21PB-078

Development of tomography algorithms for a linear cylindrical plasma
非平衡極限-直線円筒形プラズマのトモグラフィアルゴリズムの開発

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Tomography algorithms have been developed for two-dimensional measurement of turbulence observed in local emission from linear cylindrical plasma. A number of reconstruction methods, ART, ML-EM, Fourier-Bessel expansion and so on, have been tried to be applied on prescribed data, and have been compared quantitatively in their preciseness of their reconstructed data.

1. Introduction

It is important to understand turbulence-driven transport of particle, momentum and energy to realize magnetically confined plasma of sufficiently high temperature for a nuclear reactor. Nowadays, it is known that plasma turbulence should be maintained with nonlinear couplings between drift waves of microscale and mesoscale structures such as zonal flows and streamers [1,2]. For further understanding of plasma turbulence and transport, a diagnostics able to measure the whole plasma cross-section with fine resolution is absolutely necessary. Computed tomography (CT), using plasma light emission, is one of the candidate methods to satisfy such conditions. The requirement is to resolve fine structure in space and time, *i.e.,* comparable to ion Lamor radius and drift wave frequency, respectively.

Here we present a trial to realize such diagnostics by developing a prototype system in a linear cylindrical plasma device. CT is a well-known technique to obtain a local value from a set of line-integrated values observed from several angles. Various kinds of tomography techniques are well developed in medical use, and it has been applied to reconstruct plasma image using its X-ray emission. In plasma application, the number of detectors is limited compared to medical applications. In addition, the detectors are installed in a worse environment in terms of electric noise. This paper describes the development of a prototype system for a plasma tomography to aim at plasma turbulence measurement in both aspects of its algorithm and detector apparatus.

2. Algorithms

Although various techniques [3] have been proposed, we have treated mainly the three methods, Maximum Likelihood-Expectation Maximization (ML-EM) [4], Algebraic Reconstruction technique (ART), and Fourier-Bessel expansion method [5]. These algorithms are tested with assumed images of plasma emission. Here, we show examples of the reconstructed results using the three methods in Fig.1, with residual error defined as

$$S_i = \{x_i - y_i\}^2 \qquad (1)$$

Here, x_i is original values and y_i is values reconstructed from given line-integrated values of x_i. In Fig.1, S is shown under the reconstructed data. The assumption for the calculation is that the plasma is observed with totally about 1600 detectors. The detectors are assumed to be located at 4 and 16 different angle positions with 401 and 101 channels for each direction, respectively. The results suggest two major points. The reconstructed image should be closer to the original one for every method as the number of observation angle positions is larger. The other point is that the most practical method is ML-EM. Certainly, Fourier-Bessel expansion method has the lowest residual error $\sum S$, however, the method is built upon a finite number of the prescribed function form so as to have a difficulty to resolve an unexpected discrete change, like the sharp peak as is shown in Fig. 1, while the other two methods succeed in catching the presence of the peak. In addition, the residual error $\sum S$ of ML-EM is smaller than that of ART. Therefore, our temporal conclusion is ML-EM should be the most practical for plasma tomography for our purpose.

