**Princeton Plasma Physics Laboratory**

# NSTX Experimental Proposal

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| **Title:** | **Hiroshima fast camera measurements of divertor X-point and inner midplane fluctuations & ELMs** | |
| **XP-???** | **Revision:** | Effective Date: *(Ref. OP-AD-97)*<br>Expiration Date: *(2 yrs. unless otherwise stipulated)* |

## PROPOSAL APPROVALS

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|---|---|
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| **ATI – ET Group Leader: Henry Kugel** | Date |
| **RLM - Run Coordinator: Stan Kaye** | 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

The goal of the proposed experiment is to image the fluctuations near the X-point and inner midplane regions with the fast camera(s) loaned to NSTX by Hiroshima University. This data should give new information on the structure of ELMs and on the turbulence level at the high-field region near the inner midplane. Of course, other edge turbulence diagnostics will also be used as much as possible during this XP.

The present Hiroshima Photron camera acquires images at up to 40,500 frames/sec continuously during a shot, while the new Photron camera (which can be borrowed for the period July 19-31) can acquire images at up to 100,000 frames continuously. For this experiment, the present camera will view the X-point region and the new camera will simultaneously view the inner midplane region. A deuterium gas puff can be used in both fields of view to increase the local D$\alpha$ light seen by these cameras (i.e. a lower dome puff and the inner wall/CS/ gas puff).

The experiment will consist of B=3.0 kG, I=800 kA DND discharges similar to 113745. An H-mode transition is expected at ≈ 180-200 msec and ELMs are expected from ≈200-300 msec.

## 2. Theoretical/ empirical justification

This experiment will produce high resolution images of the structure of edge fluctuations in the divertor and the inner midplane regions of NSTX. Although images have already been obtained of both regions by "piggy-backing" on other experiments during this run, these images are usually too dim at the highest framing rated due to the lack of a local gas puff in the regions of interest. The main justification for this dedicated XP is to be able to control the gas puffs at the lower dome (for the X-point region) and the inner wall (for the inner midplane region), so the optimized images can be obtained. A secondary justification is to be able to control the inner wall gap for optimum imaging of inner wall fluctuations, and the X-point and strike-point positions for optimal imaging of the X-point region.

It was found that ELMs was going up near the center stack region along the field line at DND plasma (#113650, $I_p$=800 kA, $B_t$=0.35 T) on 6 July 2004 (XP-402) by fast camera. This feature is new, usually ELMs is going down to the (inside) striking point at LSN plasmas. Therefore, we have to take a look for this ELM (Type I, II or Type VI?), and if possible we would like to inquire that the inner wall gas puff affects the behavior of this ELM. From lower divertor filterscopes and other diagnostics, these appear to be rather small Type I ELMs or possibly Type II ELMs, but the vertical upward movement on the high-field side (indeed any strong perturbation at all) was unexpected. One goal is to compare these ELMs with normal type I ELMs in lower single-null to see if they are completely different or just the high-field side ELM component in a balanced double-null.

There is so far almost no high speed imaging of these regions in tokamaks. This experiment will allow optimum exploration of the state of these edge fluctuations in NSTX. There will no doubt be considerable interest in these results both from the experimental and theoretical edge physics communities.

## 3. Experimental run plan

This experiment can be done at B=3 kG at a current of ≈800 kA. Parameters for a baseline or template shot are listed below.

Table 1: Main parameters for fast imaging experiment at B=3.0 kG

| Template | #113745 |
|---|---|
| Ip (kA) | 800 |
| Bt (kG) | 3.0 |
| NBI (MW) | 4.1 |
| Inner gap | 2 cm |
| Outer gap | 5 cm |
| L-H (msec) | 190±10 |

### Shot Plan

(1) Repeat shot #113745 and take images with both Photron cameras.

(2) Vary inner wall gas puff strength for optimal images of ELMs and edge turbulence.

(3) Vary inner gap for optimal images of ELMs and edge turbulence.

(4) Replace center stack midplane fueling with center stack shoulder fueling@700 torr, and add small center stack gas puff to highlight midplane region if needed.

