Princeton Plasma Physics Laboratory
NSTX Experimental Proposal

Title: **Improvements to the NSTX vertical control system**		
OP-XP-1106	Revision:	Effective Date: *(Approval date unless otherwise stipulated)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

Responsible Author: S.P. Gerhardt (& E. Kolemen)	Date
ATI – ET Group Leader: S.P. Gerhardt and M.G. Bell	Date
RLM - Run Coordinator: S. Sabbagh	Date
Responsible Division: Experimental Research Operations	

RESTRICTIONS or MINOR MODIFICATIONS
(Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL

TITLE: **Vertical Control Improvements** No. **OP-XP-1106**
AUTHORS: **S.P. Gerhardt, E. Kolemen** DATE:

---

1. Overview of planned experiment

This experiment will consist of three parts:
1: Implementing the improved realtime observer for $d(I_P Z_P)/dt$.
2: Using that observer to optimize the derivative feedback term using the PF-3 coils as the actuator.
3: Using that observer to optimize the derivative feedback term using the RWM coils as the actuator.

2. Theoretical/ empirical justification

The NSTX research program will spend some time in FY-11 & 12 studying the properties of equilibria with higher aspect ratio and elongation than has been typical in the past. A first look at these equilibria in 2010 demonstrated that they have reduced vertical stability margin compared to the typical NSTX "fiducial" plasma. Indeed, the maximum value of internal inductance for vertically stable operations at A=1.75 was l_i~0.6. In order to make these plasmas more stable for a range of users and to prepare for operation in NSTX-Upgrade, this XP will attempt to make improvements to the NSTX vertical control system.

3. Experimental run plan

Notes

N1: In the following, "freeze vertical control" refers to setting the derivative gain terms in the system category to zero, and using the relay controller to freeze the PF-3 voltages from the ISOFLUX category.

N2: It is assumed below that XMP-77 had been completed, and that the software for the new vertical position controller is fully qualified.

3.0 Initial testing of the multi-loop VDE observer.

The code calculating $d(I_P Z_P)/dt$ in realtime is always running and archiving its result (in "\PCS.SY:SYS_DZIPDT"), regardless if it is being used for the vertical controller. This archived output will be compared to off-line calculations before this XP is run, using the α parameters to be utilized in the XP.

3.1 Implementation of multi-loop VDE observer.

The purpose of this step is to include additional voltage loops in the vertical position observer.

3.1.1 Load the reference shot, using the old n=0 controller. This should be the highest aspect ratio and elongation that the device can support at the time of the XP (given machine conditions).

For instance, load the morning fiducial discharge, reduce I_P to 800 kA and increase the PF-1A coil currents to 16-20 kA. The discharge should not have a non-VDE induced disruptions for at least 0.8 seconds. Likely utilize 4 MW of input power.

Shot(s) ______ _______ _______ *(up to 3 shots)*

3.1.2 Load the optimized $d(I_P Z_P)/dt$ parameters and turn on the new VDE controller. In this case, use parameters that have been optimized (off-line) for detecting the motion of high-kappa and aspect ratio plasmas. Repeat the discharge.

Shot(s) ___________ ______________ *(up to 2 shots)*

Weight parameter α	Value
α_{PPP2}	
α_{PPP4}	
α_{SPP1}	
α_{SPP4}	
α_{OBD3}	
α_{Evv2}	
α_{PF1A2}	
α_{PF1A4}	
α_{OH4}	

3.1.3. Further increase the aspect ratio and elongation until n=0 control is lost.

Shot(s) ___________ ______________ ________ *(up to 3 shots)*

3.2 Optimization of the n=0 derivative gain using the PF-3 coils.

The purpose of this step is to optimize the n=0 control derivative gain in the system category.

The previous section should have established a reference condition at the stability limit for the vertical controller. Do a scan of the derivative gain term, from approximately 10 to 80. *(up to 6 shots)*

Derivative Gain	Shots
10	
20	
40	
80	

3.3 Contingency. Repeat derivative gain scan with different loop weighting parameters

The purpose of this step is to a second set of flux loop weights in the $d(I_P Z_P)/dt$ observer. Those weights above were optimized for the detection of motion in high-κ discharges. Examples of additional optimization methods include optimizing over a wider range of shapes, or to spread the weights more evenly among the many loops. *(up to 6 shots)*

Weight parameter α	Value
α_{PPP2}	
α_{PPP4}	
α_{SPP1}	
α_{SPP4}	
α_{OBD3}	
α_{Evv2}	
α_{PF1A2}	
α_{PF1A4}	
α_{OH4}	

Derivative Gain	Shots
10	
20	
40	
80	

3.4 Development of vertical control with the RWM coils

The purpose of this step is to test the use of the RWM coils for n=0 control

3.3.1 Select and run target shot. This can be either a discharge from the previous sections, or a standard NSTX morning fiducial discharge.

Shots __________ _________ __________ (*up to 3 shots*)

3.3.2 Freeze vertical control at some time during the flat-top and observe plasma drift. Best time for freeze is likely around 450 msec. If no drift is observed, increase the PF-1A coil current to increase the aspect ratio. Goal is to have a moderately unstable configuration.

Time of freeze: _________

Shots: _________ ___________ (*up to 2 shots*)

3.3.3 Repeat with 2.5 kA pk-pk, 20 Hz square wave from the RWM coils, in n=0 configuration.

Shots: _________ __________ (*up to 2 shots*)

If n=0 fields were observed to have an effect on the plasma vertical position evolution, then continue with next steps. Also note for clarity which sign of n=0 current resulted in upward (or downward) plasma motion.

