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Studies of MHD instabilities in TJ-II plasmas

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Introduction

TJ-II is a four period heliac-type stellarator with low magnetic shear, magnetic well all over the plasma radius and high magnetic configuration flexibility (rotational transform can be varied between $0.9 \leq \iota/2\pi \leq 2.2$). These characteristics allow controlling the presence of low order rationals in the rotational transform profile and, consequently, facilitate the identification and characterization of magnetohydrodinamic (MHD) instabilities.

The excitation of Alfvèn Eigenmodes (AE) by energetic ions produced by NBI and ICRH, and also by alpha particles in deuterium-tritium plasmas is an important research topic in reactor-grade plasmas [1]. In a fusion reactor, the destabilized AEs may quench the fusion burn and damage the first wall due to a significant loss of alpha particles from the confinement region before they get thermalised. The AEs research is also an interesting topic for helical systems [2,3]. Depending on the magnetic configuration characteristics of the device, different types of modes arise. The low magnetic shear of TJ-II points to Global Alfvén Eigenmodes (GAE) as the most likely AE to be observed [4].

In this work we study the MHD activity related to the presence of rational surfaces in the rotational transform profile as well as the Alfven modes found in NBI heated plasmas.

Experimental setup.

Magnetic field fluctuations are measured in TJ-II using three Mirnov coil sets distributed at different toroidal sectors of the vacuum vessel: two sets with four coils distributed along a vertical direction that measure the three components of the magnetic field and one set with fifteen coils spanning a poloidal angle of $\pm\pi/2$, which measure the poloidal field component. The installation of a poloidal array encircling completely the plasma column is impossible in TJ-II because there is no room between plasma and vacuum vessel. The sampling frequency is 1 MHz for the vertical coils sets and 100 kHz for the poloidal coils set. Coherent fluctuations are also observed with microwave reflectometry [5] and HIBP [6] diagnostics.

Experimental results

In ECH plasmas, the effect of low order rationals inside the rotational transform profile on MHD and transport properties has been experimentally described [7,8]. The impact of these

MHD modes on plasma confinement is expected to be small due to the stabilizing effect of the magnetic well at these low plasma pressure experiments. In both ECH and NBI heated plasmas, low frequency coherent modes, usually below 100 kHz, have been detected. Singular Value Decomposition (SVD) and correlation analysis techniques [9] have been applied to the measurements of poloidal field coil set in order to obtain the poloidal structure and rotation direction of the modes.

As an example, figure 1a shows the spectrogram of magnetic fluctuations obtained in the standard magnetic configuration, where a coherent mode appears in a range frequency of (20-25) kHz. Figure 1b represents the singular value distribution for t ≈ 1070ms. In this particular case the two first coherent MHD vectors represent 73% of the fluctuation energy content of the mode and the rest shows irregular spatial and temporal structure and small eigenvalues and, thus, represents noise. The study of basic poloidal mode number fitting indicates that the rational surface m=3, n=5 is probably responsible of this mode, although the complexity of the TJ-II magnetic geometry introduces a high degree of uncertainty. Correlation analysis between different coils magnetic signals show that the mode moves in the ion diamagnetic drift direction. Scans in plasma density and magnetic configuration show that this mode appears in a narrow configuration window around the standard configuration. This is an experimental indication of the relation between the appearance of the mode and the rotational transform profile. HIBP and Reflectometry measurements show that the mode is localized at $\rho > 0.6$. A more internal mode occasionally detected by HIBP is not seen by the Mirnov coils.

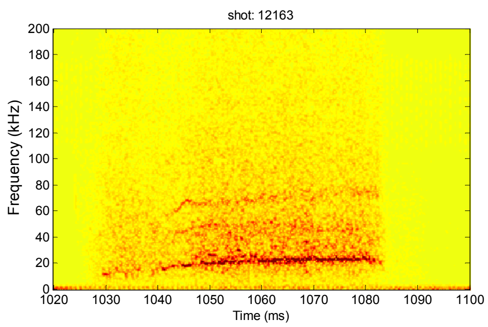

Figure 1a: Magnetic fluctuations spectrogram

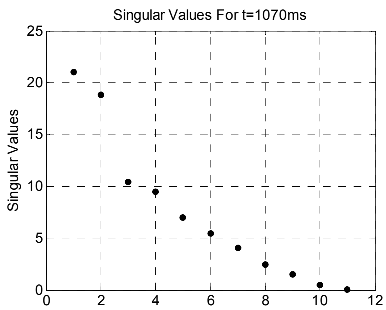

Figure 1b: Singular Values

In some ECH plasmas a frequency bifurcation event is observed when the plasma density reaches a certain value. Figure 2a shows time traces of plasma density and plasma current as well as the magnetic fluctuations spectrogram. A coherent mode with almost linear dependence with density bifurcates in two branches with frequencies about 60 and 80 kHz when a given density is achieved. Simultaneously a third mode with lower frequency (about 20 kHz) appears. The poloidal mode number fit of the low frequency mode yields a poloidal number m = 2, in agreement with the low order rational surface that can be expected, since this magnetic configuration has a rotational transform profile slightly above 2 and being the plasma current negative, the rational surface n/m=4/2 could enter the $\iota/2\pi$–profile. The correlation diagram in figure 2b shows that the mode rotates in the ion diamagnetic drift direction. Bispectral analysis shows that there are magnitude and phase relations between the three modes. In particular, the magnitude of the bicoherence has three maxima that satisfy $\omega_3 = \omega_1 + \omega_2$.

Reflectometer measurements show that the modes are located at $\rho \approx 0.6$- 0.7 and that the high frequency modes and the low frequency one rotate in opposite directions.

