Princeton Plasma Physics Laboratory **NSTX Experimental Proposal**		
Title: **Investigation of "X-point limiter" plasmas**		
OP-XP-826	Revision: **0**	Effective Date: *(Approval date unless otherwise stipulated)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS	
Responsible Author:	Date
ATI – ET Group Leader:	Date
RLM - Run Coordinator:	Date
Responsible Division: Experimental Research Operations	

Chit Review Board (designated by Run Coordinator)

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL

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AUTHORS: **M. Bell, R. Maingi, K-C. Lee** DATE: **Mar 18, 2008**

1. Overview of planned experiment

This experiment will investigate plasma "X-point limiter" plasma configurations where the dominant lower X-point is brought very close to, or possibly beyond, the outer divertor plate. Access to the H-mode, energy confinement and the heat flux onto the divertor plate will be assessed. The initial experiment is planned to be run before lithium coating. If successful, a second investigation will be carried out with lithium evaporated onto the lower divertor.

2. Theoretical/ empirical justification

Coping with both steady-state and transient heat loads is a critical issue for ITER and any future even larger tokamak because the ratio of the plasma volume to plasma contact area increases with size. Conventional poloidal divertors are usually incorporated in tokamaks because they are associated with reliable access to the improved confinement of the H-mode. However, divertors in which the X-point is separated from the divertor target tend to exacerbate the power handling problem by increasing the poloidal field where the scrape off contacts the target, so extreme tilting of the plate and/or sweeping of the strike point are required in large tokamaks.

The H-mode can be obtained, however, without an X-point defining the boundary. A good example comes from JET in its early investigation of H-modes in the 1980s. It was discovered, after the fact, that many of its H-mode discharges that had been thought to be diverted were actually limited by armor at the top of the vacuum vessel with the X-point just outside the last closed flux surface. Some of these large-volume discharges had produced the highest energy confinement times achieved in JET. Another example is the H-mode which was regularly produced by ramping down the plasma current in TFTR "supershots" which were limited by a nearly conformal surface on the inboard side. The high poloidal beta and high internal inductance produced by this technique reduced the poloidal field at the inboard midplane producing an X-point just beyond the limiter surface. In addition to triggering an H-mode transition, this configuration spread the heat flowing through the scrape-off layer over a large area on the limiter surface. The critical factor for the H-mode may not be an X-point defining the boundary but simply a region of high magnetic shear near the plasma boundary.

In his Alfvén prize address to the EPS Conference in Rome (2006), P-H. Rébut suggested that the "X-point limiter", similar to the early JET configuration, would a better approach to managing the plasma-material interface in ITER than the present divertor because flux expansion approaching the poloidal field null and the nearly tangential contact of field lines with the surface would spread the heat load. An assessment of this configuration in NSTX would be relevant both to ITER and ST development.

This experiment will also provide data to test the theory [K.C. Lee, *Phys. Plasmas,* **13**, 062505 (2006)] that the radial gradient in the edge neutral density is a critical parameter for triggering the H-mode so that reducing the distance of the X-point to the divertor target should reduce the H-mode power threshold.

3. Experimental run plan

1. Rerun shot 123139 (1.0MA) and compare H-mode access and overall performance. *(1 shot)*
2. If the flattop is too short and limited by OH flux, decrease the plasma current to 0.9MA *(1)*
3. Measure the approximate H-mode power threshold by a binary power search on successive shots, using PWM of source B for fractional power steps: 2 sources, 1 source, 1.5 or 0.5 sources. *(3)*
4. Reduce PF1AL, PF1AU currents to zero, and set the ratio of PF2L to plasma current to 4kA/MA and PF2U to 2.5kA/MA. Run a shot with 2 NB sources. If necessary adjust outer boundary control parameters. Assess need for small programmed PF1A currents to compensate for the time-varying OH leakage field. *(3)*
5. Reduce PF2L current control ratio to 3.5kA/MA and repeat step 3 assessments. *(3)*
6. Decide whether to lower PF2L current control ratio further to 3kA/MA depending on equilibrium shape achieved and plasma performance. *(3 additional shots possible)*
7. At lowest X-point achieved, assess whether conditioning of the new contact point is occurring *(3)*
8. When conditions stabilize, measure the H-mode power threshold by a binary power search on successive shots, as at step 2 but with at least one additional iterative step. *(4)*
9. If the threshold is substantially different, return to an intermediate X-point location and repeat the power theshold search. *(4)*
10. Return to the original shape at step 2 and reconfirm the power threshold. *(2)*

Total shots: 24 – 27

The extremes of the scan may be repeated after lithium conditioning is routinely available.

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

1. The reference shot from 2007 does use rtEFIT and this is the preferred method of control.
2. The first phase of this experiment should precede use of lithium conditioning, either with LITER or the proposed lithium powder injection.
3. Modulation of NB source B or C is needed to assess the H-mode power threshold.
4. Reliable H-mode operation in standard NB-heated fiducial shots is a prerequisite.

5. Planned analysis

Data will be obtained for full transport analysis. The data will also be analyzed for the assessing the effect of the edge neutral density on the H-mode transition.

6. Planned publication of results

First reports will be made at the APS meeting in November 2008. A journal publication will be prepared after the initial conference presentaitons.

PHYSICS OPERATIONS REQUEST

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Machine conditions (specify ranges as appropriate)

I_{TF} (kA): **-53** Flattop start/stop (s): **-0.025 / 1.0**

I_P (MA): **1.0** Flattop start/stop (s): **0.2 / 0.8**

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

Outer gap (m): **0.1** Inner gap (m): **0.05**

Elongation κ: **2.3** Upper/lower triangularity δ: **~0.7 – ~0**

Z position (m): **~0**

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

NBI Species: **D** Sources: **ABC** Voltage (kV): **90** Duration (s): **1.0**

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

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

LITER: Off initially; if successful, experiment may be continued with LITER

Shot numbers for setup: **Start with 123139, then proceed to lower PF1A and increase PF2 currents according to prescription in Sec. 3.**

An alternative starting shot is 125272 (0.8MA, non-rtEFIT) or 127050

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 – 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. - H		
X-ray crystal spectrom. - V		
X-ray fast pinhole camera		
X-ray spectrometer - XEUS		√