ECEI and magnetic measurements during inter-ELM modes

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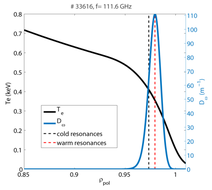
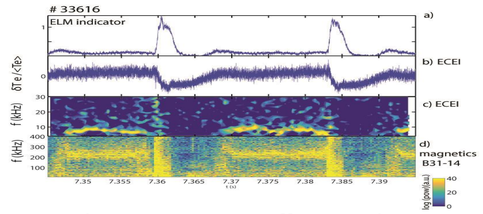
Introduction

- ECEI measures electron temperature and its fluctuations.
- H-mode discharges, Bt = -2.5 T, Ip = 800 kA.
- Different edge diagnostics at AUG shows the mode between the ELMs.
- Lithium Beam Emission Spectroscopy (Li-BES), ECE, ECEI – single low frequency mode ~ 10 kHz.
- Magnetic pick-up coils measure multiple modes in the high frequency range.





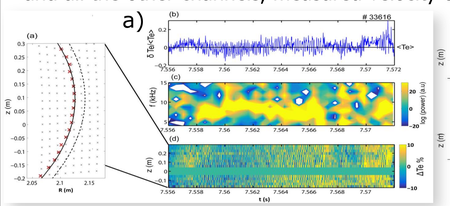
•Edge plasma optically thin => radiation transport effects and geometry of the ECEI have to be taken into account.

•ECFM [1] calculates warm resonances of the ECEI system.

Characterization of the low frequency mode using ECEI

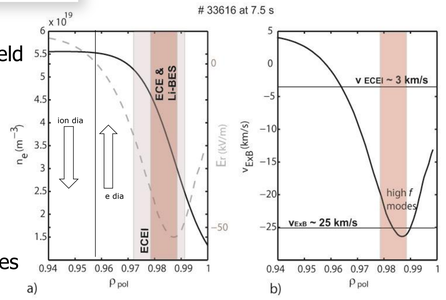
a) The low frequency mode propagates from the bottom to the top along the flux surface. Mode induces about 10 % variation in the radiation temperature. Such poloidally resolved measurements enable the determination of the poloidal velocity.

b) Using the cross correlation function between the reference channel at z =-0.1 m and all the other channels, measured velocity of the mode is v ~ 3km/s.



Localization

- v_{ExB} =Er / B, where radial electric field profile Er is evaluated using the neoclassical assumption for the poloidal flow [2] and experimental profiles for the ion/electron temperature and density.
- Location of the high frequency Modes [3] and the low frequency modes corresponds to the Er minimum.
- High frequency modes => rotate with the ExB background flow.

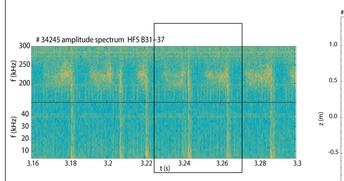


Beating of two high f modes => resulting mode moves in the electron diamagnetic direction with group velocity of 3 km/s

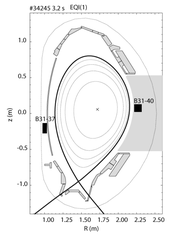
Mode rotates in the ion diamagnetic direction with large phase velocity of 22 km/s

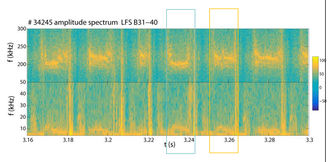
Magnetic measurements

- Magnetic pick-up radial field coils measure high frequency modes in the HFS and the LFS at ASDEX Upgrade [3] and have toroidal mode numbers 8,9,10 [4].
- Low frequency mode is measured only at the LFS.



HFS: fast oscillations





LFS: fast & slow oscillations

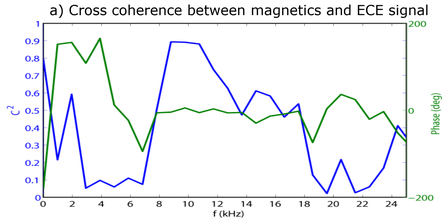
Correlation between magnetics and the ECE/causality

a) Cross coherence between magnetic and ECE signal at the LFS midplane shows the ~ 10 kHz coherent mode present in both signals, with zero phase.

