19PB-091

Density fluctuation measurements in the GAMMA 10 central cell by using the Fraunhofer diffraction method

GAMMA10セントラル部におけるフラウンホーファー回折法を用いた密度揺動計測

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We applied a Fraunhofer diffraction (FD) method to the GAMMA10 central cell plasma. The FD method can measure the density fluctuation in detail and obtain the frequency and wave number of the fluctuation. We successfully obtained the density fluctuation spectra in the GAMMA 10central cell. By analyzing the FD method signals of radial fluctuation intensity profile, we can successfully obtain the frequency, wave number and the phase velocity of the density fluctuation.

1. Introduction

Measurements of spatially and temporally resolved frequency and wave number spectra of the fluctuations are important in the fusion plasma experiments. A measurement of spatially and temporally resolved frequency (ω) and wave number (k) spectra is essential for the waves. Microwave to infrared laser scattering techniques have been used for the purpose. There are two types of instabilities which are a rotationally driven mode with the lowest azimuthal mode number and a drift-wave mode with high azimuthal mode numbers. In tandem mirrors the rotational mode is driven by $E_r \times B$ rotation energy at the lowest azimuthal mode number, m = 1. Higher modes with m > 2 will be stabilized by finite Larmor radius effects. On the other hand, the drift-wave mode arises because of the existence of a density gradient. The radial electric field E_r arising from the potential causes the $E_r \times B$ plasma rotation in the direction of the ion diamagnetic drift velocity, which may enhance instabilities, such as rotational flute and drift-wave modes, and degrade radial confinement. However, present study shows that the suppression of drift type fluctuation in the potential and density fluctuations with producing axial confining potential in GAMMA 10[1]. Typical plasma parameters of the electron and ion temperatures, electron density, and the plasma potential are about 40 eV, 5 keV, 2×10^{12} cm^{-3}, and 200 V, respectively. The electron and ion temperatures are measured by using an yttrium-aluminium-garnet Thomson scattering system[2] and a charge exchange neutral particle analyzer, respectively. The electron density and the potential are measured by using the microwave interferometer system and the gold neutral beam probe (GNBP) system, respectively. In GAMMA10, there are several fluctuation measurement systems, such as the electrostatic probes, magnetic probes, GNBP system, microwave interferometer systems, reflectometry systems, a Fraunhofer diffraction (FD) method, and end plate systems[3]. The FD method is one of the forward scattering methods. The FD method system can measure the radial profile of the density fluctuations in plasma in detail. With comparing the probe beam and the scattered beam by the fluctuation in the plasma, we can obtain the frequency and wave number of the fluctuation. In GAMMA 10, the FD method system consists of the eight detectors array system in order to obtain the radial fluctuation profile in a single plasma shot. In this study, we show the fluctuation spectra and the k-ω spectra of the fluctuation in GAMMA10 central cell plasma.

2. GAMMA10 tamdem mirror

GAMMA10 tamdem mirror is an effectively axisymmetrized minimum-B anchored tandem mirror with thermal barrier at both end-mirrors. The main plasma confined in GAMMA10 is produced and heated by ion cyclotron range of frequency heating(ICH). The potentials are produced by means of electron cyclotron heating (ECH) at the plug/barrier region. Low frequency density and potential fluctuations in several kilohertz are excited in the central cell. Present studies show the suppression of low-frequency fluctuations of the density and the potential during axial confining potential formation with application of plug-ECH.

3. FD method system

The FD method system is installed in the central cell of GAMMA10(Fig.1). In the FD method system, a heterodyne detection is applied to the scattered and incident beams to detect them within the undeviated incident beam, i.e. within the divergence of the probing beam. The scattering angle has to be larger than the divergence angle of the incident beam in order to avoid stray light.

