§39. Exploration and Comparison of Physical Mechanisms Related to the Dynamic Evolution of Density Profiles in Toroidal Confinement Systems

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It is necessary to understand mechanism of anomalous transport to improve plasma confinement. It is thought that anomalous transport comes from fluctuations of magnetic field, electric field, plasma density, and temperature out of various instability of plasma. Therefore, it is important to measure these parameters. Measurement of density fluctuations with electrostatic probes and a beam emission spectroscopy has been developed and used in Heliotron J. However, they can apply only to the edge plasma region. Microwave reflectometer has a capability of measuring fluctuations over the confinement region for ECH and/or NBI plasmas by choosing injection frequency. In this research, we have been developing a microwave reflectometer system to measure electron density fluctuations. The goal of the research is to clarify the behavior of electron density fluctuations in the plasma where plasma confinement is improved or energetic-particle-driven MHD instabilities are excited.

We have designed and assembled a microwave reflectometer and performed a characteristic test. Figure 1 shows the schematic of microwave reflectometer. The injection frequency of microwaves to plasma are from 26.26 to 41.14 GHz (Ka-band), corresponding that the cut-off electron density ranges from 0.9 to 2.1×10^{19} m^{-3}. A function generator supplies DC or step function to a voltage controlled oscillator (VCO). The microwaves are then divided into the waves injected to plasma and the reference waves by using a directional coupler. After the injection waves are up-converted with 100 MHz by a local oscillator, these frequency is doubled by a x2 frequency multiplier and the waves are injected into the Heliotron J plasma and received through pyramidal horns. The received microwaves are mixed with reference waves to down-convert to the frequency of 200 MHz with fluctuations, delivering to an I/Q detector. We can estimate the complex phase difference between the received waves and the reference waves through the I and Q signals.

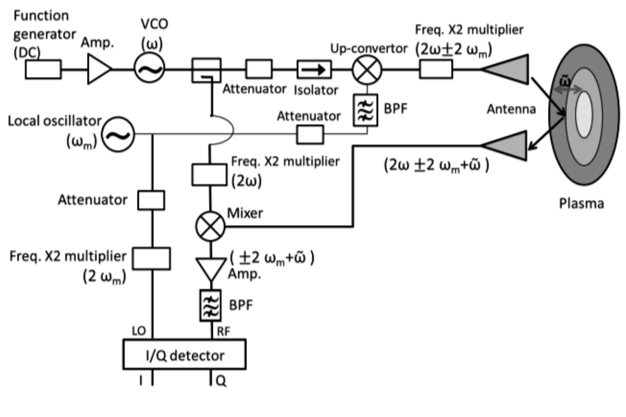

Fig. 1. Schematic of reflectometer system for density fluctuation measurement

We have examined the performance of the reflectometer in a test stand. The incident horn is moved away from the received horn by 1mm and measured the intensity of I and Q signals. The upconvertor generates both sideband frequency waves, making the I and Q signals with the constant phase. It is found that the wavelength of I and Q signal corresponds to that of carrier frequency, λ = 1.14 cm. It suggests that the amplitude of I and Q signals reflects the phase between incident and reflected waves, expecting that we can measure the density fluctuations.

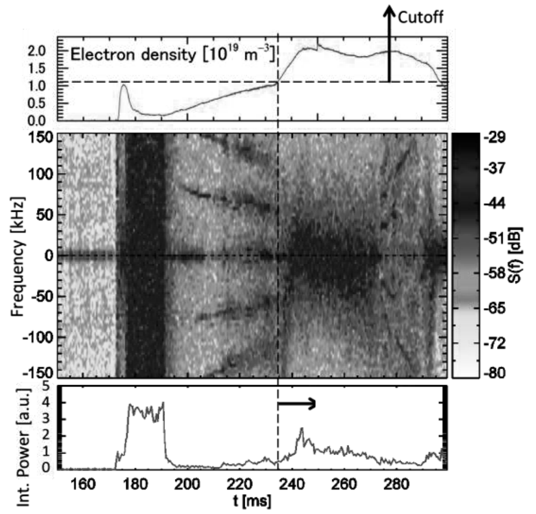

Fig. 2. Time evolution of electron density and density fluctuation at shot#58343

Figure 2 shows the time evolution of FFT power spectrum of density fluctuation measured with this reflectometer system in a plasma discharge. When the electron density exceed the cut-off, the I/Q signal intensity increases, and the power spectrum density at low frequency range increases. Although the density is below the cut-off before 235 msec, coherent modes of 50-90 kHz and 120-150 kHz are observed. As shown in Fig. 3, the modes has a high coherence with magnetic probe signals, suggesting that the modes are energetic particle driven MHD modes.

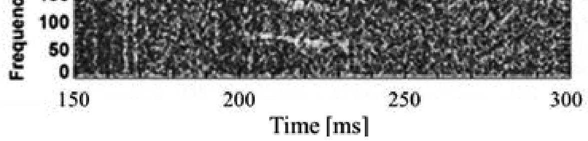

Fig. 3. Time evolution of coherence between reflectometer signal and magnetic probe signal