(5) Add lower dome gas puff strength for optimal images of ELMs and edge turbulence.

Time permitting:

(6) Identify/develop a LSN discharge with comparable lower divertor shape, timing and with Type I ELMs to contrast with these DND ELMs.

(7) Vary X-Point location for optimal imaging in DND and in LSN

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

For B=3.0 kG, same NBI as for 113745 (no RF, CHI)

## 5. Planned analysis

If the measurement is successful, ELM speed along the field line near the center stack will be analyzed, and the birth location of ELM will be estimated. Also, the color image will be made into MPEG movies and shown at next NSTX Physics. If the inner wall gas puff affects ELMs behavior, they probably will be visible by eye.

The image data will be analyzed by standard statistical techniques as time-dependent Fourier analysis and correlation function. This will provide a gross characterization of the edge turbulence structure, e.g. frequency spectra, correlation lengths.

At present we have no general statistical method that can analyze the 2-D structure of the ELM, which will most likely occupy only about 10-20 frames of fast camera data. However, the more precise frequency analysis might be provided by MEM (maximum entropy method). Also, we will consult with experts once we have the data.

## 6. Planned publication of results

Various conferences, and if a comparison with type I ELMs can be obtained, in a refereed journal article.

# PHYSICS OPERATIONS REQUEST

**For B=3.0 kG: use shot # 113745 as template for L-H transition discharge.**

Machine conditions (specify ranges as appropriate)

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

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

Configuration: **Double Null**

Outer gap (m): _____, Inner gap (m): **0**

Elongation κ: _____, Triangularity δ: _____

Z position (m): **0.00**

Gas Species: **D** Injector: **Midplane / Inner wall / Lower Dome**

NBI - Species: D, Sources: A/B/C, Voltage (kV): 80/60/80, Duration (s):BU/0.75/0.01-0.1

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

CHI: Off

*Either:* List previous shot numbers for setup: for B=3.0 kG, use #113745

*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

## XP-454

| Diagnostic | Need | Desire | Instructions |
|---|---|---|---|
| Bolometer – tangential array | | X | |
| Bolometer array - divertor | | | |
| CHERS | | X | |
| Divertor fast camera | | X | |
| Dust detector | | | |
| EBW radiometers | | | |
| Edge deposition monitor | | | |
| Edge pressure gauges | | | |
| Edge rotation spectroscopy | | X | |
| Fast lost ion probes - IFLIP | | | |
| Fast lost ion probes - SFLIP | | | |
| Filtered 1D cameras | | X | |
| Filterscopes | X | | |
| FIReTIP | | X | |
| Gas puff imaging | | X | |
| Infrared cameras | | | |
| Interferometer - 1 mm | | X | |
| Langmuir probe array | | X | |
| Magnetics - Diamagnetism | X | | |
| Magnetics - Flux loops | X | | |
| Magnetics - Locked modes | X | | |
| Magnetics - Pickup coils | X | | |
| Magnetics - Rogowski coils | X | | |
| Magnetics - RWM sensors | X | | |
| Mirnov coils – high frequency | X | | |
| Mirnov coils – poloidal array | X | | |
| Mirnov coils – toroidal array | X | | |
| MSE | | X | |
| Neutral particle analyzer | | X | |
| Neutron measurements | | | |
| Plasma TV | | X | |
| Reciprocating probe | | X | |
| Reflectometer – core | X | X | |
| Reflectometer - SOL | | X | |
| RF antenna camera | | X | |
| RF antenna probe | | | |
| SPRED | | X | |
| Thomson scattering | X | | |
| Ultrasoft X-ray arrays | | X | |
| Visible bremsstrahlung det. | X | | |

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|---|---|---|---|
| Visible spectrometers (VIPS) | | | |
| X-ray crystal spectrometer - H | | | |
| X-ray crystal spectrometer - V | | | |
| X-ray PIXCS (GEM) camera | | | |
| X-ray pinhole camera | | | |
| X-ray TG spectrometer | | | |