§16. Study on Electron Density Fluctuations by Microwave Imaging Reflectometry

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Microwave imaging diagnostics can be potentially used to observe 3-D structure of fluctuations and instabilities in magnetically confined high temperature plasmas. Microwave reflectometry is a radar technique used for the measurement of electron density profiles and density fluctuations. This measurement is achieved by probing the electron density-dependent cutoff layers in plasmas. Turbulence and MHD instabilities are accompanied by electron density fluctuations. Microwave imaging reflectometry (MIR) can be one of the most powerful diagnostic techniques for investigation of localized electron density structures[1].

In the MIR system on LHD, microwave at four different frequencies (60.41, 61.81, 63.01 and 64.61 GHz) are projected simultaneously onto target plasmas for the observation of four different cutoff surfaces. The illumination waves and reflected waves from each cutoff surface are focused wiht microwave imaging optics. The optics consists of beam splitter made of acrylic plates, ellipsoidal and paraboloidal mirror made of aluminum alloy. In combination with a 2-D horn-antenna mixer array (HMA)[2] having 6×7 channels, the 3-D observation at radially 4, toroidally 6 and poloidally 7 positions can be carried out. Reflection amplitude and phase are detected using power detectors and quadrature demodulator circuits. Narrow-band, surface acoustic wave (SAW) filters with a bandwidth of ~ 4 MHz are applied to the detection circuits with GaAs low-noise amplifiers for noise reduction. The electronic components mounted on the detection circuits are those used in advanced mobile communication modules, such as global positioning systems or mobile phones, and are provided at low cost.

Figure 1 shows waveforms in the case of High-Temperature experiment, #106139. In this shot, MIR reflection power measurement revealed a harmonic oscillation signal during a NBI injection period. This mode with higher harmonics is called as "edge harmonic oscillation " (EHO). The frequency of the oscillations appeared to vary with increasing electron density. Because of MIR uses X-mode cutoff, observation area is a function of the electron density and the magnetic field strength.

Figure 2 indicates 3-D wave numbers inferred from MIR reflection power signals at a time slice of 4.0. Harmonic oscillation signals were observed in all the MIR channels. Each wavenumber (toroidal, poloidal and radial directions) were calculated by from phase delays along each direction array, toroidally 6 channels, poloidally 7 channels and radially 4 channels. Obtained wavenumbers are significantly large compared with other diagnostics.

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1) Y. Nagayama, et al., J. Plasma Fusion Res. 87, **6**, 339-344 (2011).
2) Kuwahara, D. et al.: Rev. Sci. Inst. **81**, 10D919 (2010).

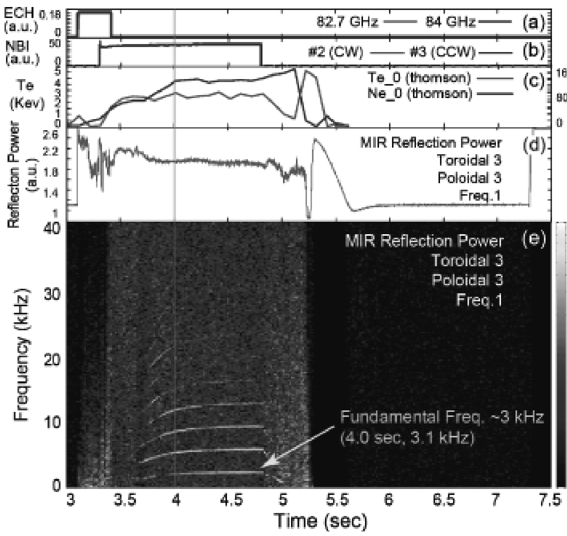

Figure 1 Waveforms of shot No. 106139. (a) ECH timing, (b) NBI timing, (c) electron temperature and electron density, (d) MIR reflection power (60.41 GHz), (e) FFT spectra of (d).

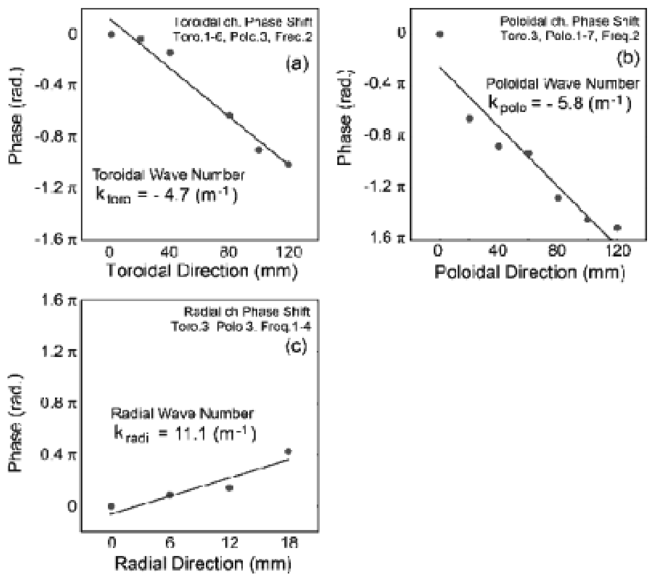

Figure 2 Wave numbers in (a) toroidal, (b) poloidal and (c) radial directions.