FIRST RESULTS OF THE ION BERNSTEIN WAVE EXPERIMENT ON FTU

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1. Introduction

The coupling of the ion Bernstein waves (IBW) via the slow wave mode-conversion scenario [1, 2] is the main purpose of the IBW experiment on FTU [3]. The operating frequency is 433 MHz; at the toroidal magnetic field of 7.8 T on the axis, the 4^{th} ion cyclotron harmonic of the hydrogen will be located about 10 cm away from the axis, on the low field side, with the 5^{th} harmonic located out the vacuum vessel. One of the three antennas planned for injecting 1.5 MW of total rf power, consisting of two phased waveguides, has been utilised for testing the IBW coupling by launching the Lower Hybrid (LH) wave. The mode-conversion into IBW is expected to occur near the cold LH resonant layer which is located in the scrape-off plasma, at a distance of the order of 1 cm from the antenna mouth.

A total power of about 350 kW has been coupled to the FTU plasma during the experiment, limited only by the rf generator. The corresponding rf power density coupled by the waveguide antenna was about 1.2 kW/cm^2. This value is in the range of the waveguide antenna performance expected extrapolating, at the operating frequency of 433 MHz, the maximum rf power density values obtained by the similar waveguide grill antennas employed in the Lower Hybrid experiments (see Fig. 1).

The measured rf power reflection coefficient was about 10%, with a dependence on the plasma density, measured at the antenna mouth, in agreement with the linear theory of the LH wave coupling [4]. This result suggests that the antenna should properly excite the slow electron plasma wave which is necessary for coupling the IBW to the plasma.

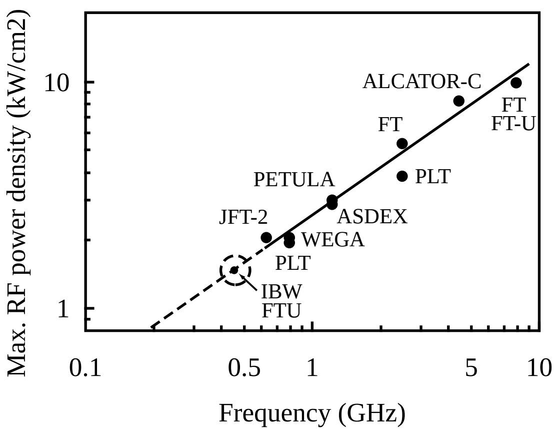

Fig. 1. Extrapolation, from the LH grill performances, of the expected rf power density performance of the IBW-FTU waveguide antenna.

In previous IBW tokamak plasma heating experiments [5 - 7] the antenna loading was found dependent on the operating rf power level, due to the ponderomotive induced reduction of the plasma density in the scrape-off plasma. During the IBW experiment on FTU, no influence of the injected rf power level was found on the measured reflection coefficient, suggesting that no important role is played by non linear phenomena in the antenna-plasma coupling. Therefore the optimum antenna coupling was found, for a given plasma target, only by adjusting the antenna-plasma distance and the waveguide phasing [3].

No evidence of parametric instabilities has been found, in the operating conditions explored up to now.

2. Impurity injection during rf

The antenna-plasma coupling has been optimised on a plasma target with the following parameters: plasma density (Hydrogen) $n_e \approx 8\ 10^{19}\ m^{-3}$, B_T = 6 ÷7.7 T, plasma current I_p=900 kA, ohmic input $P_{OHM} \approx$1.5MW. No substantial effects of plasma heating or confinement improvement [8] were observed; it should be noted, however, that the operating ratio of the injected rf power to the ohmic input power was: $P_{RF}/P_{OHM} \approx 0.2$. Figure 2 shows the evolution of the main plasma parameters during a typical hydrogen plasma shot. A 10% increase of the line-averaged plasma density is observed during the rf pulse, with no significant change of the peak electron temperature; the Z_{eff} shows an increase of about 10%.

The impurity behaviour was monitored during the rf pulse. The comparison of UV spectra in the range 200÷1200 Å, before and during rf injection, is shown in Fig. 3. During rf, we observe a 15% reduction of the heavy impurity lines and about a factor 2 increase of the Oxygen ones. Moreover, a reduction of the soft x-ray emission was observed during the rf pulse.

