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Fluctuation Spectral Analyses and Tomography Development with Multi–channel Spectroscopy in Linear Cylindrical Plasma
非平衡極限–直線プラズマにおける多チャンネル分光観測による揺動スペクトル解析とトモグラフィーの開発

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Tomography can be an excellent means to observe plasma structure and fluctuations without perturbing plasmas. A prototype system of multi-channel spectroscopy is developed to realize such tomographic measurement for observing simultaneously the whole and local structure of turbulence in linear plasma. In this paper, the results of power spectral analysis are presented to show existence of several coherent modes represented by sharp peaks. Cross-coherence and cross-phase analyses are performed on a coherent mode to infer its spatial structure.

1. Introduction

In order to understand plasma turbulence and turbulence transport, it is necessary to make global and simultaneous measurement of fluctuating structures of the plasma turbulence, such as drift wave and zonal flows with fine spatio-temporal resolution. Tomography can be an excellent means without disturbance on plasma to realize such measurements. In this study, we report the development of a prototype of the multi-channel tomography system in linear cylindrical plasma, PANTA, and present results of cross-power analysis to infer coherent mode structure.

2. Experimental Device

The experiments were performed in a cylindrical linear plasma device, PANTA (Plasma Assembly for Nonlinear Turbulence Analysis[1]) in Kyushu University. In this study, we observed ArII line at 476.5 nm emitted from the plasma with the magnetic field of 900 G and filling Ar pressure of 1 mTorr. As is shown in Fig. 1, the line-integrated

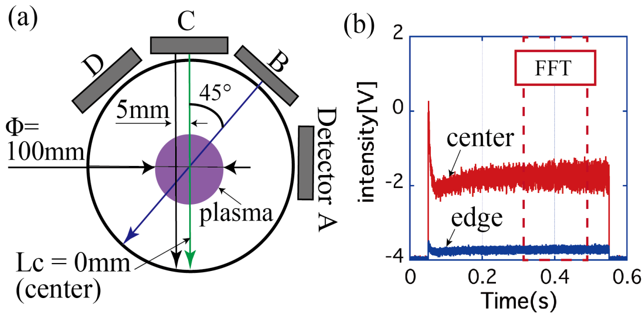

Fig.1. (a)A schematic view of spectroscopic system, and (b) examples of temporal evolution of emission from center and edge

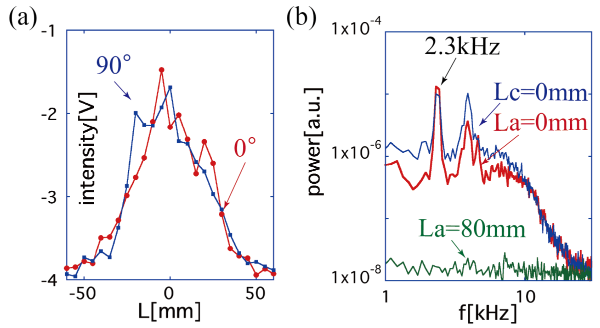

Fig.2. Examples of (a) emission profiles, and (b) power spectra.

light signals are detected with four sets of 32 channel detector arrays (total 128 channels) at azimuthal positions at 0 °, 45 °, 90 °, and 135 °. The detectors in an array are aligned with 5 mm interval to face the plasma radially. The range of observation is from L = -80 to 80 mm, where L means distance from the central position of the detector array, thus the detectors cover the whole plasma diameter of 100 mm.

3. Experimental Data

3.1 *Fast Fourier Transform*

We obtain 128 ch. line-integrated data of ArII emission with sampling time of 1 μs. Figure 2 shows examples of the obtained data, (a) emission profiles, and (b) power spectrum. The line-integrated emission profile has a maximum at L = 0 mm. Fast Fourier Transform (FFT) analysis is performed on data during 0.3 ~ 0.5 s on. The data of 200,000 points (or 0.2 s) data, then ensemble-averaged spectra are calculated. The power spectra shown in Fig.2 are ones at L = 0 mm (center) and 80 mm (edge). The spectra indicate several peaks over broadband fluctuations, and the largest peak is found at 2.3 kHz.

3.2 *Analysis of mode structure*

A mode structure at 2.3 kHz is investigated using the cross-power in addition to auto-power analysis. Figure 3 shows the line-integrated power of the mode around 2.3 kHz as a function of radius. The spectra integrated over 2-3 kHz have maxima at the position of L ~ ±20 mm, and have a local minimum at the center.

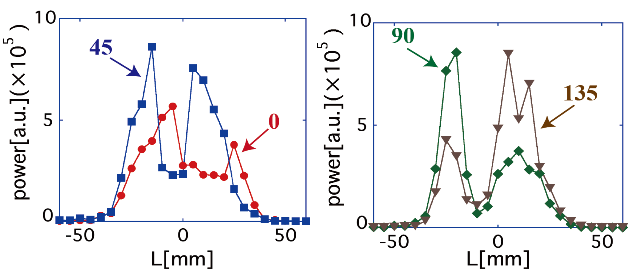

Fig.3. Mode power profile at 2.3kHz.

The cross-coherence and cross-phase analyses are performed. The reference channel in the analyses is Lc = -20 mm, and the target frequency is 2.3kHz. Using the cross-power S_{xy} and auto-powers S_{xx} and S_{yy}, squared coherence and phase can be written as follows, respectively,

$$\mathrm{coh}^2(\omega) = \frac{S_{xy}^2(\omega)}{S_{xx}(\omega)\,S_{yy}(\omega)} \qquad (1)$$

$$\mathrm{phase} = \tan^{-1}\left(\frac{\mathrm{Im}\ S_{xy}(\omega)}{\mathrm{Re}\ S_{xy}(\omega)}\right)$$

High coherence is found between a reference and every other line-integrated signal on the mode at 2.3 kHz, thus, the phase between two positions can be evaluated in a good precision. The mode at 2.3 kHz has the maximum amplitude around 20 mm, thus, the mode fluctuations on tangential lines-of-sight to the radius could reflect mostly the local phase difference at the position to the reference. Figure 4 shows that the evaluation of the local phase difference. The result implies that the azimuthal mode number should be m = 1.

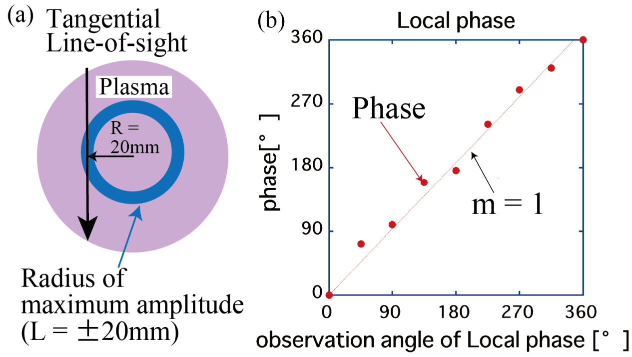

Fig.4. (a) A schematic view of a tangential line-of-sight to the radius with maximum amplitude of the mode at 2.3kHz for evaluating its local phase. (b) The evaluated phase as a function of azimuthal angle of the cross-point.

4. Summary

The prototype of multi-channel spectroscopic system is installed successfully to provide the line-integrated profiles of emission, their power spectrum in PANTA. The experimental data shows that 2.3 kHz mode should be the property that the azimuthal mode number should be m=1. The next step is to deduce the detailed structures of these coherent modes directly with tomography.

References

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