*33rd EPS Conference on Plasma Phys. Rome, 19 - 23 June 2006 ECA Vol.**30I**, P-1.138 (2006)*

Characterization of the quasi-coherent oscillations by HIBP diagnostic in the TJ-II stellarator

L. Krupnik[1], A.A. Chmyga[1], L. Eliseev[2], A.D. Komarov[1], A.S. Kozachok[1], A.Melnikov[2], S. V. Perfilov[1], R. Jiménez-Gómez[3], A. Alonso[3], M.A. Pedrosa[3], J. L. de Pablos[3], C. Hidalgo[3], T. Estrada[3], E. Ascasíbar[3]

[1] *Institute of Plasma Physics, NSC KIPT, Kharkov, Ukraine*

[2] *Institute of Nuclear Fusion, RRC Kurchatov Institute, Moscow, Russia*

[3] *Laboratorio Nacional de Fusión, EURATOM-CIEMAT, Madrid, Spain*

1. Introduction

Quasi-coherent oscillations in the TJ-II stellarator are being experimentally characterized in various plasma parameter regimes and heating scenarios using different diagnostics: probes (Mirnov and Langmuir) and, more recently, by means of the Heavy Ion Beam Probe (HIBP) diagnostic. The improvement of the probe beam passing and the signal to noise ratio of the HIBP has allowed to observe the radial structure of those oscillations from the plasma edge to the core region, and to identify the radial location where the modes are developed. Comparative studies of the properties of those quasi-coherent modes by means of electrostatic (HIBP and Langmuir) and magnetic (Mirnov) probes can shed some light about their underlying electromagnetic nature.

MHD activity in TJ-II depends on the heating method used (ECH or NBI). The effect of low order rationals inside the rotational transform profile on MHD activity and transport properties has been studied experimentally and described previously for ECH plasmas[1-4]. The appearance of low frequency modes (some tens of kHz) in ECH plasmas depends on the rotational transform profile and plasma density. In NBI plasmas, high frequency (150-300 kHz) modes have been found in plasmas with line density range $0.6 – 3 \times 10^{19}$ m^{-3} and heated with on/off-axis electron cyclotron heating. They are good candidates for Global Alfven Eigenmodes related to the low order resonance n/m = 3/2 [4]. In this paper some properties of quasi-coherent modes investigated by HIBP and probe diagnostics in ECRH plasmas are reported.

2. Experimental set-up

HIBP diagnostic is used in TJ-II stellarator (four-period flexible heliac, B_0 = 1 T, R=1.5 m, a=0.22 m) to study directly the plasma electric potential with a good spatial (up to 1 cm) and

temporal (up to 2 μs) resolution [5]. The singly charged heavy ions Cs^+ with energies up to 125 keV are used to probe the plasma column from the edge to the core. ECRH heated plasmas (P_{ECRH}= 200 - 400kW) were studied. MHD instabilities in TJ-II stellarator are investigated using various Mirnov coil sets distributed at different toroidal sectors of the vacuum vessel [4]. In addition, edge fluctuations are characterized by multi-arrays of Langmuir probes [6]

3. Influence of magnetic topology

When rationals move towards the plasma core ($r \approx 0.3$), the modes are clearly seen in ECE emission and in HIBP secondary current and potential signals. These quasi-coherent oscillations (in the range of 20 kHz) have been connected with the development of electron internal transport barriers (e-ITB) triggered by the low order rational 3/2. Recent results show a decrease in the mode amplitude as e-ITBs are fully developed [3].

Quasi-coherent modes have also been observed in the plasma edge region. Detailed configuration scans moving low order rationals (8/5 and 5/3) through the edge region have shown that the appearance of the mode, as deduced from probes and HIPB measurements, depends on plasma configuration. In addition, HIBP measurements have shown that edge modes are usually located in the gradient region. The effect of magnetic configuration on the properties of quasi-coherent modes suggests the importance of the presence of low order rationals in the plasma edge. In addition, HIBP measurements show that the amplitude of edge modes is not the same in the high and low field side regions (see Fig. 1). In some cases the amplitude appears to be larger in the low field region, but no systematic trends have been observed so far with the present database.

