1. Purpose of Experiments

This experiment focuses on two aspects of the weakly coherent edge fluctuations seen in I-mode discharges (WCM): the relationship between the intensity of the mode and the particle and energy transport in I-mode plasmas as well as characterizing the dependency of the WCM on the pressure gradient normalized to the poloidal magnetic pressure ($\alpha_{\text{MHD}}$).

This experiment will use a coordinated suite of fluctuation diagnostics (GPI, O-mode reflectometry, PCI, FRCECE, CXRS and fast magnetics) to study the characteristics of the WCM. In order to study changes in the particle transport, the LFS H$\alpha$ diode array will also be used to view changes in ionization profiles. This is an experimental approach at trying to identify the WCM dependencies and to connect any changes in strength of the WCM to changes in particle and energy transport as identified by $\chi_{\text{eff}}$ and $D_{\text{eff}}$.

2. Background

The study of the I-mode regime is of great interest both as a physical parameter space where the particle and energy transport channel of the plasma can be separated, as well as the potential of an operational regime with an H-mode like temperature profile while maintaining ash and impurity contamination under control.
One of the characteristics observed in this regime is the presence of the WCM, a weakly coherent fluctuation mode, at ~250kHz with a width ~100kHz accompanied by a reduction in broadband fluctuations from ~50-150kHz. The relationship between the WCM and the changes in transport has been proposed [1][2] but there are still open questions regarding causality and a systematic approach has yet to be taken to study it. Since the WCM appears when the temperature profile steepens and is localized at the steep gradient region, there is reason to believe that the trigger is related to VP or VT close to the LCFS. Based on this, it is hypothesized that the WCM may follow the characteristic dependencies of ballooning modes. [Since the magnetic shear can be well constrained throughout a shot, the \( \alpha_{\text{MHD}} \) parameter can be scanned independently by varying the VP at the pedestal during the I-mode and during the L-I-L transitions.] This dependency is being actively studied in relation to the QCM that is observed during EDA H-Modes and this proposal expands this study into the I-mode regime. Correlations of WCM amplitude, frequency and mode number with local edge parameters such as normalized gradients and collisionality may help elucidate the physical drive terms for the fluctuations.

3. Approach
Describe the methodology to be employed; explain the rationale for the choice of parameters, etc. Describe the analysis techniques to be employed in interpreting the data, if applicable. If the approach is standard or otherwise self-evident, this section may be absorbed into the Experimental Plan.

In order to optimize the use of the edge Thomson scattering diagnostic which will be relied upon for \( \alpha_{\text{MHD}} \) acquisition and particle transport analysis, it is requested to run in LSN magnetic configuration. Since I-mode plasmas have been well established for unfavorable drift direction plasmas, in order to operate in LSN, a reverse magnetic field configuration will be used.

In order to cover a wide parameter range, it is proposed to study 4 target conditions: \((n_l 0.4 (x10^{20} \text{m}^{-2}), I_p(\text{MA})) = (0.9,1.2), (1.1,1.2), (0.7,1.0), (1.0,1.0)\). These values are based on I-modes produced on 1110215xxx as well as target conditions desired. At each one of these conditions I-modes will be developed and sustained.

During I-mode plasmas, changing the temperature gradient at the edge can serve as a knob to change \( \text{VP} \) and therefore \( \alpha_{\text{MHD}} \). The \( \text{VT} \) will be varied by scanning the ICRF power during the I-mode.

In order to acquire measurements of particle transport, the H\( \alpha \) LFS GPI fast camera will be used in conjunction with density and temperature profile measurements close to the LCFS and in the near SOL, for which the edge TS system and the X-Mode reflectometer are to be used[3]. The particle transport is estimated by computing \( D_{\text{eff}} \) as defined from \( \Gamma = D_{\text{eff}} \nabla n \). The measurement of the cross-field flux requires ionization profiles at the edge of the plasma which can be obtained using inversions of chord-integrated \( D\alpha \) signal from the GPI camera. Since the neutral density profiles obtained from the \( D\alpha \) inversion...
are not absolutely calibrated, post-shot analysis using KN1D will be used to estimate the
absolute values of the profiles. The inversion will require brightness measurements at the
outermost GPI chords to be significantly smaller (~<1/4) than the brightest chords. This
might require increasing the equilibrium outer gap of the plasma.
Energy transport will be estimated by calculating the $\chi_{\text{eff}}$ from the measured power and
density and temperature profiles. It will be useful to use the transport code TRANSP
after the run to obtain $\chi_{\text{eff}}$ for comparison.

Since it has been observed that GPI is more sensitive to the WCM using He puffing, the
CXRS data will be acquired using the DNB and not D2 gas puffing. This leads to larger
uncertainties in the Er and rotation measurements but it is determined that for the purpose
of this experiment, the optimization of GPI measurements is a priority.

Due to the fact that each fluctuation diagnostic system relies on different physical
principles of operation and are sensitive to different physical quantities (e.g $f_n$, $\tilde{n}_{\text{cutoff}}$, $\tilde{B}$,
$\tilde{T}_e$ etc.), it is not surprising that the WCM is observed differently across each system.
One of the main objectives of this experiment is to characterize the WCM across the
different diagnostic systems. In order to analyze signals from different diagnostics in
relation to each other, it is important to ensure a synchronized time basis between the
systems. Therefore, it is desired that as many of the fluctuation diagnostics used in this
experiment as possible employ the timing scheme developed by J. Stillerman, W. Burke,
B. LaBombard, et al. This implementation will improve the reliability of cross-system
post-processing techniques such as cross-correlation analysis between systems.

