§11. Development of a Microwave Frequency Comb Reflectometer for Multi-scale Turbulence Measurement

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Nonlinear coupling in multi-scale turbulence is one of the keys in the transport mechanism, and dynamical changes of the mean and fluctuation profiles must be measured with high spatio-temporal resolutions for the identification. In this research, development of a new experimental diagnostic for detailed fluctuation measurements is promoted with the integration of theoretical, simulation and experimental approaches. For that purpose, a reflectometer using microwave frequency comb has been developed [1]. The comb signal with the frequency range of 12 - 27 GHz and the frequency interval of 0.5 GHz is injected and reflected in the plasma, and the density profile can be reconstructed from the comb signal. Turbulence Diagnostic Simulator (TDS) [2], which is an assembly of simulation codes for numerical diagnostics in magnetically confined plasmas, is used as the platform. This is the second year of the research planned for three years, and the diagnostic system has been developed to carry out plasma experiments both in the basic plasma and high-temperature torus plasma.

An experimental test has been begun on the PANTA device in Kyushu University from the last year, and the efficiency of the system is confirmed with plasma experiments in this year [3]. The signals are directly transferred to the digital storage oscilloscope (DSO), so the waveforms of the incident and reflected signals are detected with high temporal resolution. The O-mode microwave reflectometer system enables simultaneous monitoring at more than 30 distinct spatial locations. The signals are considered to be a series of pulse (the full width at half maximum of the envelope is 0.07 ns and the repetition period is 2 ns). Digital convolution between incident and reflected pulses allows estimating the phase delay, which is proportional to the distance to the reflection point, with a low level of noise. Reconstruction of the density profile becomes possible, as in Fig. 1, which is not contradictory to that obtained from probe measurements. The spatial and temporal resolution will be improved for simultaneous measurement of the mean profile and its fluctuations.

For the reconstruction of the profiles, it is necessary to carry out a numerical simulation, so the routine to simulate the microwave frequency comb reflectometer has been developed in the TDS [4]. The module of the ray tracing of the RF wave in the integrated simulation code TASK [5] is developed to include the density profiles from experiments. Calculation of the ray and the phase delay gives the evaluated output signal in accordance with the plasma density profile. Figure 2 shows an example of comparison between different discharges in PANTA. Different Fourier components have the different phase delays related to different reflected points as in Fig. 2 (b) and (c). This simulation gives the insight to experimental observations

The method is applied to the LHD experiment [6,7]. The direct measurement of reflected signals using the DSO enables simultaneous monitoring of fluctuations and mean profiles. The obtained mean electric field profile near the plasma edge is consistent with that from the charge exchange spectroscopy. The system is developed to observe fluctuation levels at 36 distinct spatial locations, which will be applied for more detailed measurements of fluctuations. The development of the data analysis method is also important, so the response of turbulence is investigated in detail both with experimental [8] and simulation data [9]. These methods are effective to clarify the characteristic responses of the turbulence.

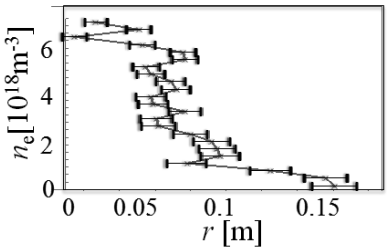

Fig.1: Initial result of the density profile measurement with the microwave frequency comb reflectometer in PANTA.

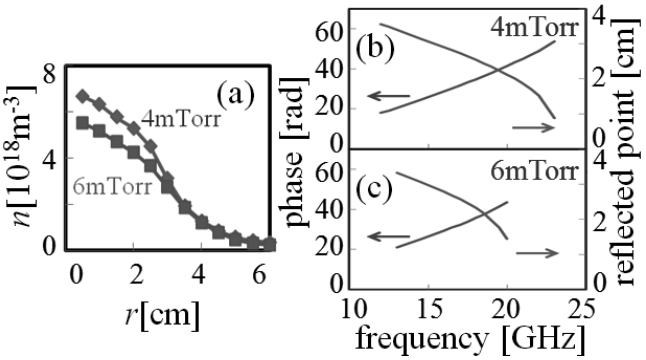

Fig.2: (a) density profiles with different gas pressures (4mTorr and 6mTorr) in PANTA. Simulation result of the reflected points and the phase delays in (b) 4mTorr and (c) 6mTorr discharges. The incident comb signal has the frequency range of 12 - 27 GHz and the frequency interval of 0.5 GHz in these cases.

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