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直線プラズマのトモグラフィ計測とウェーブレットによる揺動の時空間発展解析

Tomography measurement and wavelet analysis of spatiotemporal dynamics of fluctuations in a linear plasma

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Effect of plasma turbulence on plasma confinement should be studied in order to produce high performance plasma for the realization of nuclear fusion reactor. The turbulence is composed of the fluctuations of various spatiotemporal scales therefore; it is necessary to observe plasma turbulence not only at the local region but also over the entire plasma. Tomography is one of the methods that satisfy the requirement. For measuring plasma turbulence, tomography is being developed in Plasma Assembly for Nonlinear Turbulence Analysis (PANTA)[1]. In the tomography system, the first results of the spatial evolution of the local emission profile are obtained in every 1 μs with parallel computing of 120 cores. The tomography reconstruction with such high temporal resolution allows us to evaluate not only Fourier spectral analysis but also temporal evolution of local fluctuation spectra using wavelet analysis.

In PANTA, cylindrical argon plasma is produced from the helicon antenna with the diameter of 0.1 m. The experimental results introduced here are obtained in Ar plasma under the condition that magnetic field is 900 G and gas pressure is 1 mTorr, The tomography system has four detector arrays set on different azimuthal positions every 45° degrees apart. The measurements are performed for ArI and ArII emissions; blue (476.5 ± 20 nm ArⅡ), and infrared (900 ± 25 nm ArⅠ) light. Tomography images of the local emission profile are reconstructed using the Maximum Likelihood-Expectation Maximization (ML-EM) technique. The ML-EM is one of the tomography algorithms to deduce local values through iterative calculation from a set of line-integrated signals.

Figure 1(a) shows an example of the local emission profile of ArII. The local emissions are calculated as values on 121 (= 11 x 11) grids with width of ~ 14.5 mm on the observation square (160 mm x 160 mm). Such tomographic images and local emissions are obtained in every 1 μs. Figure 1(b) shows temporal evolution of local emission intensity at the plasma center denoted position A (x = 0, y = 0 mm) with that of position B (x = - 15, y = - 15 mm). Figure 1 (c) shows the Fast Fourier Transform (FFT) power spectra at position A and B with frequency resolution of Δf = 0.122 kHz in the period from 0.10 ms to 0.58 ms.

Since the temporal evolution of local emission is calculated in such a high resolution of 1 μs, the fluctuation power can be evaluated up to the Nyquist frequency of 500 kHz. Utilizing the high temporal resolution, we can deduce a temporal evolution of frequency spectra using wavelet technique. The definition of the wavelet analysis is

$$\omega_{\varepsilon}(f,t) = \int_{-\infty}^{\infty} \varepsilon(\tau)\, \Phi(f,t-\tau)\, dt$$

with $\Phi(f,t-\tau) = \sqrt{f} exp\,[i2\pi ft-(ft)^2/2]$ [2].

Figure 2 shows the result of wavelet analysis at position C (x = 0, y = 15 mm) from 0.10 s to 0.58 s, where the ArI emission has a maximum, with the temporally averaged power of the wavelet spectra. The wavelet analysis clearly demonstrates the presence of temporal variation in the coherent mode around 2.5 kHz, and rather turbulent activity around 4 kHz.

In summary, temporal evolution of local emission over the entire plasma is successfully obtained in every 1 μs with the tomography system using MLEM algorithm on cylindrical linear plasma, PANTA. The high temporal resolution enables us to analyze properties of local fluctuations, not only with Fourier spectra but also wavelet spectra. As future work, spatial correlations between local emissions and those between their envelopes are studied with FFT and wavelet analyses. In this poster will show the first results of local emissions obtained with tomography, and their fluctuation properties analyzed with FFT and wavelet analyses.

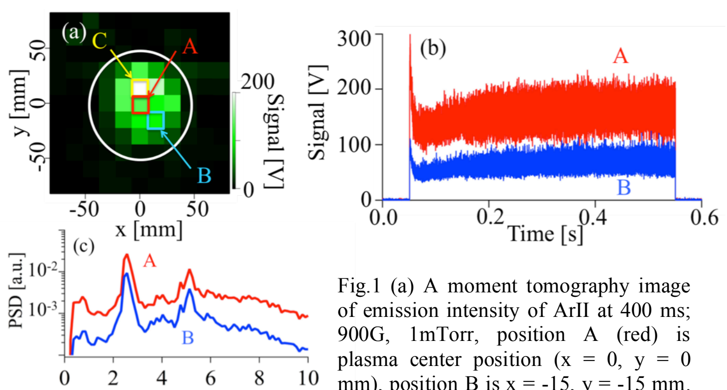

Fig.1 (a) A moment tomography image of emission intensity of ArII at 400 ms; 900G, 1mTorr, position A (red) is plasma center position (x = 0, y = 0 mm), position B is x = -15, y = -15 mm. (b) Time evolution result of emission intensity at A (red) and B (blue). (c) FFT spectra at A (red) and B (blue).

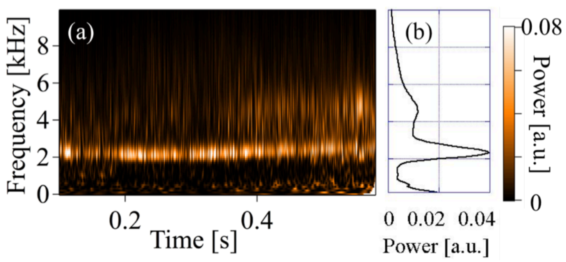

Fig.2 (a) The wavelet spectra at position C (x = 0, y = 15 mm). (b) temporally averaged power of the wavelet spectra.

References

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