3.3.4 Repeat with the RWM n=0 control turned on at the same time as control is frozen. Do a scan of the derivative gain (likely from ~50 to ~500) Use the previously identified best $d(I_P Z_P)/dt$ observer configuration.

Shot for $d(I_P Z_P)/dt$ observer (in system category): ________

Shot	Derivative Gain (RWM)	Time of RWM n=0 Control

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

Need at least 4 MW of power, and this must include source A for MSE measurements.

PF-2 coils are not necessary. All of these cases will be diverted with PF-1A only.

It is required that XMP-77 ran before this XP.

5. Planned analysis

High time resolution EFITs and LRDFITs to understand the vertical stability issues. Data at high aspect ratio will also contribute to the development of "NSTX-U like" shapes.

6. Planned publication of results

They will be presented at the 2011 APS-DPP meeting and the 2012 IAEA FEC meeting. They will be published in papers associated with those two meetings.

These results will be included in the report for the relevant milestone (R11-2).

PHYSICS OPERATIONS REQUEST

TITLE: **Vertical Control Improvements** No. **OP-XP-1106**
AUTHORS: **S.P. Gerhardt, E. Kolemen** DATE:

Brief description of the most important operational plasma conditions required:

We will need the standard morning fiducials (900 kA, 4-6 MW) to be lasting with ~0.7 sec of flat top.

SPAs configured for 6 subunit, 6 coil operation.

PCS upgrades for VDE control (in “psrtc_request” and “tmf_master.h”) need to be in the live version of the code.

Previous shot(s) which can be repeated: Will start from a 900 kA fiducial.

Previous shot(s) which can be modified:

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

I_{TF} (kA): **4.5 T** Flattop start/stop (s):

I_P (MA): **0.7-0.9** Flattop start/stop (s):

Configuration: **close to DN, maybe slightly biased down**

Equilibrium Control: **Isoflux** (rtEFIT)

Outer gap (m): **0.1-0.15** Inner gap (m): will be scanned Z position (m): ~0

Elongation: **2.3-3.0** Triangularity (U/L): **0.65-0.85** OSP radius (m): **PF-1A diverted**

Gas Species: D_2 Injector(s): Standard LFS + HFS for H-mode access, may also want some divertor gas injections as a way of increasing l_i

NBI Species: **D** Voltage (kV) **A:** 90 **B:** 70-90 **C:** 70-90 Duration (s): up to 1.3 sec

ICRF Power (MW): **0** Phase between straps (°): Duration (s):

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

LITERs: On Total deposition rate (mg/min): in the vicinity of 25 mg/min

LLD: Off Temperature (°C):

EFC coils: On Configuration: **6 subunits mapping to 6 RWM coils.**

DIAGNOSTIC CHECKLIST

TITLE: **Vertical Control Improvements** No. **OP-XP-1106**

AUTHORS: **S.P. Gerhardt, et al.** DATE:

Note special diagnostic requirements in Sec. 4

Diagnostic	**Need**	**Want**
Beam Emission Spectroscopy		**X**
Bolometer – divertor		
Bolometer – midplane array	**X**	
CHERS – poloidal		**X**
CHERS – toroidal	**X**	
Divertor L-alpha array		**X**
Divertor visible camera		**X**
Dust detector		
Edge deposition monitors		
Edge neutral density diag.		**X**
Edge pressure gauges		**X**
Edge rotation diagnostic		**X**
Fast cameras – divertor/LLD		**X**
Fast ion D_alpha - poloidal		**X**
Fast ion D_alpha - toroidal		**X**
Fast lost ion probes - IFLIP		**X**
Fast lost ion probes - SFLIP		**X**
Filterscopes	**X**	
FIReTIP		**X**
Gas puff imaging – divertor		**X**
Gas puff imaging – midplane		**X**
Hα camera - 1D		**X**
High-k scattering		**X**
Infrared camera – standard		**X**
Infrared camera – 2-color		**X**
Infrared camera – wide-angle		**X**
Interferometer - 1 mm		**X**
Langmuir probes – divertor		**X**
Langmuir probes – LLD		**X**
Langmuir probes – bias tile		**X**
Langmuir probes – RF ant.		**X**
Magnetics – B coils	√	
Magnetics – Diamagnetism		**X**
Magnetics – Flux loops	√	
Magnetics – Locked modes		**X**
Magnetics – Rogowski coils	√	
Magnetics – Halo currents		**X**
Magnetics – RWM sensors	**X**	

Note special diagnostic requirements in Sec. 4

Diagnostic	**Need**	**Want**
MAPP		
Mirnov coils – high f.		**X**
Mirnov coils – poloidal array		
Mirnov coils – toroidal array		**X**
Mirnov coils – 3-axis proto.		
MSE-CIF	**X**	
MSE-LIF		**X**
NPA – E‖B scanning		
NPA – solid state		
Neutron detectors	**X**	
Plasma TV		**X**
Reflectometer – 65GHz		
Reflectometer – correlation		
Reflectometer – FM/CW		
Reflectometer – fixed f		
Reflectometer – SOL		
RF edge probes		
Spectrometer – divertor		**X**
Spectrometer – SPRED		**X**
Spectrometer – VIPS		**X**
Spectrometer – LOWEUS		**X**
Spectrometer – XEUS		**X**
SWIFT – 2D flow		
TAE Antenna		
Thomson scattering	**X**	
USXR – pol. arrays		**X**
USXR – multi-energy		**X**
USXR – TG spectr.		**X**
Visible bremsstrahlung det.		**X**
X-ray crystal spectrom. - H		**X**
X-ray crystal spectrom. - V		**X**
X-ray tang. pinhole camera		**X**