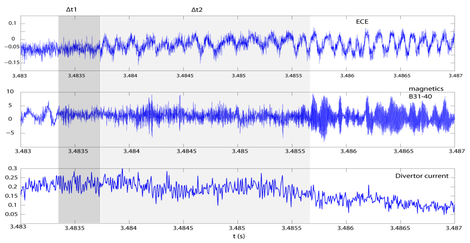
b) Time delay in the mode appearance between magnetics and ECE signal is observed for this particular case.

c) The power of the fast oscillations in the magnetics changes with the phase of the slow oscillations detected also in the ECEI/ECE signal.

a) Cross coherence between magnetics and ECE signal



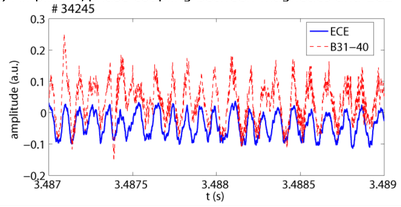
b) Time traces of one inter-ELM for ECE, magnetics and divertor current



Δt1 – time delay between magnetics and ECE.

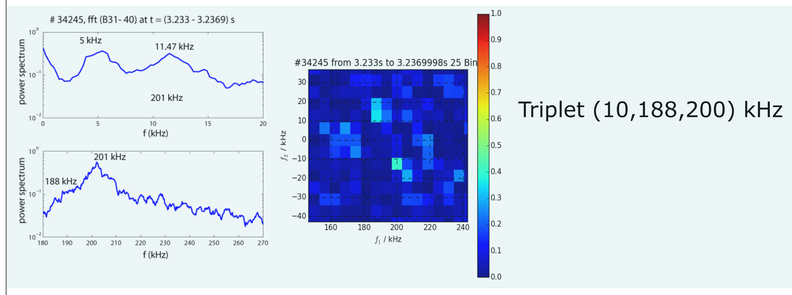
Δt2 – time delay in the amplitude modulation between ECE and magnetics.

c) Amplitude/phase coupling between magnetics and ECE

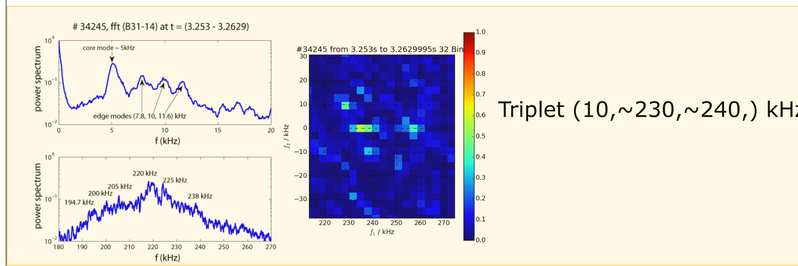


Amplitude modulation of the high frequency modes (in red) in phase with the ECE signal (in blue).

Bicoherence analysis



Triplet (10,188,200) kHz



Triplet (10,~230,~240,) kHz

•Bicoherence analysis suggests non linear coupling of low and high frequency modes for those two cases.

•These frequencies are shown at the fft (signal) at the LFS.

•Not all the high frequencies detected on the LFS are visible on the HFS.

Summary & Conclusion

- ECE/ECEI measure low frequency inter-ELM mode at the LFS.
- Magnetics measure low frequency inter-ELM mode at the LFS.
- Magnetics also measure high frequency inter-ELM modes at the LFS & HFS.
- Low frequency mode ballooning.
- Bicoherence shows coupling between low *f* and high *f* modes at the LFS.
- Non linear excitation of low n modes by high n modes also found with JOREK [5].

Two high *f* modes at the LFS	➡	Superposition of the two high *f* modes generates low *f* modulation instability at the LFS	➡	High *f* modes couple to the phase of the low *f*. Modulation instability affects the amplitude of the high *f* modes.
Single high *f* mode and single low *f* mode at the LFS	➡	Coupling of the low and high *f* on the LFS	➡	Side band mode is generated and amplified.

References:
[1] S. Denk et al. EC19, 2016.
[2] E. Viezzer et al. NF, 2014.
[3] F. M. Laggner et al. PPCF, 2016.
[4] F. Mink et al. PPCF, 2016.
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