Princeton Plasma Physics Laboratory

NSTX Experimental Proposal

Title: **Search for the "I-mode"**		
OP-XP-10??	Revision:	Effective Date: *(Approval date unless otherwise stipulated)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS

Responsible Author: R. Maingi	Date **Oct. 19, 2010**
ATI – ET Group Leader: V.A. Soukhanovskii	Date
RLM - Run Coordinator: E.D. Fredrickson	Date
Responsible Division: Experimental Research Operations	

RESTRICTIONS or MINOR MODIFICATIONS

(Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL

TITLE: **Search for the "I-mode"** No. **OP-XP-10??**

AUTHORS: **R. Maingi, A.E. Hubbard, J.W. Hughes, D.G. Whyte** DATE: **Oct. 20, 2010**

1. Overview of planned experiment

The primary goal of this XP is look for the Intermediate of "I-mode" confinement regime recently reported from the Alcator C-Mod group. This experiment is part of the NSTX contribution to the FY2011 Joint Research Target on pedestal physics structure.

2. Theoretical/ empirical justification

Recent experiments on Alcator C-mod have identified an operational regime that sits between L-mode and H-mode, i.e. an intermediate or "I-mode" scenario [McDermott, PoP 2009; Whyte NF 2010]. I-mode is observed with the "unfavorable" grad-B drift direction, just below the L-H transition power threshold. I-mode is characterized by a thermal barrier but with a weak particle barrier as seen in H-mode. Specifically the edge profiles show a pedestal-like T_e profile with a tanh shape (Figure 1). This scenario is devoid of ELMs but achieves an H98y2 energy confinement multiplier ~ 1, comparable to EDA H-mode. An example of the evolution of an I-mode discharge is shown in Figure 2.

An important change in turbulence is measured in I-mode from L-mode, that differs from EDA H-mode: the QC mode does not form. Rather there is a general decrease in the broadband L-mode turbulence in I-mode, with a few bands of turbulence persisting (some times referred to as a "quasi-quasi coherent mode", e.g. Figure 2).

Access to clear, sharp I-mode transitions is facilitated at low q_{95} (or more specifically high I_p) and low target density, as shown in Figure 3. Note that low q_{95} does require a higher L-I power threshold. High δ is also favorable for access, also produces more stable discharges in NSTX, and will facilitate this search. There is no known κ dependence, and δ_r^{sep} is typically strongly single-null in C-Mod.