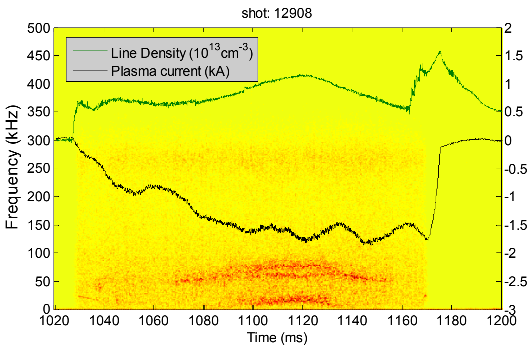

Figure 2a: Mirnov signal spectrogram, line density and plasma current.

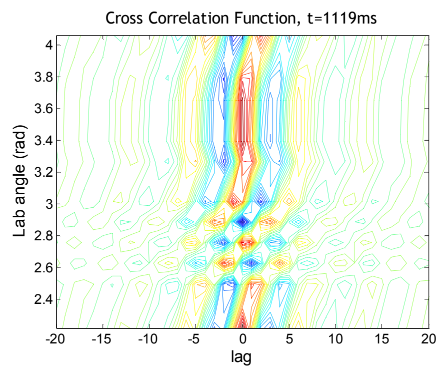

Figure 2b: Cross correlation function vs. probe position.

In NBI heated plasmas, high frequency modes that can be described as GAEs are found in different configurations related to several low-order rationals, n/m=3/2, 5/3. The Alfvén modes appear as coherent and continuous oscillations whose frequency (between 100kHz and 400kHz) shows a clear dependence with plasma density: $f \sim 1/n^{1/2}$.

The behaviour of Alvén modes has been found to depend on the ECH heating conditions of the plasma target that determine the shape of the electron temperature and density profiles. In plasmas heated with ECH on-axis, the plasma density profiles are rather flat and the modes are observed in a broad range of plasma density values, being their amplitude maximum for densities above the ECH cut-off (n_c = 1.7 10^{19} m^{-3}). However, when the plasma target is heated with ECH off-axis ($\rho \geq 0.4$), as the density increases the density profile becomes peaked and the Alfvén modes disappear.

These Alvén modes are also detected by the reflectometer. An example is displayed in figure 3a (magnetic fluctuations) and 3b (reflectometer). The modes are localized in the radial range ρ: 0.5 - 0.7, and they are absent at more external radial positions (ρ > 0.75). Unfortunately, the central part of the plasma (ρ < 0.5) is not accessible to the reflectometer.

Some experiments have been performed changing the working gas, helium instead of hydrogen, to study the dependence of the Alfvén modes on the main plasma species. As expected, a reduction in the frequency of the modes is observed when helium is the working gas (though the NBI always injects hydrogen).

Occasionally the Alfvén modes show multiple frequency values, however, further studies are needed to characterize these observations.

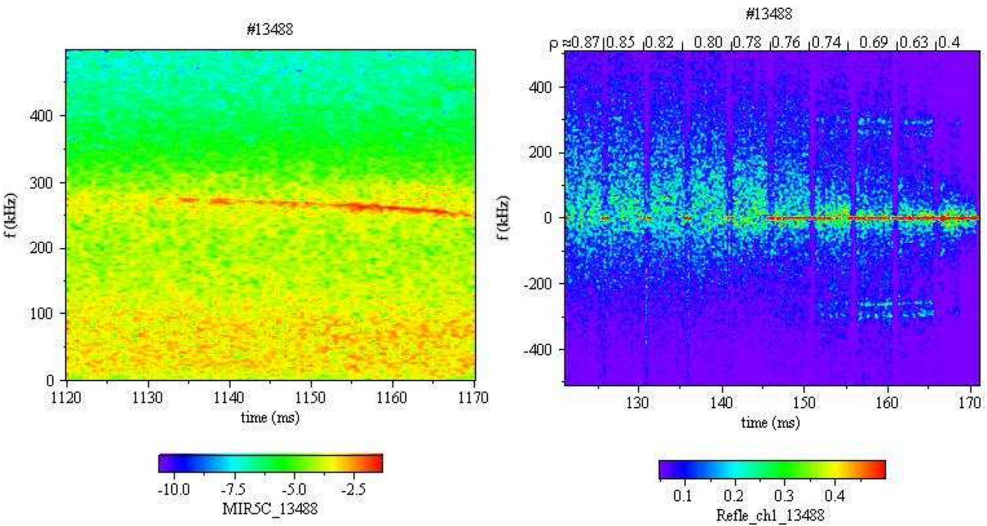

Figure 3: a) Mirnov coil and b) microwave reflectometer spectrograms.

References

[1] King-Lap Wong. Plasma Phys. Control. Fusion **41** (1999) R1-R56

[2] A. Weller, D.A. Spong, R. Jaenicke et al. Phys. Rev. Lett. **72** (1994) 1220

[3] Y. Teo, A. Weller, C. Konrad et.al. Nuclear Fusion, 38, No 3 (1998).

[4] D.A. Spong, R. Sánchez and A. Weller, Phys. Plasmas **10** (2003) 3217

[5] T. Estrada, E. Blanco, L. Cupido et al. These proceedings.

[6] L. Krupnik, J.A. Alonso, A. Cappa et al. These proceedings.

[7]. I. García-Cortes et al., Nuclear Fusion **40** (2000) 1867-1874.

[8] T. Estrada et al., Plasma Physics and Controlled Fusion, **44** (2002) 1615-1624.

[9] M. Anton et al., 24th EPS Conference on Controlled Fusion and Plasma Physics, Berchtesgaden 1997, ECA 21A part IV, 1645-1648.