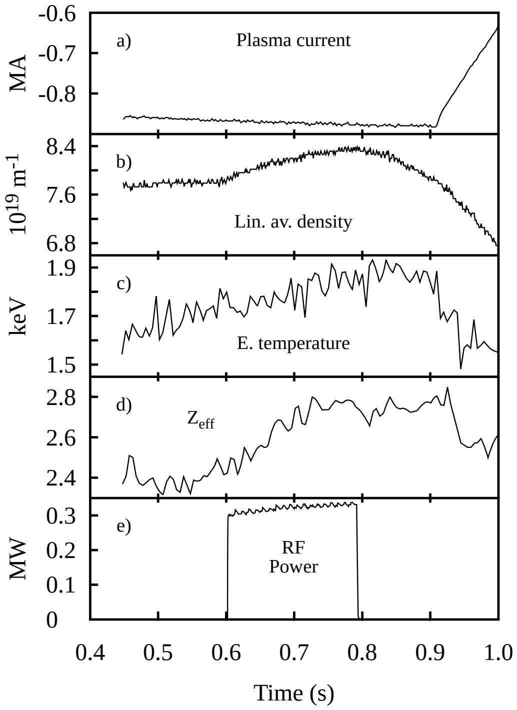

Fig. 2. Plasma paramters of a typical IBW-FTU plasma shot. B_T*=7.7T, Ip=900kA,* P_{RF}*=350kW@433MHz.*

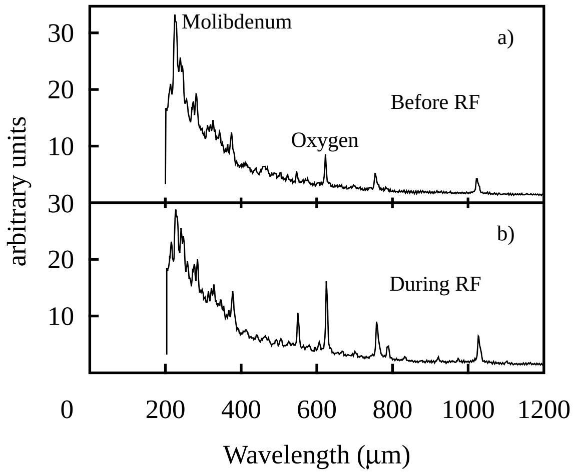

Fig. 3. U.V. spectroscopy observed during a typical plasma shot.

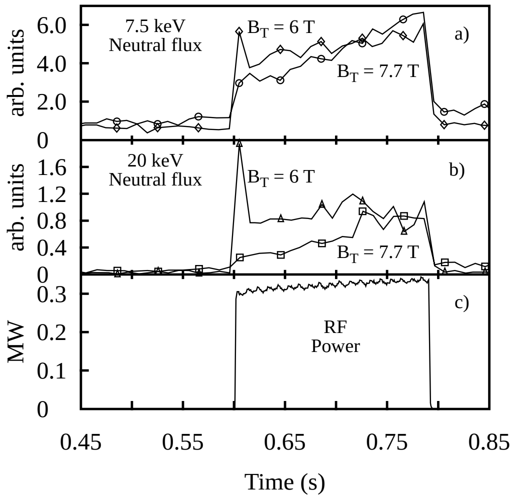

Fig. 4. Comparison of the neutral flux observed by the CX analyser during rf injected plasma shots with similar paramenters, but toroidal field B_T*=7.7T* (a), and B_T*=6T* (b).

3. Neutral flux during the rf pulse

The measurements of H neutral fluxes were carried out by CX analyser at different energies. In Fig. 4 fluxes are compared for two similar discharges, but with toroidal magnetic field of 7.7 T and 6 T, corresponding to operate with only the 4^{th} Ω_{cH} in the plasma, located near the plasma centre, and the 6^{th} Ω_{cH} located near the plasma edge, respectively. A smooth increase of the flux in the energy range 7 ÷ 20 keV has been observed at the rf power switch-on, when operating with the higher magnetic field value. A prompt increase of the flux has been observed at all energy values, when operating with the toroidal magnetic field value of 6 Tesla. This different behaviour could be attributed to a deeper penetration of the rf power in the high field operation case, and related to the increase of the line averaged plasma density produced by the rf pulse.

4. Comments and conclusions

Encouraging results about the waveguide antenna coupling have been obtained during the IBW experiment on FTU. The value of the coupled rf power density is in the range of the performance expected by frequency scaling the best results of the Lower Hybrid grills; the trend of the rf power reflection coefficient with the plasma density has been found in agreement to the one expected exciting the LH wave, necessary for coupling the IBW to the plasma. The operating frequency of IBW-FTU experiment, which is a factor 3÷10 higher than the frequency of the previous experiments, has probably made the antenna-plasma coupling less sensitive to the ponderomotive phenomena than in previous experiments [9,10].

The small Z_{eff} increase observed during the rf pulse should allow to detect possible effects of IBW, relevant for plasma heating and confinement, expected when operating with higher rf injected power, so that $P_{RF}/P_{OHM} \approx 0.5$.

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