§17. Visualization of Low Coherence and Low Amplitude Fluctuation of Long Pulse Discharge Experiment

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In high temperature plasma, every fluctuation has possibility to couple another fluctuations. This leads the energy dispersion and determines the whole plasma confinement. Fluctuations with low fluctuation level or low coherence, such as high-order harmonics of coherent mode or turbulence, would be no exception. We usually observe the fluctuations with high amplitude or coherence mode by various diagnostics such as magnetics, soft-X ray, reflectometer, ECE and so on. However, fluctuations whose amplitude is comparable to the noise level of the measurement devices, can not be detected clearly. The one of the solution of this problem is the correlation technique such as correlation ECE [1]. For applying this analysis technique, the long steady state-plasma is desirable to study such low coherence fluctuation.

In tokamak or RFP plasma, in principle, the time of the steady state discharge is not basically long because the transient toroidal current are usually observed. In helical devices, comparatively, the long pulse discharge including steady state can be easily realized. In LHD, steady-state operation has been studied using electron cyclotron heating (ECH) and ion cyclotron heating (ICH) [2].

Fig.1 shows the typical time evolution of electron density, input ECH power and dynamic spectrum of coherence of electron temperature fluctuation (#131054). The density is controlled by the H-pellet injection. The change of ECH power is due to switching active gyrotrons at approximately 100 sec interval. We can see the change of the fluctuation state is coincided with switching of gyrotorns. During using the same input power state, we can assume the continuous 100 second steady state. So we can select long time windows (~100sec) for Fourier analysis.

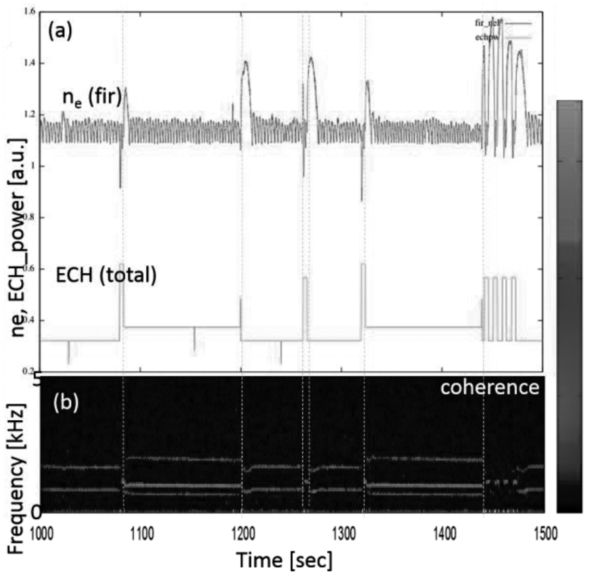

Fig. 1. (a) The time evolution of line averaged electron density (n_e) by FIR and input total power of ECH. (b) The coherence of electron temperature fluctuation measured by ECE. The coherence is calculated using neighbor channel of ECE. The discharge time is 2240. Only 1000-1500sec data is shown in this figure.

Fig.2 shows the comparison of coherence calculated from between short (~0.4sec) and long (~105sec) time window. The fluctuation data of temperature measured by ECE is continuously acquired in rate of 500kHz-sampling. In case of the short time window case (number of spectra for ensemble average is 15), the back ground level is ~0.07. This analysis condition is corresponding to the case of short pulse experiment. In this case, only Effective peak at 1.13kHz, and its 2nd harmonic 2.26kHz are detected. However the coherence of 2nd harmonic peak is comparable to the back ground level. In case of long time window (number of spectra is 3051), we can clearly see not only the fundamental mode (1.13kHz) but also its 2nd harmonic. In addition, we can identify significant modes of 0.76kHz and 1.51kHz. In this way, using long steady state discharge, we can find the low level coherent mode which can not be detected in short pulse experiment and there is possibility to study their non-linear coupling. However this technique requires the continuous data acquisition with high sampling rate. In this campaign, ECE data can be acquired. In next campaign, this technique will be applied in other diagnostic such as reflectometer or magnetic probe.

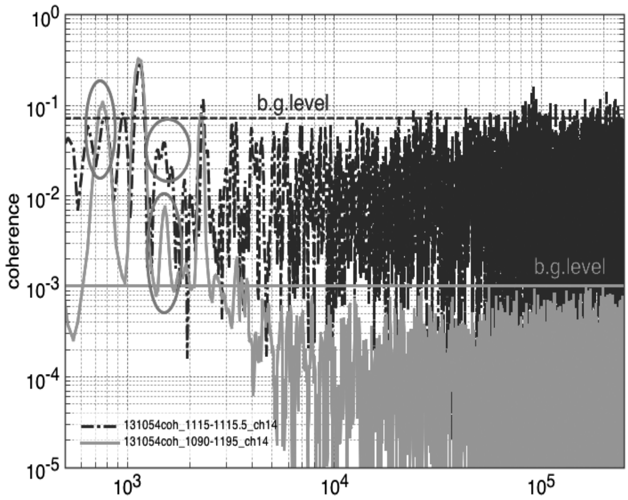

Fig. 2. the comparison of coherence between short time window (0.4sec, 15 spectra, b.g.level 0.07) and long time window (100sec, 3051 spectra, b.g.level 0.001)

1) C. Watts, Fusion Sci Tech. **52**, 176 (2007).
2) H. Kasahara, et al., 2014 Phys. Plasmas. **21** 061505 (2014)