Observations of the cold pulse propagation during multi-pulse molecular beam injection on HL-2A

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1. Introduction

As an advanced fuelling method on tokamak, molecular beam injection (MBI) has successfully been developed in HL-1M firstly and applied to HL-2A later. Many advantages such as peaked density profile[1] and the energy confinement time increasing[2] have been found in the MBI experiments. Some interesting phenomena[1~3] have been observed in the previous MBI experiments. But up to now the mechanism of the MBI seems not very clear.

The mechanism of the interaction of hydrogen molecular beam with plasma has been discussed in Ref.[4-5]. Although they are in dispute until now, they are helpful for us to understand the mechanism of MBI. In this paper, asymmetric perturbations of electron temperature and large-scale perturbations of central electron density have been observed during multi-pulse MBI.

2. Arrangements of experiment

HL-2A is a divertor tokamak with the following parameters: R=1.65m, a<0.45m, B_t~2.2T; $I_p = 0.32$ MA, $\overline{n_e} = 4.2\times10^{19}$ m^{-3}, T_e=800eV. At present, the gas source pressure is about 0.4MPa during the MBI experiments. Fig. 1 shows the experimental arrangement for the MBI in the HL-2A tokamak. The pulse molecular beam was driven by electric-magnetic valve. The molecular beam injects from the low field side (LFS). The width and the period of one pulse are 10ms and 30ms, respectively. Ten pulses of molecular beam can be injected during one discharge.

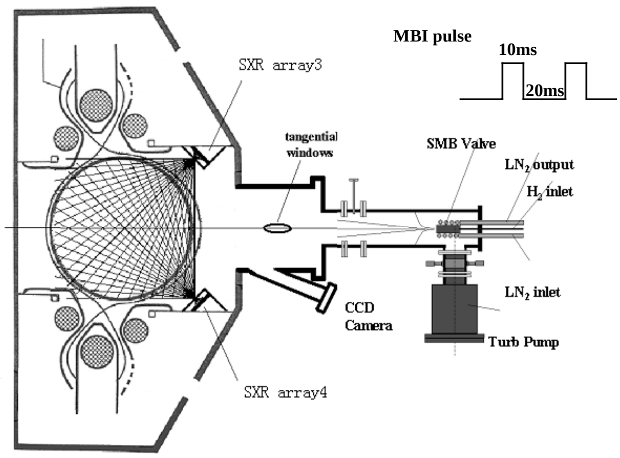

Fig. 1. Arrangement for MBI in the HL-2A tokamak.

At present, the ECE has twenty channels in once sweeping frequency which covering from 104 to 181GHz in 4ms. The FIR laser interferometer only has one channel through central plane. Four soft-X-ray (SXR) arrays have been arranged and every array has 20 channels. The main data analyzed in this paper are obtained by SXR array, ECE diagnostic and FIR laser interferometer. Note that the data of FIR laser interferometer and SXR are the central chord line-average signal and chord integrated signal respectively, and only the ECE is local parameters due to the toroidal magnetic field decreases monotonically with radius.

3. Experimental results

3.1 The features of the cold pulse propagation

Fig.2 shows the evolution of the ECE 2nd harmonic at the different radius during multi-pulse MBI. The propagation of the cold pulses from plasma edge to its inside has been observed obviously. In the high field side (HFS) the cold pulses propagate from r = 41cm to r = 30cm. The amplitude of the cold pulse decreases with the decreasing of the radial position. The phase difference of the cold pulses at the different radius is difficult to be distinguished because the time resolution of the ECE diagnostic is not high enough, then the phases of the cold pulse look like very similar. In the LFS the cold pulses can propagate to r = 12cm. The propagation depth of the cold pulse in LFS is much longer than that in HFS, indicating that propagation depth of the cold pulse during the MBI is asymmetric. As we know, the intensity of the ECE 2nd harmonic at the edge of the plasma is not always proportional to the electron temperature because of the low optical thickness[6], but the propagation of the cold pulse is only related with the variation of the electron temperature obviously, comparing with the edge electron temperature with the electrostatic probe, which is shown in bottom of Fig 2.

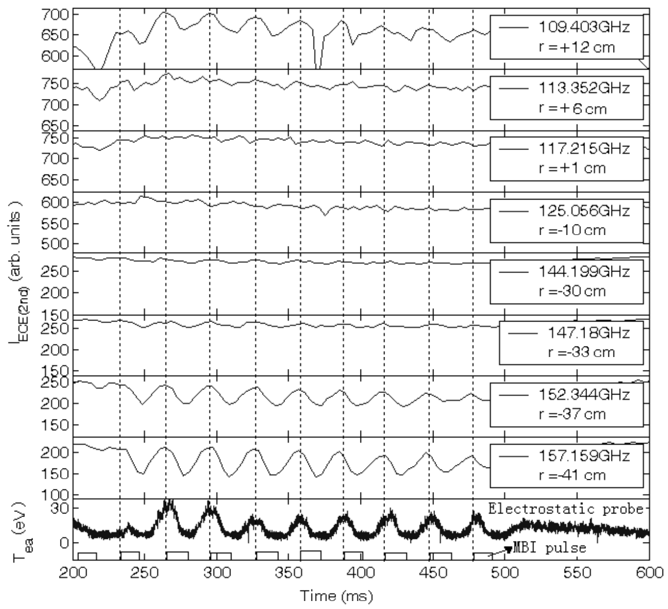

Fig. 2. Time evolution of the Te during MBI

The asymmetric propagation of the cold pulse can also be observed by SXR array. Fig. 3 shows the time evolution of the SXR intensity. It can be found that the phase of the SXR intensity pulses in the plasma center is reverse to the phase of the pulses at the plasma edge, which is in-phase with the ECE 2nd harmonic measurement. The SXR intensity pulses in the plasma center are related with variation of the electron density, which will be analyzed in the next section. But the different propagation depth in LFS and HFS is very clear. The cold pulses of the SXR at the plasma edge have small phase shift. The propagation depths of the cold pulse in LFS and HFS are about 29cm and 14cm, respectively, which is in good agreement with the results of the ECE measurement.

