Princeton Plasma Physics Laboratory

NSTX Experimental Proposal

Title: Measurement of SOL widths in ELM-free H-mode plasmas		
OP-XP-952	Revision:	Effective Date: **06/24/09** *(Approval date unless otherwise stipulated)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

Responsible Author: J-W. Ahn	Date 06/24/09
ATI – ET Group Leader: V. Soukhanovskii	Date 06/24/09
RLM - Run Coordinator: R. Raman	Date 06/24/09
Responsible Division: Experimental Research Operations	

Chit Review Board (designated by Run Coordinator)

MINOR MODIFICATIONS (Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL

TITLE: Measurement of SOL widths in ELM-free H-mode plasmas | No. **OP-XP-952**

AUTHORS: J-W. Ahn, R. Maingi, J. Boedo, R. Maqueda, S. Zweben, J. Myra | DATE: **06/24/09**

1. Overview of planned experiment

This experiment aims to measure SOL plasma profiles (T_e, n_e, j_{sat}, and q_{target}) for ELM-free H-mode discharges for fixed operation parameters (*eg*, I_p, B_t, and power). The T_e, n_e, and j_{sat} profiles are measured by the mid-plane fast probe and the q_{target} profile is measured by divertor IR cameras. The newly installed high speed (up to 6.3 kHz) IR camera will be used for detailed measurement of heat flux profiles. Various other diagnostics (GPI, FIReTIP, USXR, fast visible camera, etc) will also measure blob characteristics in the SOL plasma. All the measured profiles will be flux mapped to the mid-plane for comparison.

Previous data for ELMy plasmas from NSTX showed that the relation between λ_{Te} and λ_q at the midplane followed the prediction by electron conduction model within 25-30%. However, λ_{Te} measured by TS was by a factor of ~2 shorter than by the probe. This is believed to be due to the time scale issue of the TS measurement, which is instantaneous. That is, unless the line of sight of the TS laser intersects with an ELM filament at a particular time slice, it will not reflect the T_e and n_e information carried by the ELM, while the probe measurement is over 30-40ms time period and averages over multiple ELMs and inter-ELMs periods. Therefore, we could check this hypothesis and complete the picture by measuring profiles for ELM-free H-mode plasmas. Particularly important is the comparison of T_e profiles between the probe and TS measurements. Our hypothesis expects that they would agree with each other in the ELM-free case, and it will confirm that ELMs do broaden temperature and heat flux profiles, as well as the parallel heat transport is dominated by electron conduction.

Another goal of this experiment is to provide a solid experimental basis for the SOLT modeling. ELM-free H-mode plasma is a good candidate because of the absence of electromagnetic disturbance by the ELMs. GPI measurement is necessary to provide constraint in the modeling.

2. Theoretical/ empirical justification

The electron temperature and heat flux SOL widths, λ_{Te} and λ_q respectively, have a conventional relation of λ_{Te}=7/2λ_q, assuming a dominant parallel electron heat conduction and a simple exponential function for the T_e and q_{target} profiles. However, it has been observed that the profiles have a long tail in the far SOL and this can be approximated by introducing an offset value in the exponential function, *ie* $a = a_0 + a_1 \exp\left(-\frac{R - R_{sep}}{\lambda_a}\right)$. If we use the offset exponential function for both T_e and q profiles and apply it to the parallel electron heat conduction equation in the near SOL, we obtain a new relation between λ_{Te} and λ_q ,

$$\lambda_{Te,u} = \frac{7}{2}\lambda_q\left(\frac{T_{e,u} - T_{e0}}{T_{e,u} - Cq_0 T_{e,u}^{-5/2}}\right)$$

, where T_{e0} and q_0 are the offset T_e and q values, and κ_0 is the electron conduction coefficient. The measured value of λ_{Te}/λ_q differs from the new prediction by 17%, compared to the 26% difference from the conventional prediction. The use of offset temperature and heat flux values, T_{e0} and q_0, in the parallel e-conduction equation can be interpreted as a representation of relatively strong perpendicular heat transport.

Although all other plasma parameters will be kept constant, the density will increase during the H-mode phase. This will give a chance of density scan. We plan to take three density points by plunging the probe at different times. We would be able to investigate the dependence of SOL width on the density using the probe data. Previous investigation using the TS data revealed a strong insensitivity to the line averaged density, implying that the separatrix density does not increase with increasing core density. This issue will be also investigated by the SOLT modeling and a first round discussion was already made with Lodestar modelers.

3. Experimental run plan

- **10mg/min Lithium rate, 12.5 min shot cycle**
- **Use NBI src A or B to minimize the fast ion effect**
- **Keep the NBI power level at 1MW to avoid Type-V ELMs**
- **Use rtEFIT: rmidout = 149cm at z=0 (147.5cm at z = -17.3cm)**
- **GPI gas puff start time 60ms earlier than max probe plunge time**

1. Establish a baseline shot: 132956 (or 132721)
   NBI time: A or B (180-800ms: 1MW)
   I_p=900kA (800kA), B_t =0.45T, 1MW NBI
   Plunge time: Max penetration at 300ms (**5 shots**)

2. Keep all discharge conditions the same once a reproducible ELM-free H-mode regime is established.

3. Start density scan
   - Probe plunge for max penetration at 500ms (**5 shots**)
   - Probe plunge for max penetration at 700ms (**5 shots**)

4. If time permitting, try I_p scan (**5 shots**)
   - **I_p=1.1MA, raise B_t to 0.55T** to keep the pitch angle the same
   - **Plunge time**: Max penetration at 300ms for lowest density to ensure deepest penetration

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

This XP requires a fully operational NBI system. We desire HeGDC between shots of ~ 6.5 minutes for a 12.5 minute repetition rate.

5. Planned analysis

The SOL widths will be analyzed from the data obtained from the fast probe, TS, and the IR camera, and relationships between the SOL widths will be investigated. Comparison of λ_{Te} between the probe and TS is the most important. There is an issue of surface emissivity change due to the Lithium coating on the tiles, therefore the heat flux measurement from the IR data is subject to the detailed analysis for the relation between surface temperature and emissivity. The GPI data will be analyzed to yield blob characteristics and this will be used as inputs to the SOLT code. EFIT will be necessary for the flux mapping of the profiles to the mid-plane.

6. Planned publication of results

Data and analysis for the measured SOL widths will be presented in major international conferences and will be published in an appropriate refereed journal.

PHYSICS OPERATIONS REQUEST

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Describe briefly the most important plasma conditions required for the XP:

Access to ELM-free H-mode in low NBI power (1MW) is the most important plasma condition.

List any pre-existing shots: 132713

Equilibrium Control: Gap Control / rtEFIT(isoflux control):

Machine conditions *(specify ranges as appropriate, use more than one sheet if necessary)*

I_{TF} (kA): **63** Flattop start/stop (s):

I_P (MA): **0.8 – 1.0** Flattop start/stop (s): **0.15/1.0 (max)**

Configuration: **Limiter / DN / LSN / USN** *(strike out inapplicable cases)*

Outer gap (m): **0.1** Inner gap (m): **0.05-0.1** Z position (m): **0.0**

Elongation κ: **2.0** Upper/lower triangularity δ: **0.45**

Gas Species: **D** Injector(s): **Inner wall Mid-plane**

NBI Species: **D** Voltages (kV or off) **A:** **B:** **C:** N/A Duration (s): <1sec

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

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

LITERs: On Total deposition rate (mg/min): **10mg/min**

EFC coils: Off/On Configuration: **Odd / Even / Other** *(attach detailed sheet)*

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		