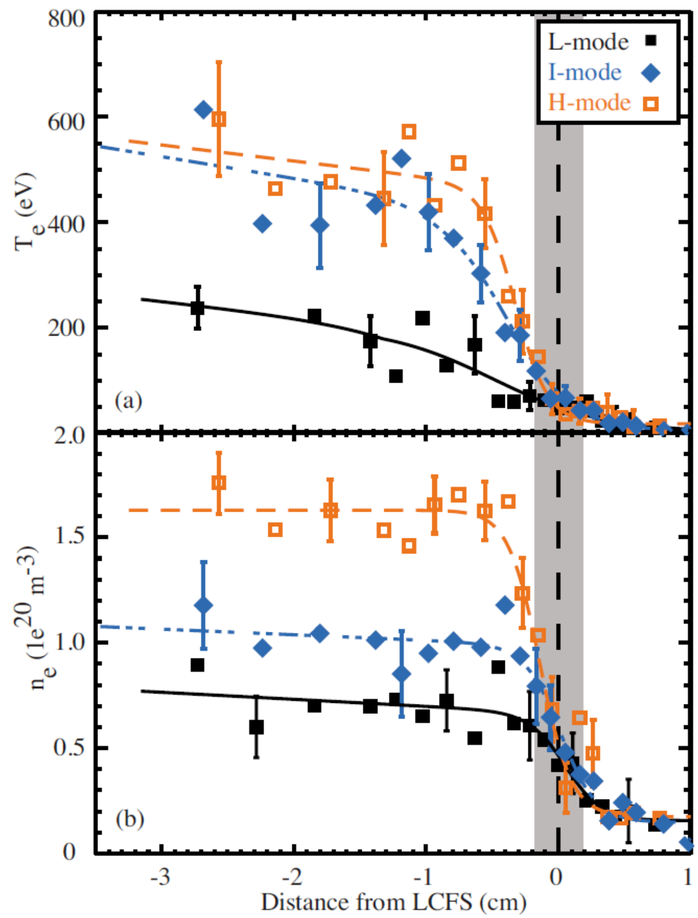

*Fig. 1: Comparison of edge profiles in L-mode, I-mode, and H-mode [McDermott, PoP **16** (2009) 056103].*

3. Experimental run plan (1/2 day)

I-mode access and sharp transitions are optimum at high I_p (more so than low B_t); high δ is also favorable. We request all fluctuation diagnostics to be available. We also propose to use 150 mg of lithium between discharges for access to low L-mode target density, if possible, or a heavy liter coating in morning if that's the only option.

1. Start with a fiducial plasma: 0.9 MA, 0.45 T, but with drsep <~ 0 cm, slightly biased down, with 4 MW NBI (2)
2. Perform slow drsep ramp: 0->+10mm from 100-300ms, and then back down to 0 from 300-500ms (2). The idea is to prevent the L-H (at 180 msec nominally) to study the L-mode operating window to look for I-mode. The ramp back down later is to confirm the L-H transition power.
3. Implement β_N feedback < 2-3, depending on best guess for stable L-mode (2)
4. Increase I_p up to between 1.1 and 1.2 MA to facilitate I-mode access at low q_{95}. If unsuccessful, drop I_p to 0.7 MA for high q95 for completeness. (4)
5. Do fixed drsep values at most stable Ip: nominal +5, +10 mm (4)
6. Optimize PNBI for L-mode again (2)
7. Compare with reference H-modes with drsep ~ 0 with same NBI timing (2)

Note: if I-mode like profiles observed, stop and document profiles and try to obtain long-pulse quasi-steady I-mode.