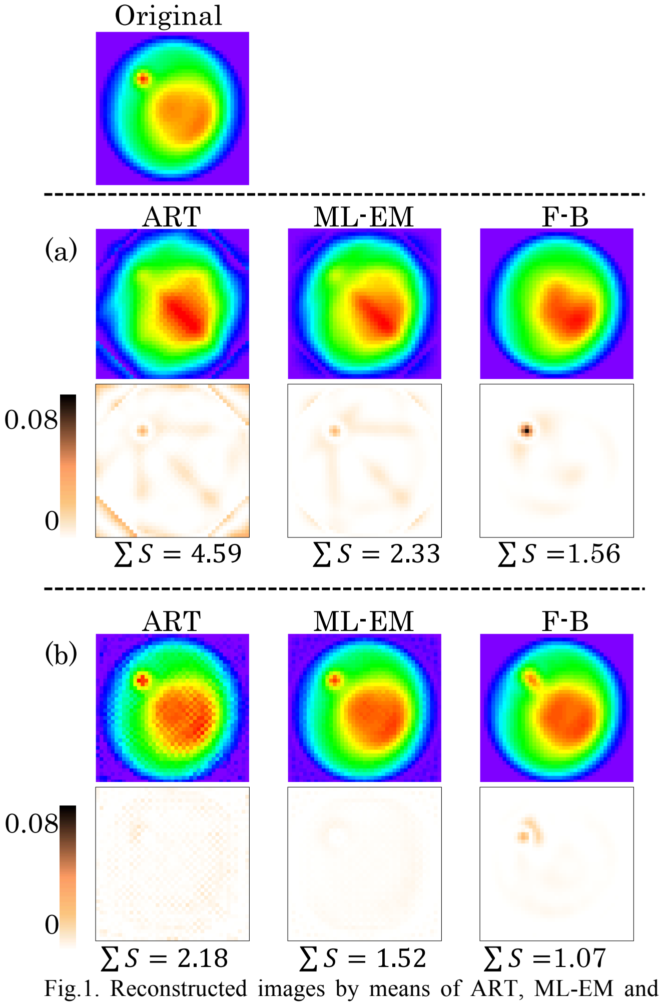

Fig.1. Reconstructed images by means of ART, ML-EM and Fourier-Bessel expansion method
(a) Images reconstructed with the data from 401×4 channels and the residual error S
(b) Images reconstructed with the data from 101×16 channels and the residual error S

3. Experiment

A prototype of tomography system is installed on the device PANTA (Plasma Assembly for Nonlinear Turbulence Analysis) in Kyushu University, and the device generates linear cylindrical plasma with the diameter of 100 mm and axial length of 4000 mm. In the tomography system, the plasma is measured with four detector arrays installed at azimuthal angles 0°, 45°, 90°, and 135°. In each detector array, 33ch viewpoints are lined up in column at regular intervals of 5 mm, and cover diameter of the plasma completely. Each detector can detect line-integrated emission from Argon plasma. The arrays can measure blue (476±30nm), and red (696.5±30nm) light. Fig.3 shows intensity of blue light observed in the condition of 1mTorr gas pressure, 900G magnetic field and 2kW RF power from four direction of angles with 33 channels in each detector. The developed algorithms are being applied on the obtained data.

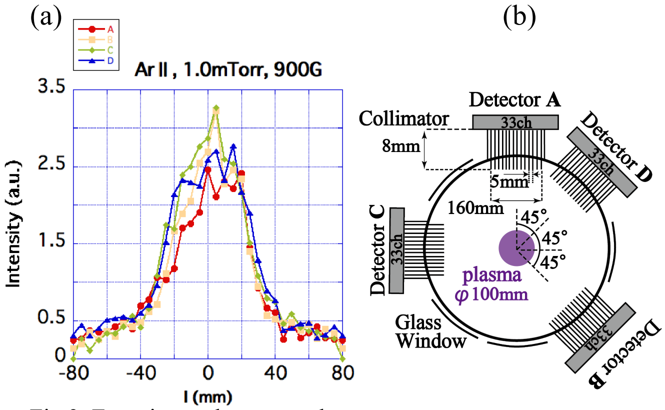

Fig.3. Experimental tomography
(a) Emission intensity of blue light from Ar Ⅱ plasma
(b) A conceptual view of the device from the perpendicular direction to the plasma axis

4. Summary

This paper reports mainly the status of the development of tomography algorithms, particularly on the comparison between three existing methods, ART, ML-EM and Fourier-Bessel expansion method and discusses the advantage and disadvantage of the three methods. Moreover, the developed algorithms are being applied on the real experimental data shown above, and the results will be presented in the poster.

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