Subject: Investigation of the mode structure of the WCM with a scanning Mirror Langmuir probe


Group: Pedestal

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Approved by: Date Approved:

1. Purpose of Experiments
The primary goal of these experiments is to investigate the mode structure of the Weakly Coherent Mode (WCM) with a new diagnostic – a scanning Mirror Langmuir Probe (MLP).

2. Background
The MLP has recently demonstrated the ability to resolve the mode structure of a 110 kHz Quasi-Coherent Mode (QCM) [1], directly recording time series snapshots (1.1 MHz sampling rate) of density, electron temperature and plasma potential in the mode layer on multiple electrodes. These measurements have allowed the relative phase angles among these quantities to be resolved and the phase propagation velocity in the plasma frame to be deduced by simultaneously recording the electric field in the mode layer (i.e., accounting for $\text{ExB}$ plasma motion). The goal of this MP is to perform similar measurements of the WCM.

Successful execution of this experiment will be much more challenging, however. First, the WCM exists in I-mode discharges, which typically require at least a modest amount of ICRF heating power. Second, the WCM typically lives in a higher frequency range of 200 to 300 kHz, which pushes nearer to the limit of the MLP system. (On the other hand, GAMs, which tend to accompany the WCM may be well resolved.) Third, it is not yet known where the WCM exists in the I-mode pedestal relative to the electron and ion temperature profile. If it lives inside $T_e = 100$ eV, then the probe head will not be able to reach the mode layer safely. Finally, the WCM is much broader in frequency than the QCM, which will likely make it more challenging to unfold the temporal dynamics. But, despite these challenges, the tremendous benefit of directly recording WCM fluctuations in density, electron temperature and plasma potential fluctuations and directly assessing the radial particle transport associated with the mode makes it well worth trying.
3. Approach

Some candidate low-power I-modes with good WCMs can be found on Amanda’s run on 1100827 (MP#615). These employed a forward field, LSN configuration and a ‘JFT-2M’ shape with the outer divertor strike point just grazing the EF1 protection tiles (see Fig. 1).

![Graph showing I-mode discharge parameters](image)

**Fig. 1** – Example of a forward-field I-mode discharge from Amanda’s 1100827 run day with plasma current of 0.8 MA and 0.8 MW ICRF heating.

Shot#1100827030 was a 0.8 MA, 5.5 tesla discharges that exhibited a clear WCM on the 88 GHz reflectometer channel (Fig. 2) with only 0.8 MW ICRF heating.

![Reflectometer fluctuations and H-alpha signals](image)

**Fig. 2** – Reflectometer and H-alpha signals from 1100827030. A clear WCM was seen.
Fig. 3 – Example of a forward-field I-mode discharge from Amanda’s 1100827 run day with plasma current of 1.0 MA and ICRF power ramping from 0.6 to 1.5 MW. I-mode phase begins around 0.92 seconds with a clear WCM starting at 1.0 seconds.

Shot#1100827026 was a 1.0 MA, 5.5 tesla discharges that exhibited a very strong WCM on the 88 GHz reflectometer channel (Fig. 4) with ICRF ramping from 0.6 to 1.0 MW.

Fig. 4 – Reflectometer and H-alpha signals from 1100827026. A very clear WCM is seen (Perhaps one the most coherent WCMs ever — noted in a logbook entry by Arturo.)
Although the WCM looks best in the 1.0 MA discharge, the 0.8 MA discharge (1100827030) probably should be the starting point for this investigation because the SOL profiles tend to be a less steep at the lower current and the total power into the discharge is less.

4. Resources
4.1 Machine and Plasma Parameters

Toroidal Fields: 5.5 tesla (forward field direction)
Plasma Currents: 0.8 MA, possibly 1.0 MA also
Working Gas Species: D₂
Densities: NL04 ~ 0.6x10²⁰m⁻²
Boronization: Not required.

Equilibrium configuration: Start with 1100827030

4.2 Auxiliary Systems

ICRF Power, pulse length, phasing: up to 2 MW
LHCD Power, pulse length, phasing: None
Pellet Injection (species): None
Impurity blow-off injection: None
Diagnostic Neutral Beam: None
Special gas puffing: D₂ and He puffs from NINJA as required for GPI and GP-CXRS
Cryopump: None
Non-axisymmetric Coils: Standard compensation
Other:

4.3 Diagnostics

- Horizontal probe (ASP) with Mirror Langmuir Probe (MLP) system connected. The standard Langmuir-Mach probe head must be installed on the A-port drive system. This is the most robust head for high heat flux.
- Reflectometer
- GPI fast-diode system (may need to change outer gap to accommodate this diagnostic at the risk of altering the ‘magic’ of the plasma shape in obtaining these low power WCM conditions - need to assess during run time.)
- GP-CXRS
- Phase contrast imaging
- Fast Mirnov coils
- Edge Thomson scattering
- FRCECE
5. Experimental Plan

5.1 Run sequence Plan
The MP may be executed in one half-day run.

5.2 Shot sequence plan

**Step A – Establish 0.8 MA I-mode – 5 shots**
Set up 5.5 tesla, 0.8 MA, NL04 ~ 0.6 x10^{20} m^{-2} discharge similar to 1100827030 but with RF power ramp from 0.5 to 1.0 MW from 0.7 to 1.0 seconds and holding at 1.0 MW until 1.3 seconds. Track onset time of I-mode and WCM and reduce max RF power if possible while maintaining I-mode and WCM.

**Step B – Target WCM with MLP – 5 shots**
Optimize probe timing and increase plunge depth of probe shot-by-shot in an attempt to scan through the mode layer. Optimize gas puffs for GPI and GP-charge exchange systems so as to sample WCM just after probe insertion time.

**Step C – Establish 1.0 MA I-mode – 3 shots**
If probe survives Step B or if 0.8 MA I-modes/WCMs are found to be poor, increase current to 1.0 MA and optimize/reduce RF power to attain I-mode with good WCM.

**Step D – Target WCM with MLP – 3 shots**
Optimize probe timing and increase plunge depth of probe shot-by-shot in an attempt to scan through the mode layer. Optimize gas puffs for GPI and GP-charge exchange systems so as to sample WCM just after probe insertion time.

6. Anticipated Results
If successful, the experiment should provide key information on the WCM – mode type (drift vs. interchange), mode propagation direction in plasma frame, fluctuation amplitudes in $n$, $T_e$, and $\Phi$), and perhaps even mode-driven radial particle and energy transport fluxes.

7. References