In order to make comparisons between the experimental results and current theoretical
models of possible candidates for the WCM, post-run analysis will include the use of
linear stability codes to study which modes (if any) are unstable. There is a wide variety
of tools that can help shed light on the underlying physics such as GYRO and TGLF
(taking into account the regime of validity such as FLR restrictions). Codes such as
ELITE and BOUT++ can also be used to study the possible onset of P-B modes.
Depending on the results of initial data analyses, different approaches can be taken with
respect to using modeling codes to study the WCM and the I-mode regime.

Resources

4.1 Machine and Plasma Parameters

Give values or range for:

- Toroidal Field: 5.7T (higher than typical 5.4T in order to better control sawteeth)
- Plasma Current: 1.0-1.2MA
- Working Gas Species: D$_2$
- Density: 0.7-1.0 x10$^{20}$ m$^{-2}$
- Boronization Requested (if yes, specify whether overnight or between-shot, how recently
  needed, and any special conditions.): No
- Equilibrium configuration (if possible, refer to database equilibria): 1110215023 for the
  1.2MA, nl04=0.9x10$^{20}$ m$^{-2}$ case, 1110215014 for the 1.0MA, nl04=0.7x10$^{20}$ m$^{-2}$ case.
4.2 Auxiliary Systems

ICRF Power, pulse length, phasing: 3-6MW @80MHz
LHCD Power, pulse length, phasing: No
Pellet Injection (species): No
Impurity blow-off injection: Yes
Diagnostic Neutral Beam: Yes
Special gas puffing: He for NINJA
Cryopump: Yes
Non-axisymmetric Coils (Connections, Current): Yes, configured for optimal error field correction

Other:

4.3 Diagnostics
List required diagnostics, and any special setup or configuration, e.g. non-standard digitization rate.

Core and Edge TS, TCI, PCI (with masking optimized for WCM), GPI, Fast Magnetics, O-Mode reflectometry, LFS Hα, FRCECE, X-Mode reflectometry, MSE, CXRS, Hirex Sr, bolometry

4. Experimental Plan
Both sections must be filled in.

5.1 Run sequence Plan
Specify total number of runs required, and any special requirements, such as consecutive days, no Monday runs, extended run period – 10 hours maximum – etc.

1 Day

5.2 Shot sequence plan
For each run day, give detailed specification for proposed shot sequence: number of shots at each condition, specific parameters and auxiliary systems requirements, etc. Include contingency plans, if appropriate.

Start with 1110215023 as the reference shot to start with. Ip=1.2MA, target nl04=0.9x10^{20} m^{-2}.

1) 3 shots: Develop a shot with an I-mode at 1.2MA with a target nl04=0.9x10^{20} m^{-2} by ramping the ICRF:
   • at ~0.5s ramp ICRF:0 - 3MW during 100ms
   • Ramp the P_{ICRF} from 3-5MW from 0.6-1.6s and determine the P_{IH}.

2) 3 shots: Using the recipe developed in (1), scan the P_{ICRF} in 100ms steps from P_{LH} to right below the P_{IH} and then step back down to below the P_{LH} (this step assumes some level of hysteresis). The target power scan, assuming (1) provides estimated values of P_{IH} and P_{LH}, is plotted in figure 1:
Note that this is only the power scan during the I-mode phase. It is assumed that the necessary power ramp that causes the initial L-I transition occurs before the plot. During the second half of the scan, for which \( P_{\text{ICRF}} < P_{\text{L-I}} \), the step heights (\( \Delta P \)) might be too large since L-I-L hysteresis hasn’t been characterized. It will be determined in the control room if the step height should be reduced in order to stay in I-mode.

3) 18 shots:
Repeat 1) and 2) for:
   a) \( n_{\text{L}} = 1.1 \times 10^{20} \) m\(^{-2}\) and for \( I_p = 1.2 \) MA
      for (3a) scan ICRF from \( \sim 3.5 - 5.5 \) MW
   
   b) \( n_{\text{L}} = 0.7 \times 10^{20} \) m\(^{-2}\) and for \( I_p = 1.0 \) MA
      for (3b) take 1110215014 as reference and scan ICRF from \( \sim 2 - 4 \) MW

   c) \( n_{\text{L}} = 1.0 \times 10^{20} \) m\(^{-2}\) and for \( I_p = 1.0 \) MA
      for (3c) scan ICRF from \( \sim 3 - 5 \) MW

For each one of the conditions the \( P_{\text{L-I}} \) and \( P_{\text{L-H}} \) will be different so the scan limits will have to be modified based of the \( P_{\text{ICRF}} \) ramps in (a).

5. Anticipated Results
Discuss possible experimental outcomes and implications. Indicate if the program may be expected to lead to publications, milestone completions, improved operating techniques, etc. Indicate if the experiments are intended to contribute to a joint research effort, an ITER request, or an external database.

- Contribution to PhD thesis research
- Contributions to A. Hubbard EPS invited talk
- Broaden the I-mode database
- Test H\( \alpha \) particle transport measurement technique for I-mode plasmas
- Experimental approach at characterization of WCM
- Opportunities for collaboration with theory groups, both at MIT as well as outside institutions during post-run analysis.
- Contribution to FY2011 Joint Research Target on Pedestal Physics
- TTF/APS presentations

6. References
Include references both to external and internal literature or communications which bear on this proposal. See Section 2.