18pD2-1

Multi-point Measurements for Study of Plasma Turbulence in the LHD
同時多点計測によるLHDプラズマ乱流揺動の研究

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In order to study a spatio-temporal turbulence dynamics in the Large Helical Device (LHD) plasmas, the turbulent diagnostics with high spatial and temporal resolution were needed. A *ka*-band multi-channel Doppler reflectometer system was constructed for the LHD using a comb frequency generator as a source. A filter bank system is utilized for precise quadrature phase detection, and preliminary back-scattered waves caused by the turbulence were obtained in LHD plasma experiments.

1. Introduction

A spatio-temporal turbulence dynamics, which shows the linkage between micro-, meso-, and macro-scale turbulence, is one of the hot topics in the magnetic confined fusion plasma study. For this study, the technique of global observation of turbulence is demanded.

Doppler reflectometry (also called Doppler back-scattering: DBS) is one of the answer. It is a unique technique when used in combination with the back-scattering method, which provides a wavenumber resolution, and reflectometry, which provides a high-spatial resolution [1]. Doppler reflectometry can measure the perpendicular velocity of electron density fluctuations $v_\perp$, the radial electric field E_r, and the perpendicular wavenumber spectrum $S(k_\perp)$ in magnetized confinement plasmas. There are some systems in worldwide fusion plasma devices, such as tokamaks and helical/stellarators [2].

When a multi-channel system is operating over a broad frequency range, the system is utilized for measuring not only the spatial structure of the parameters, but also the temporal relationship between two (or many) points in space. These measurements are quite helpful for evaluating plasma turbulence, transport, and confinement phenomena. For these reasons, a new multi-channel Doppler reflectometer has been developed for the LHD.

2. Diagnostics System

The *ka*-band (26–40 GHz) microwave frequency comb Doppler reflectometer system is described as follows. A passive, nonlinear transmission line (NLTL: PSPL model 7112) modulated by a stable synthesizer is used as the frequency comb source. NLTLs have excellent low phase noise performance and generate an array of equally spaced (presently, Δf = 0.71 GHz) frequencies with a slow decay in output power. The wave is amplified in the frequency range of 12–20 GHz. The wave frequency is subsequently doubled followed by a frequency active multiplier in the *ka*-band. Around 20 (= (40-26)/0.7) frequency components can be simultaneously launched to the plasma. The Doppler-shifted back-scattered signal from the turbulent plasma is received and mixed with a local wave of 32.84 GHz. The IF signal has several frequency comb components, as shown in Fig. 1. Comb frequency components less than 6 GHz are clearly observed. Currently, a seven-channel filter bank system is employed for the IQ detection. Finally, the data are acquired by ADC with a 1

MHz sampling rate and 16-bit resolution. In addition, we attempted to apply the direct signal acquisition system.

3. Observation example of Meso- and Micro-scale turbulence interaction [3]

We investigate the interaction between radial electric field E_r and density fluctuation in transient plasma experiments. Some former fusion plasma experiments show that the transport barrier phenomena (such as L-H transition) is strongly related with the local electric field but the barrier location does not completely match with the E_r maximum location nor the maximum E_r shear location [4]. And, theoretical prediction [5] says the meso-scale mean flow which is indicated by the $\alpha(-E_r\ E_r'')$ affect the turbulence. Now, we can observe both profiles of the E_r and the turbulence intensity simultaneously by multi-channel Doppler reflectometer.

The experiment is carried out in the electrode biasing experiment in LHD. The turbulence intensity is evaluated by the summation of high frequency (>100 kHz) components in back-scattering signal amplitude. The calculated spatio-temporal behavior of turbulence intensity is shown by the contour map in Fig. 2 (b). Turbulence intensity seems to be localized in around $r_{\mathrm{eff}} = 0.51$ during the transition period. Figure 2(a) shows the calculated value of $-E_r\ E_r''$. Here, the color of red means positive value and the blue color means the negative. Intensity of turbulence looks like strong in the negative region of $-E_r\ E_r''$ in space and time. This result is not conflict with the theoretical hypothesis which says “turbulence reduction /concentration is trapping a through or summit according to the sign of E_r''”. Therefore, it is found that the meso-scale parameters of E_r and also E_r'' are important for reduction of micro-scale turbulence.

Acknowledgments

The present study was supported in part by KAKENHI (Nos. 26630474, 25289342, 23244113, 23360414, 22360394, 22017007, and 21224014), by a Grant-in-Aid from the auspices of the NIFS Collaboration Research Program, and by the collaboration programs of the RIAM of Kyushu University and the Asada Science foundation. Additional support was provided by Japan / U.S. Cooperation in Fusion Research and Development.

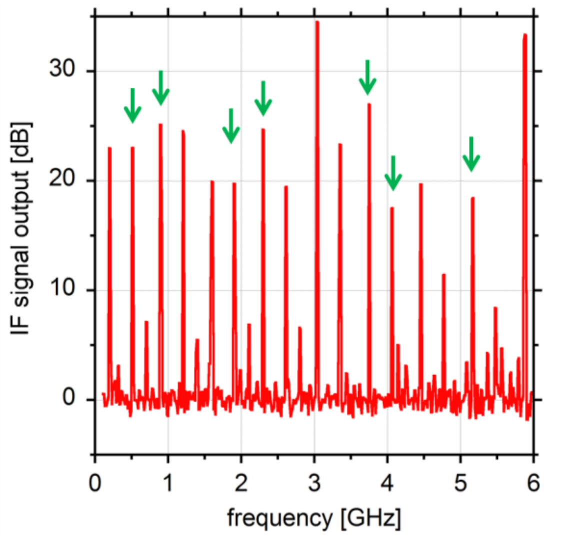

Fig.1. Frequency spectrum of the IF signal, which is the microwave mixer output. The arrows indicate the utilized frequency components in the filter bank system.

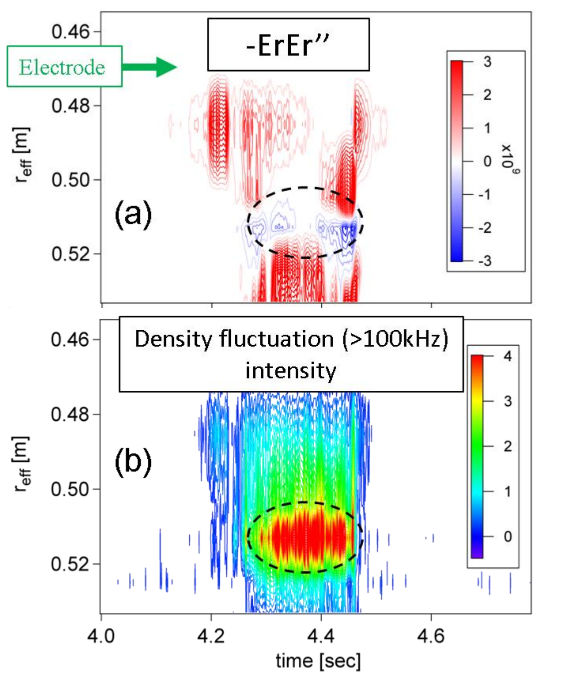

Fig.2. Contour map of (a) the estimated value of $-E_rE_r''$ and (b) the intensity of high frequency fluctuation component [3].

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