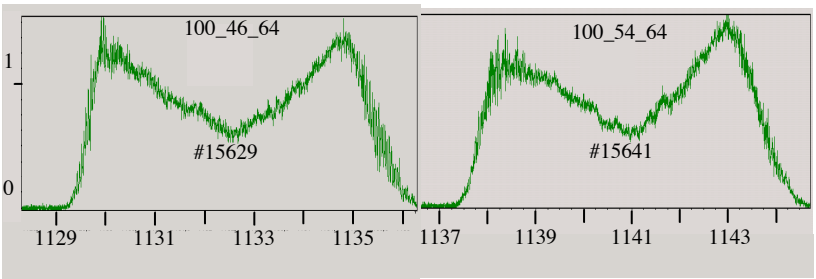

Figure 1: HIBP profiles showing the asymmetry of the mode amplitude in low and high field regions,

4**. Influence of plasma density and heating power**

Edge quasi-coherent fluctuations (with frequencies near 20 kHz) have been observed in some configuration windows when plasma density / heating power are above a threshold in ECRH heated plasmas.

Fig. 2 shows the time evolution of HIBP (total current), Langmuir probe (ion saturation) and Mirnov coil spectrograms in a ECRH discharge with rotational transform $\iota/2\pi(a) \approx 1.67$. In this shot, one gyrotron provides 200kW heating power during all the discharge. In the time window 1110-1210 ms the second gyrotron is switched on providing 100kW additional power. Edge quasi-coherent modes are triggered during the high (300 kW) heating power phase. The HIBP signals are strongly correlated with probe (Langmuir and Mirnov) signals.

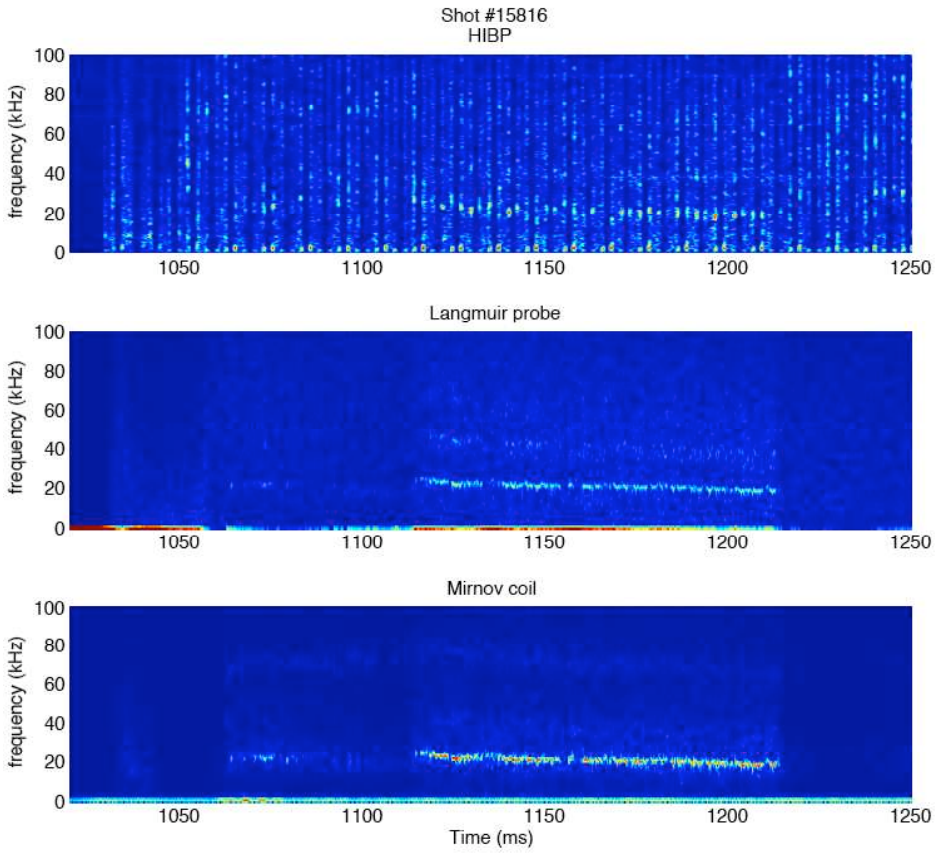

Figure 2: HIBP. Langmuir probe and Mirnov spetrograms showing the existence of a heating power threshold for the appearance of quasi-coherent modes.

