§31. Measurement of Radio-frequency Wave by Microwave Reflectometry

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Wave heating using ion cyclotron range of frequency (ICRF) is one of popular heating methods in fusion plasmas. In order to understand wave physics in plasma and to achieve higher heating efficiency, it is necessary to measure the local RF electric field in the plasma. One of the methods is to measure the density oscillations induced by the RF electric fields. Microwave reflectometry is known as a method which has a very high sensitivity to local density fluctuations. Detection of ICRF waves by the use of microwave reflectometry has been demonstrated in the GAMMA-10 mirror device, the DIII-D tokamak device and the TST-2 spherical tokamak device. Fortunately, LHD is equipped with many microwave reflectometer systems covering wide frequency ranges, and it is useful to try RF wave detection.

A heterodyne microwave reflectometer system with probing frequencies of 65 and 78 GHz was used. The microwave is reflected at the X-mode cutoff around the edge of the LHD plasma, and the wave is mixed with a local wave with a frequency of 60GHz. Thus the intermediate frequencies (IFs) are 5 and 18 GHz, respectively. The IF signals are filtered, amplified and detected. Therefore the RF pickup noise does not affect the signal before they are detected by the detectors. This procedure is useful to minimize the RF noise. If the microwave sources suffer from frequency modulation induced by the RF noise, the signals can be contaminated by the RF noise. In order to evaluate these noises, we measure the reflection from a fixed metal target instead of the plasma cutoff. In this case, the signal includes both RF noises.

The detected signals are amplified and measured by a fast oscilloscope and the data was stored on memory. Figure 1 shows the power spectrum of the microwave signal during ICRF heating with a frequency of 38.5 MHz. The plasma parameters were 2.75 T, $\langle n_e \rangle \sim 1 \times 10^{-19} m^{-3}$, $T_e \sim 2.5$ keV, and ICRF power was 1.2 MW. The noise is measured by the above described method. The peak power density was about an order of magnitude higher than the noise level, and the signal shows a broad component with a width of around 0.1 MHz. The signal seems to be larger for lower density plasmas. The signal was observed for microwave probing frequencies of 65 and 78 GHz.

Figure 2 shows the time evolution of the linear scaled power spectrum during a long period (~6 min.) discharge sustained by the ICRF heating with a frequency of 38.5 MHz. The peak power showed a large modulation with a frequency of 120 Hz.

Detection of ICRF waves by microwave reflectometry was demonstrated for the first time in helical devices. However, the S/N ratio was not sufficient in most discharges. In addition, probing microwave frequency could be changed only on a shot by shot basis. We are preparing for new system, where probing microwave frequency can be changed during a discharge.

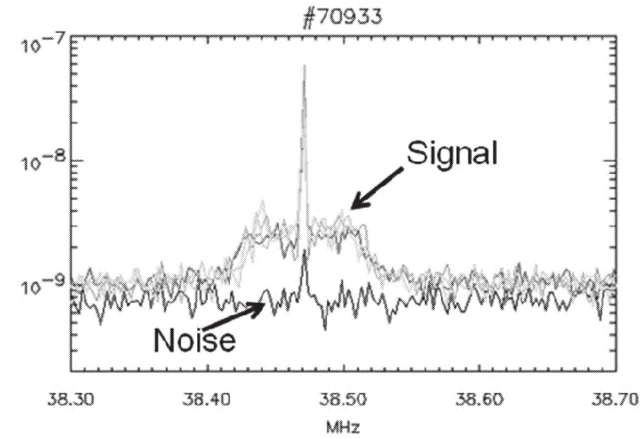

Fig. 1. Power spectral density ([a.u.]) of microwave reflectometer signal with a probing frequency of 78GHz.

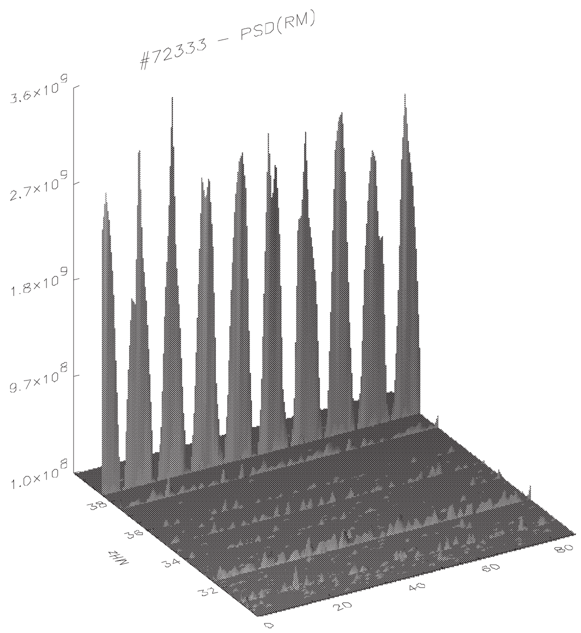

Fig. 2. Slow time evolution of the power spectrum ([a.u.]) of microwave reflectometer signal during ICRF heating.