Princeton Plasma Physics Laboratory

NSTX Experimental Proposal

Title: Type I ELM heat pulse propagation		
OP-XP-539	**Revision: 1.0**	Effective Date: *(Ref. OP-AD-97)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

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Chit Review Board (designated by Run Coordinator)

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL

Type I ELM heat pulse propagation OP-XP-539

1. Overview of planned experiment

This XP is an investigation of the Type I ELM and corresponding T_e perturbation which is exhibited as a cold pulse that can propagate to the core of the plasma on a time scale of a few 100μs. One goal of this experiment is to distinguish between the edge localized effect of the fast timescale MHD perturbation, and the fast thermal transport which is responsible for the global decline of the electron temperature profile. We plan to change the thermal electron transport by scaling the plasma current and measure the effect this has on the propagation of the electron temperature perturbation. Finally, we plan to probe the response of the electron temperature profile to lithium pellet injection in the same plasma discharges.

2. Theoretical/ empirical justification

Type I ELM activity on NSTX can have a large effect on the electron temperature profile and the plasma total stored energy (ΔW_{tot} ~ - 10-15%). Much of the decrease in T_e and W_{tot} occurs over timescales (few 100μs – few ms) that are longer than that of the ELM perturbation (<50μs). The edge localized perturbation apparently triggers a cold pulse with a front that propagates to the core of the plasma in a few 100μs. Furthermore, T_e and W_{tot} continue to evolve over a period of a few ms. This XP is an attempt to separate and identify these different perturbative effects.

Because the stored energy loss appears primarily due to electron thermal losses, this XP will attempt to modify the electron thermal transport in equilibrium and measure how this affects the ELM induced perturbation. Scaling of energy confinement on NSTX shows a strong dependence on the plasma current ($I_p^{0.98}$). Also, TRANSP power balance analysis predicts that electron thermal transport is the dominant heat loss mechanism for NSTX in H-mode plasmas. Thus, electron thermal transport should scale with I_p.

Recent lithium pellet injections into H-mode plasmas have demonstrated a response quite similar to that of the ELM perturbation. The electron density remains largely unaffected while the electron temperature, as measured by Thomson scattering, shows a global decrease across the plasma profile of ~10-20%. Also, the timescale of the evolution of the electron temperature profile appears to follow that of the Type I ELM phenomena, which is consistent with an edge perturbation that initiates a propagating cold front. This striking similarity allows the ability to probe the electron transport of a plasma discharge with both an ELM and pellet edge perturbation in an attempt to measure and isolate the edge perturbation effects from the subsequent transport effects.

3. Experimental run plan

The first shot will be a duplication of 117410, but with 0.9MA and 5MW P_{NBI}

0.9MA, 4.5kG, LSN, NB 5MW	1 shot

This shot should exhibit regularly space large Type I ELM behavior, and will be used to determine an appropriate time for LPI, late in the ELMy period. The shot will be repeated with LPI, and all subsequent shots will have LPI.

0.9MA, 4.5kG, LSN, NB 5MW + LPI	1 shot

If the initial choice of pellet shows no perturbation, the mass of the pellet will be increased and the shot will be repeated:

0.9MA, 4.5kG, LSN, NB 5MW + LPI	1 shot (contingency)

Now, begin the Ip scan at fixed TF

1.1MA, 4.5kG, LSN, NB 5MW + LPI	2 shots

If higher current is problematic lower to 1MA

1.0MA, 4.5kG, LSN, NB 5MW + LPI	2 shots (contingency)

Finish coarse scan

0.7MA, 4.5kG, LSN, NB 5MW + LPI	2 shots
Total shots:	6 shots + 3 contingency

Next, attempt a scan in P_{NBI} at fixed I_p

0.9MA, 4.5kG, LSN, NB 4MW + LPI	2 shots
0.9MA, 4.5kG, LSN, NB 6MW + LPI	2 shots
Total shots:	10 shots + 3 contingency

If time is available, and the data shows a strong effect of the current scan, fill in the coarse current scan with intermediate points for a fine I_p scan.

