical stabilization system to handle large and sudden vertical displacements is not settled. Vertical instability is damaging to the ITER structure and thus identify range of safe operation is very important. ΔZ_{max} is proposed as a performance metric for the power supplies of the vertical stabilization loop on ITER. In particular, the rating of the power supplies feeding the Vertical Stabilization (VS) circuit might not be adequate. ΔZ_{max} is a metric proposed on DIII-D by D. Humphreys that tries to establish the largest displacement for which the plasma is still controllable [1].

[1] D. Humphreys, et al., ITER Vertical Stability Analysis and Experience from US Tokamaks for ITER Design Review, STAC Briefing.

3. Experimental run plan

The experiment consists of two parts:

1. Measure κ_{max} – maximum controllability threshold in elongation.
    a. While keeping all the control function running, increase elongation, κ, in steps from 1.8 with 0.1 increments, holding for periods > $10\tau_g$, to determine maximum robustly controllable growth rate. We expect κ_{max} to be in the range [1.8, 2.3]. We will measure the average of the κ_{max} value and the variability of κ_{max} and measurements.
2. Measure ΔZ_{max} – maximum controllable displacement for κ just below threshold.
    a. We will run this part of the experiment with elongation below κ_{max} but the κ value as close to κ_{max} as the experiment permits. We will make sure that we operate below variability of κ_{max} not to bias or let the κ_{max} values determine the results.
    b. Freeze coil commands to disable vertical control for a period to allow VDE (Vertical displacement event).

c. Let the plasma drift for a specific period starting with 10 ms for the first experiment.

d. We will restore the coil control command.

e. In order to avoid unwanted kick from the controller when it is restored, the Z integral term and the derivative term in the shape control will be set to zero throughout the experiment (Only P; no I, D). To assure that the use of full control power, a very high proportional term, P, will be used in the control system.

f. Repeat the experiment with increased drift periods. The drift period will be increased in 20 ms increments, i.e. [10, 30, 50, 70, 90]. We expect that drift periods above 90 ms will not be needed for this experiment.

g. Determine maximum controllable displacement for robust operation.

h. Repeat the experiment two, three times to get statistically sound data.

3. If time permits, we will repeat the experiment to measure ΔZ_{max} for different κ values.

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

Physical operating conditions for the experiment will be similar to the previously tested 112709 and 112711 shots. Note that these are nonrtEFIT shots from 2004 when the old 48-turn PF1A coils were in place. The PF1A currents will be adjusted to More specifically, we will use:

a. Helium to keep the density constant and thus enable reproducible results.

b. Ohmic discharge.

c. $I_P = 600$ kA.

d. $B_T \sim 0.45$T.

e. $l_i \sim 1.5$.

5. Planned analysis

Currently, PID controller is used for the vertical mode control. We are developing a model based optimal control for the vertical stability by employing low-dimensional models of the axisymmetric vertical mode of instability using the simplified models of Hofmann as a starting point. We will use these models to design feedback laws using modern control techniques, such as optimal Linear Quadratic Gaussian (LQG) control. The experimental results will help us validate and tune system models that will be used for the control algorithm.

6. Planned publication of results

Nondimensional parameter $\Delta Z_{max}/a$ will be used to compare different fusion experiment machines. κ_{max} and ΔZ_{max} measurement for NSTX will be used to validate and improve the plasma models. The model predictions will be compared with multi-machine experimental results to establish model accuracies. These models will be applied to ITER configuration, to validate design predictions for ITER. The results will be published at Nuclear Fusion.

PHYSICS OPERATIONS REQUEST

TITLE: **Vertical Stability Physics and Performance Limits in Tokamaks with Highly Elongated Plasmas** No. **OP-XP-811**

AUTHORS: **Egemen Kolemen** DATE: **2/21/08**

Machine conditions (specify ranges as appropriate)

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

I_P (MA): **600** Flattop start/stop (s): **.12 - .5**

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

Outer gap (m): **4 cm** Inner gap (m): **4 cm**

Elongation κ: **1.8-2.3** Upper/lower triangularity δ: **0.4**

Z position (m):

Gas Species: **Helium** Injector(s):

NBI Species: **D** Sources: None Voltage (kV): N/A Duration (s): N/A

ICRF Power (MW): None Phasing: N/A Duration (s): N/A

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

LITER: Off

Shot numbers for setup: **112709, 112711**

Note: these shots were non rtEFIT shots run in 2004 with the old 48-turn PF1a coils. The PF1a currents will be adjusted to restore the approximate amp-turns using the present coils. PF2 currents may also need adjustment

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 - BEaP		
Langmuir probes – RF ant.		
Magnetics – Diamagnetism	✔	
Magnetics - Flux loops	✔	
Magnetics - Locked modes	✔	
Magnetics - Pickup coils	✔	
Magnetics - Rogowski coils	✔	
Magnetics – Halo currents	✔	

Diagnostic	Need	Want
Magnetics - RWM sensors	✔	
Mirnov coils – high f.	✔	
Mirnov coils – poloidal array	✔	
Mirnov coils – toroidal array	✔	
Mirnov coils – 3-axis proto.		
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		