Fig. 3 shows the time evolution of HIBP, Langmuir and Mirnov frequency spectra during a density scan experiment experiment. A low frequency mode is clearly observed in the three signals above a certain threshold density (which depends on magnetic configuration and is about 0.6×10^{19} m^{-3} in this case). It should be noted that the mode frequency slightly increases with plasma density; this result might be explained on the basis of ExB Doppler shift effects due to the link between perpendicular velocity and plasma density.

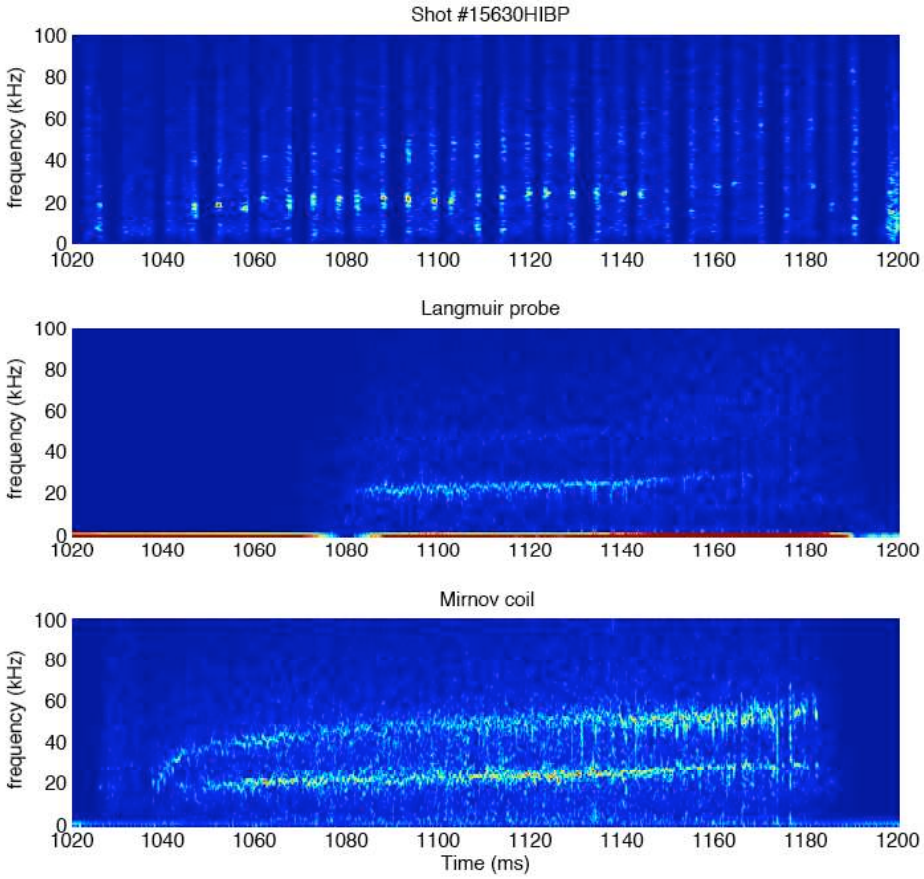

Figure 3: HIBP, Langmuir probe and Mirnov coil spectrograms in a discharge where the density is ramped up.

Although the appearance of edge quasi-coherent modes is usually observed simultaneously in HIBP and Mirnov signals, there are exceptions. In particular Fig. 3 shows that all three diagnostics, Mirnov coil, Langmuir probe and HIBP clearly detect a low frequency mode (near 20 kHz) the mode at higher frequency (40 kHz) is clearly observed only by the Mirnov coil. This can be related with the nature of those modes (i.e. electrostatic versus magnetic nature) or with the signal/noise sensitivity of HIBP diagnostic.

The existence of a threshold value in density and heating power points out to the role of threshold gradients needed to trigger quasi-coherent modes.

References

[1] I. García-Cortes et al., Nuclear Fusion **40** (2000) 1867-1874
[2] T. Estrada et al., Plasma Phys. Contr. Fusion **44** (2002) 1615
[3] T. Estrada et al., Plasma Phys. Control. Fusion **47** (2005) L57-L63
[4] R. Jiménez et al., Fusion Science and Technology (2006) (in press)
[5] L. Krupnik et al., Czech Journal of Physics **55** (2005) 317
[6] M.A. Pedrosa et al., Plasma Phys.Control. Fusion **47** (2005) 777-788