0.8MA, 4.5kG, LSN, NB 5MW + LPI	2 shots
1.0MA, 4.5kG, LSN, NB 5MW + LPI	2 shots (overlaps with 2 contingency shots)
Total shots:	14 shots + 1 contingency

If time becomes available later in the run during high field operation, it would be interesting to extend the current scan at high field:

1.1MA, 5.0kG, LSN, NB 5MW + LPI	2 shots
1.2MA, 5.5kG, LSN, NB 5MW + LPI	2 shots

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

The base discharge will be a replication of shot 117410, LSN, NB 5MW, which has large Type I ELMs that exhibit a substantial effect on the electron temperature profile. This shot has a large outer gap (~10cm) which is necessary to optimize the position of the boundary with respect to the high resolution edge Thomson channels.

The neutral beams will operate at 4MW, 5MW, and 6MW, with this configuration:

4MW: A @ 90kV, B @ 90kV

5MW: A @ 90kV, B @ 80kV, C @ 80kV

6MW: A @ 90kV, B @ 90kV, C @ 90kV

5. Planned analysis

A primary tool will be multi-color X-ray analysis necessary to calculate fast evolution of the electron temperature profile, including the magnitude and propagation velocity of the induced cold pulse. Profile analysis may require fast EFIT reconstruction (0.1-0.3ms time resolution) to account for any plasma shape change during the perturbation. TRANSP analysis will be needed to calculate the impact of the current scan on the equilibrium electron thermal confinement. The critical gradient model can be applied to both the ELM and pellet induced perturbations for calculation of the perturbed electron transport coefficients. These coefficients will then be related to the equilibrium transport coefficients.

If diagnostic coverage permits, stability calculations will be used to estimate the magnitude and depth of the ELM perturbation to measure the correlation with the reduction in the electron temperature profile.

6. Planned publication of results

The results from this XP will be presented at the APS meeting in Denver, CO. Results of significance will be considered for publication in the appropriate journal.

PHYSICS OPERATIONS REQUEST

Machine conditions (specify ranges as appropriate)

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

I_P (MA): **0.7-1.1MA** Flattop start/stop (s): _____/_____

Configuration: **LSN**

Outer gap (m): **0.1**, Inner gap (m): _____

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): **90kV**, Duration (s): _____

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

CHI: **On / Off**

Either: List previous shot numbers for setup: 117410

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

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Diagnostic	Need	Desire	Instructions
Bolometer - tangential array		✓	
Bolometer array - divertor		✓	
CHERS	✓		
Divertor fast camera		✓	
Dust detector			
EBW radiometers			
Edge deposition monitor			
Edge pressure gauges			
Edge rotation spectroscopy			Only available by special request of T. Biewer @ MIT
Fast lost ion probes – IFLIP		✓	
Fast lost ion probes – SFLIP		✓	
Filtered 1D cameras			
Filterscopes	✓		
FIReTIP			
Gas puff imaging		✓	
High-k scattering			
Infrared cameras			
Interferometer – 1 mm			
Langmuir probes - PFC tiles			
Langmuir probes - RF antenna			
Magnetics – Diamagnetism	✓		
Magnetics – Flux loops	✓		
Magnetics – Locked modes		✓	
Magnetics – Pickup coils	✓		
Magnetics - Rogowski coils	✓		
Magnetics - RWM sensors		✓	
Mirnov coils – high frequency		✓	
Mirnov coils – poloidal array	✓		
Mirnov coils – toroidal array	✓		
MSE	✓		
Neutral particle analyzer		✓	Fast ion mode
Neutron Rate (2 fission, 4 scint)			
Neutron collimator			
Plasma TV			
Reciprocating probe			
Reflectometer - FM/CW			
Reflectometer - fixed frequency homodyne			
Reflectometer - homodyne correlation			
Reflectometer - HHFW/SOL			
RF antenna camera			
RF antenna probe			
Solid State NPA		✓	
SPRED		✓	
Thomson scattering - 20 channel	✓		
Thomson scattering - 30 channel		✓	
Ultrasoft X-ray arrays			
Ultrasoft X-ray arrays - 2 color	✓		
Visible bremsstrahlung det.		✓	
Visible spectrometers (VIPS)			
X-ray crystal spectrometer - H			
X-ray crystal spectrometer - V			
X-ray pinhole camera		✓	