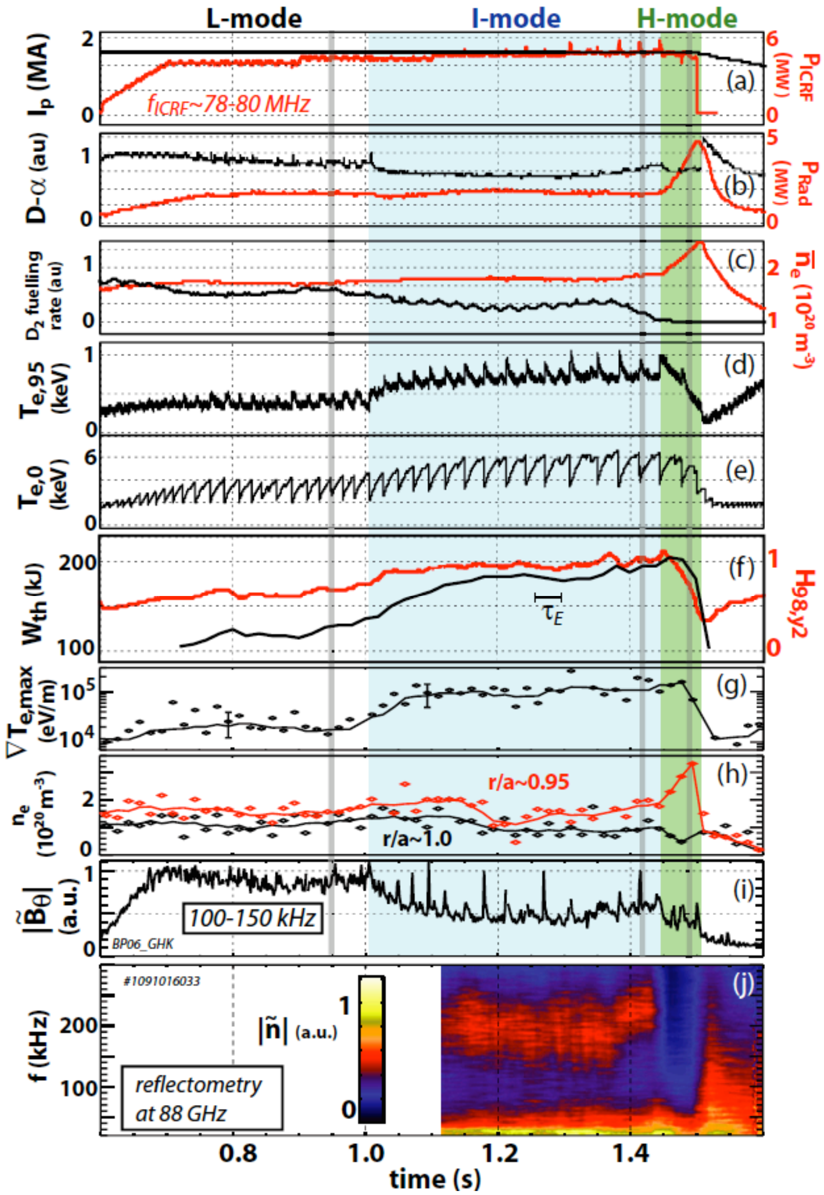

*Fig. 2: Example of upper single-null $B_T = 5.6T$, $q_{95} \sim 3.2$ I-mode discharge with divertor cryopumping with L-mode, I-mode and ELM-free H-mode phases indicated. (a) I_p and ICRF heating power, (b) D_α recycling and core radiated power, (c) D_2 gas fuelling rate and line-averaged density (d) $T_{e,95}$ pedestal T_e at $r/a \sim 0.95$ from ECE, (e) $T_{e,0}$ central electron temperature, (f) stored thermal energy W_{th} and confinement quality H98,y2, (g) pedestal T_e gradient evaluated from edge TS, (h) local density at pedestal ($r/a \sim 0.95$) and separatrix ($r/a \sim 1.0$) from TS, (i) poloidal magnetic field fluctuation amplitude $|\tilde{B}_\theta|$ averaged over the frequency range 100–150 kHz (from B_θ coils), density fluctuation amplitude spectrum from outer midplane reflectometery at 88 GHz [Whyte, NF **50** (2010) 105005].*

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

NBI up to 6 MW, no CHI or rf.

5. Planned analysis

Profile analysis and edge transport analysis will be done.

6. Planned publication of results

The results will contribute to the Joule milestone report and APS papers.

