§9. Electron Density Fluctuation Measurement with Microwave Imaging Reflectometry (MIR) in LHD

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By measuring the local electron density, the micro and macro instabilities can be investigated experimentally. The Microwave Imaging Reflectometry (MIR) is one of the most promising diagnostics on the local electron density. In MIR the plasma is uniformly illuminated with the microwave, of which source is RF, and the plasma wave reflects it at the cutoff density. Imaging optics makes the image of fluctuating plasma on imaging detectors. The electron density fluctuations cause the fluctuations of phase of the reflected wave primarily. Also amplitude fluctuations are caused by density fluctuations. Hence both the phase (ϕ) and the amplitude (A) of the reflected wave are detected with this system. The phase is detected with the I-Q demodulator that makes the I (~cos ϕ) and Q (~sin ϕ) signals.

Figure 1 shows the I, Q and A signals in the case of low density plasma (R_{ax} = 3.9 m, B_{ax} = 0.9 T, $n_e = 0.1\times10^{19}$ m^{-3}) that does not have a reflection surface. The I and Q signals are sinusoidal, of which amplitudes are constant. The phase of I signal is 90 degrees ahead of that of Q signal. So, I and Q correspond to cosϕ and sinϕ, respectively. Since the plasma does not have a reflection surface, the microwave should be reflected at the vacuum vessel wall. When the line integrated electron density (nL) rapidly changes (t = 3.4 - 3.7 s), the phase varies. Change in nL corresponds to the phase change. Actually, from t = 3.41 s to 3.42 s, the MIR phase (61.808 GHz) proceeds 12.3 fringes while the nL increases 0.2836×10^{19} m^{-3}. This corresponds to the MIR phase change of 12.3 fringes.

Figure 2 shows ECE and MIR signals in the case of standard operation (R_{ax} = 3.6 m, B_{ax} = 2.75 T, $n_{e0} = 2.5\times10^{19}$ m^{-3}). The reflection surface is at R = 4.55 m. Periodic bursts with a period of about 0.3 ms were observed in the MIR signals, but not in the ECE signals. The time evolution of FFT spectra of MIR and ECE signals are plotted in Fig. 3. At 9.1 s (timing of Fig. 2), a peak at 3 kHz with many higher harmonics was observed in the MIR signal, but nothing is seen at 9.1 s in the ECE spectrum. Thus MIR is more sensitive than ECE.

This mode with higher harmonics is called as "edge harmonic oscillation" (EHO). The MIR signal shows that EHO is a periodic burst of the electron density fluctuations. As the phase signals (I, Q) change rapidly, the reflection surface moves quickly in the radial direction. At the top of the amplitude, the phase does not proceed. In the decay phase of the amplitude the phase is reversed. This result indicates that the EHO is a radial motion of a plasma structure.

This work is supported by NIFS (KCHP017, KLHP303, ULPP008).

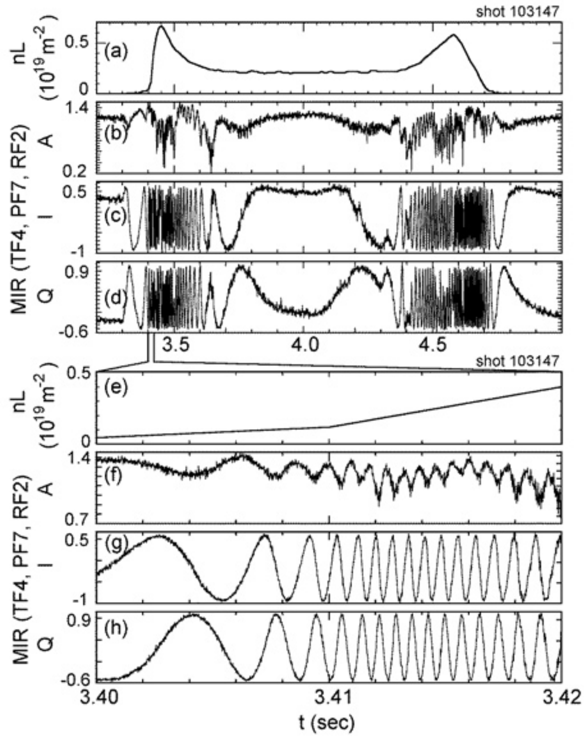

Fig. 1 MIR signal in the case of low density plasma without reflection surface.

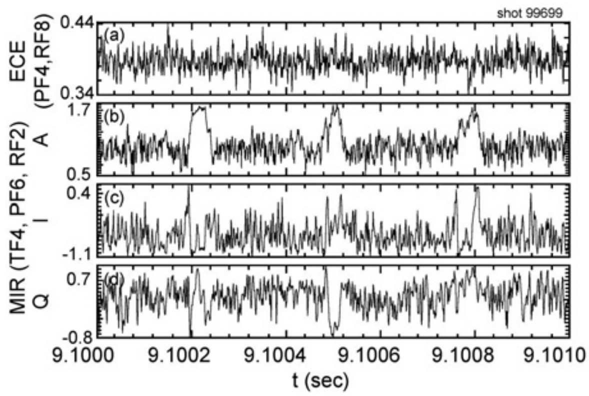

Fig. 2 ECE and MIR signal in the case of EHO.

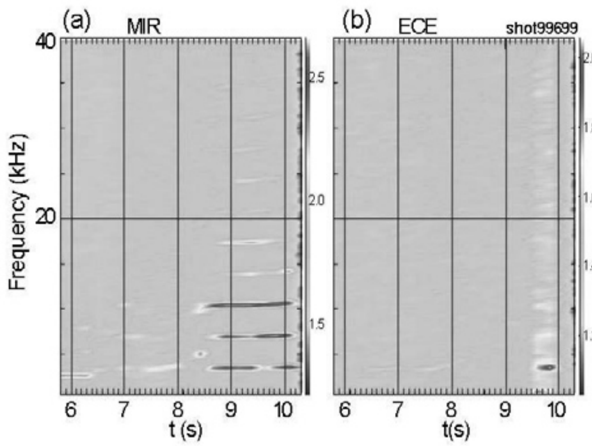

Fig. 3 FFT spectra of the MIR amplitude (A) and ECE signals in the case of EHO.