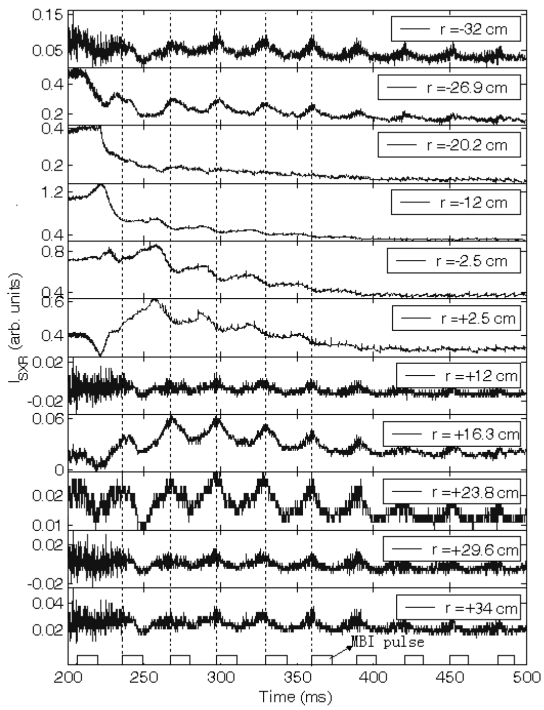

Fig. 3. Variations of SXR intensities during MBI

3.2 The features of the density perturbation

Five channels of the ECE 3rd harmonic which almost lie in LFS can be measured in the case of B_t= 2.1T. Fig.4 shows the time evolution of the ECE 3rd harmonic and $\bar{n}_e$ measured by FIR laser interferometer during multi-pulse MBI. The perturbations of the ECE 3rd harmonic have been observed during gas injection, and the phase of the perturbation in the plasma center (r= 2cm and r= –4cm) is reverse to the phase of the pulse at r = 14cm and r= 8cm, which is in-phase with the ECE 2nd harmonic measurement. The intensity of the ECE 3rd harmonic is proportional to the electron density and the cube of the electron temperature [6], so the perturbations of the ECE 3rd

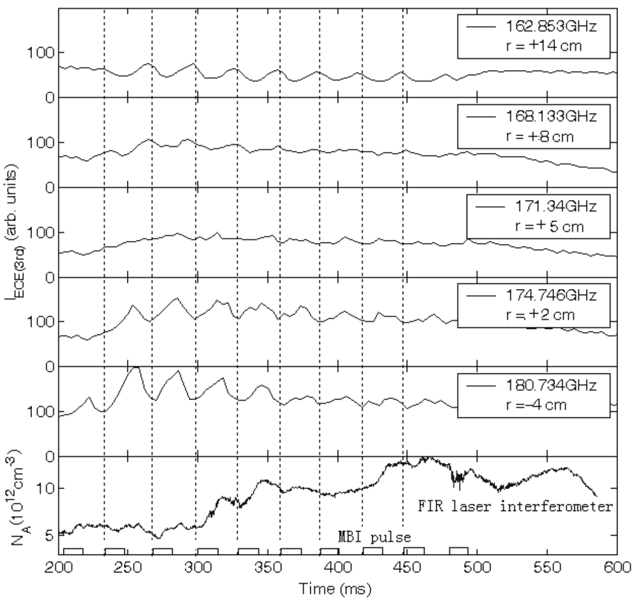

Fig. 4. Time evolution of 3rd harmonic and $\bar{n}_e$

harmonic at r = 14cm and r= 8cm are main related with the perturbations of electron temperature, because the intensity of the 3rd harmonic decreases during gas injection and the temperature perturbation has been observed at r= 12cm. But the electron temperature in the plasma center (from 6cm to –6cm) is not changed as mentioned above, therefore the perturbations of the ECE 3rd harmonic at r = 2cm and r= -4cm are only related with the electron density. The $\bar{n}_e$ increases with pulse perturbations during MBI. The phase of the perturbation is corresponding to that of the ECE 3rd harmonic in the plasma center, indicating that the perturbation in the plasma center is really produced by variation of the electron density. The SXR perturbations in plasma center have the same phase features, which means that the SXR perturbations are also related with the electron density, instead of electron temperature.

4. Summary

Heat and density perturbations have been observed in the plasma during recent multi-pulse MBI experiments. The present experimental results are as following:

1) The propagation depth of cold pulse at the two sides of plasma column during MBI is asymmetric. The propagation depth is about 30cm in LFS and is only about 10cm in HFS.

2) The cold pulses cannot propagate to the plasma center both from HFS and LFS and the electron temperature in plasma center is not changed during MBI.

3) Electron density pulse perturbations have been observed in the plasma center.

Acknowledgments

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