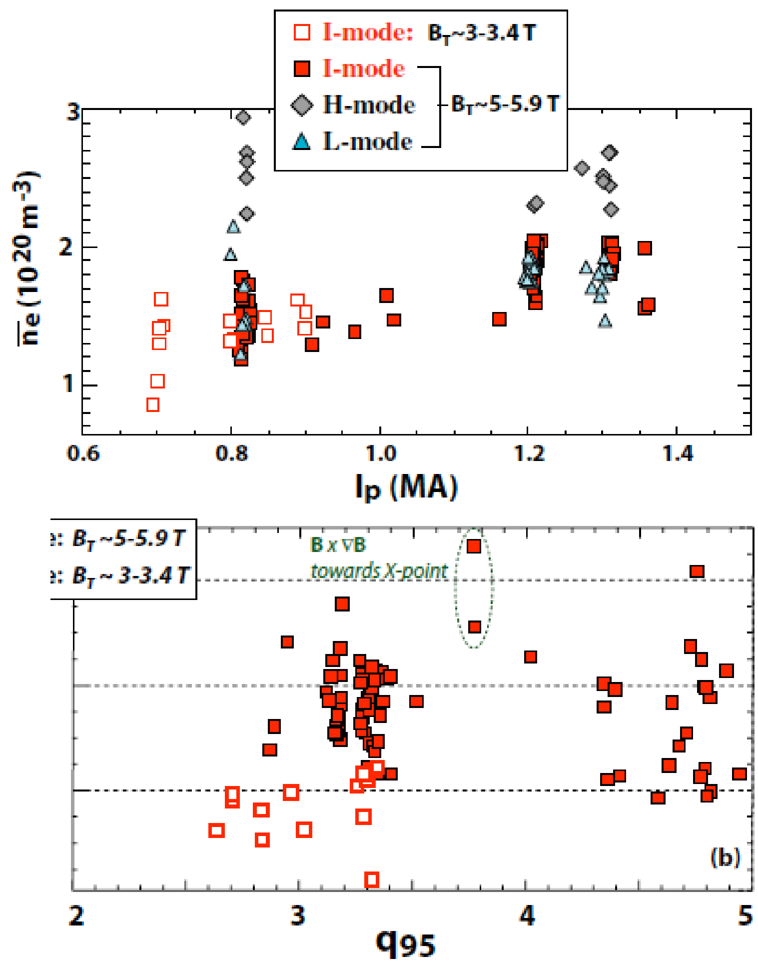

*Fig. 3: I-mode operational window [open squares] in C-Mod [Whyte, NF **50** (2010) 105005].*

PHYSICS OPERATIONS REQUEST

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(use additional sheets and attach waveform diagrams if necessary)

Brief description of the most important operational plasma conditions required:

Relatively constant OSP radius; ability to scan I_p and B_t over wide range

Previous shot(s) which can be repeated:

Previous shot(s) which can be modified: 141445, 141454

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

I_{TF} (kA): **0.45 T** Flattop start/stop (s):

I_P (MA): **0.7-1.2 MA** Flattop start/stop (s):

Configuration: Limiter **/ <u>DN</u> /** <u>LSN</u> **/ USN**

Equilibrium Control: Outer gap / **<u>Isoflux (rtEFIT)</u>** / Strike-point control (rtEFIT)

Outer gap (m): **10cm** Inner gap (m): **varies** Z position (m): **varies**

Elongation: **2.2** Triangularity (U/L): **0.8** OSP radius (m): **35cm**

Gas Species: **D_2** Injector(s):

NBI Species: **D** Voltage (kV) **A: 90** **B: 1 MW** **C: 0.5 MW** Duration (s):

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

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

LITERs: Off / **On** Total deposition rate (mg/min): **200 mg desired**

LLD: Temperature (°C): **unheated**

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**
Beam Emission Spectroscopy		√
Bolometer – divertor		√
Bolometer – midplane array		√
CHERS – poloidal		√
CHERS – toroidal		√
Dust detector		√
Edge deposition monitors		√
Edge neutral density diag.		√
Edge pressure gauges		√
Edge rotation diagnostic		√
Fast cameras – divertor/LLD		√
Fast ion D_alpha - FIDA		
Fast lost ion probes - IFLIP		
Fast lost ion probes - SFLIP		
Filterscopes	√	
FIReTIP		√
Gas puff imaging – divertor		√
Gas puff imaging – midplane		√
Hα camera - 1D		√
High-k scattering		√
Infrared cameras		√
Interferometer - 1 mm		
Langmuir probes – divertor		√
Langmuir probes – LLD		√
Langmuir probes – bias tile		
Langmuir probes – RF ant.		
Magnetics – B coils	√	
Magnetics – Diamagnetism	√	
Magnetics – Flux loops	√	
Magnetics – Locked modes		√
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 – E‖B scanning		
NPA – solid state		
Neutron detectors		√
Plasma TV		√
Reflectometer – 65GHz		√
Reflectometer – correlation		
Reflectometer – FM/CW		
Reflectometer – fixed f		
Reflectometer – SOL		√
RF edge probes		
Spectrometer – divertor		√
Spectrometer – SPRED		√
Spectrometer – VIPS		√
Spectrometer – LOWEUS		√
Spectrometer – XEUS		√
SWIFT – 2D flow		
Thomson scattering	√	
Ultrasoft X-ray – pol. 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 tang. pinhole camera		√