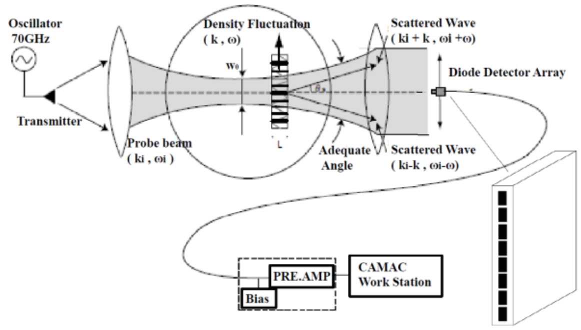

Fig. 1. Schematic diagram of FD method system.

A beam of 70 GHz microwave is focused on the plasma center by a fused quartz lens (f = 400 mm, φ= 105 mm). The frequency-shifted FD signal and the unshifted transmitted wave are focused via another lens (f = 400 mm, φ= 125 mm) onto GaAs Schottky barrier diode mixers bonded to gold bow-tie antennas, which form a monolith with a fused quartz substrate.

The sampling rate of the ADC is 100 kS/s and the maximum measuring duration is 200 ms. The eight channel detector array is used in the FD method system. The detector position can be moved in the y-axis direction in order to study the FD signal profiles in detail. The wave number of the density fluctuation can be obtained by the radial profile of FD signal analysis.

4. Experimental results

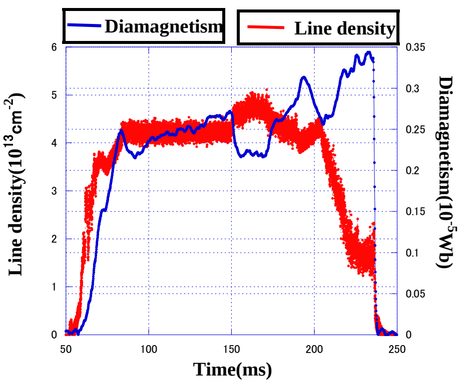

Fig.2 Electron density and diamagnetism.

The plasma is maintained and heated with applying ICH from t = 51 ms to 240 ms and the confinement potential is produced by applying P-ECH with power of 50 kW from t = 150 ms to 190ms. Figure 6 shows the time evolution of the electron density (red line) and diamagnetism (blue dotted line) in the central cell. In this plasma, the electron density and diamagnetism decrease between t = 150 ms and t = 175 ms during P-ECH periods half.

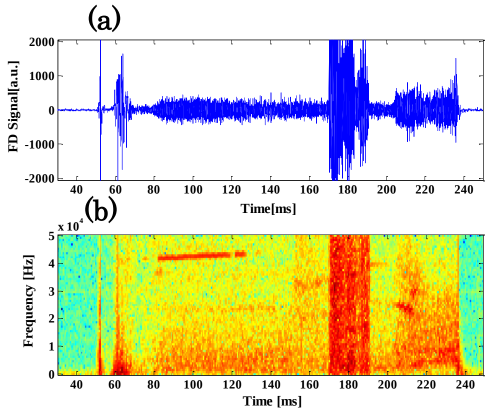

Fig.3 Time evolution of the FD raw signal (a) and the FFT spectrogram (b) of channel 4.

The time evolution of the FD raw signal and the fast Fourier transform (FFT) analyzed spectrogram of channel 4 are shown in Fig.3 (a) and (b), respectively. It is found that there are strong fluctuations from t = 155 ms to t = 165 ms with frequency of about 30 kHz.

5. Summary

The FD method was applied to the GAMMA10 central cellplasma in order to measure the low frequency density fluctuations in detail. We could successfully obtain the wave number and phase velocity of density frequency fluctuation. The every FD signals are obtained between 50ms and 250 ms with sampling rate of 100 kS/s in the single plasma shot. We can study fluctuations in plasmas in detail by using the FD method system with changing the plasma heating sequences.

Acknowledgments

The authors would like to thank the members of the GAMMA10 groups for their collaboration in the experiments and for helpful discussion. This study is supported by the bi-directional collaboration researches with NIFS(NIFS11KUGM050).

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