GAMMA10 セントラル部における多チャンネル Hα 線計測器を用いた水素中性粒子計測

Hydrogen neutral particle measurement using a multi-channel Hα line measurement system in the central cell of GAMMA10

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1. Introduction

GAMMA 10 is a 27 m long tandem mirror plasma confinement device with a thermal barrier at both end-mirrors. The plasma is created by using plasma guns and is heated and sustained by using ion cyclotron range of frequency heating (ICH) system. The x-axis and y-axis are perpendicular to the magnetic field. The z-axis is parallel to the magnetic field. In typical hot ion mode plasmas produced in the core region of the central cell, electron density, electron temperature and ion temperature are about 2×10^{12} cm^{-3}, 80 eV and 5 keV, respectively.

To measure the plasma parameters such as temperature and density, various diagnostic tools are installed to GAMMA10. Spectroscopic measurements have been carried out in a wide wavelength region from the soft X-ray to visible. The behavior and radiation loss of hydrogen atoms and impurity ions have been studied. In GAMMA10 hydrogen plasmas, Hα line emission measurement is an important diagnostic. The multi-channel Hα line measurement system installed at central cell of GAMMA10 measures the radial distributions of Hα line emissions in two directions. By using the tomographic reconstruction techniques, we can obtain spatial distribution of Hα emissivity. Moreover, applying a collisional-radiative (CR) model to tomography measurement, we can obtain the spatial structure of neutral particle of hydrogen.

2. Multi-channel Hα line measurement system

Multi-channel Hα line measurement system is shown in Fig. 1. It is constructed by the 12 detectors in horizontal and vertical direction, respectively, and the wavelength filters, the optical fibers, the lens, and the photomultiplier tubes.
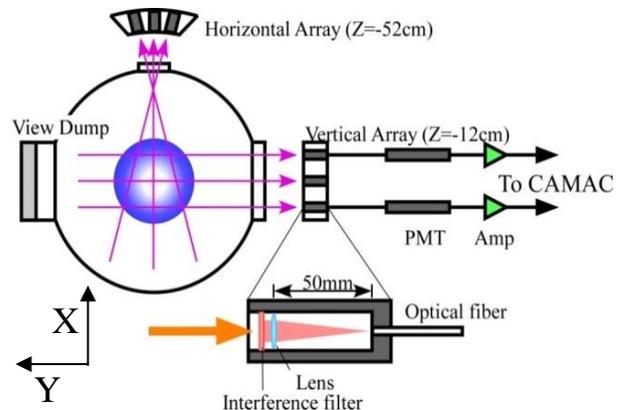

Fig. 1. Schematic diagram of multi-channel Hα line measurement system.

In addition, for signal amplification, operational amplifiers having a non-inverting amplifier circuit are mounted. In order to reduce the reflection of the vacuum chamber, viewing dump is attached to the opposite surface for the vertical array. Line of sight configuration of each detector is shown in Fig. 2. The horizontal array measures the plasma in a fan shape, and the vertical array measures in parallel.
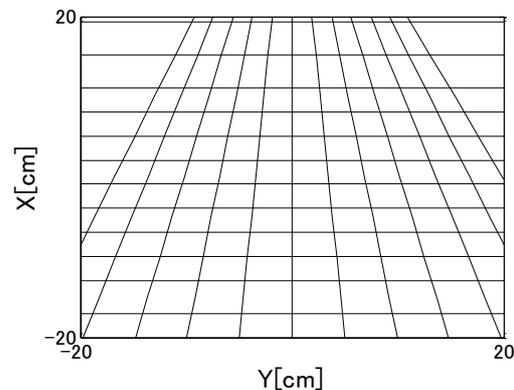

Fig. 2. Line-of-sight configuration of each detector in cross section.

3. Tomographic reconstruction

Tomography is a method to study the internal structure of object. Measurement results obtained from the multi-channel Hα line measurement system are line integral intensity. By applying the tomography technique, it is possible to obtain emissivity profiles. We have used the algebraic reconstruction technique (ART) [1] as a tomography technique. However, it is necessary to give initial values of the emissivity profile and then the reconstruction image becomes rough. Therefore, we have developed a new tomography calculation code using Phillips-Tikhonov (PT) technique [2]. PT technique can reconstruct the spatial distribution even though the information is inadequate and obtain smooth reconstruction image. Furthermore, it is not necessary to consider the reconstructed image in advance and calculation time is short. Model distributions shown in Fig. 3 (a) and (c) were used for the reconstruction simulation test. We calculated line integral intensity from the test distribution and reconstruction using PT technique. We used Gaussian distribution and hollow like distribution as model distributions. The reconstruction results are shown in Fig. 3 (b) and (d). The reconstruction images have good overall agreements with model distributions.
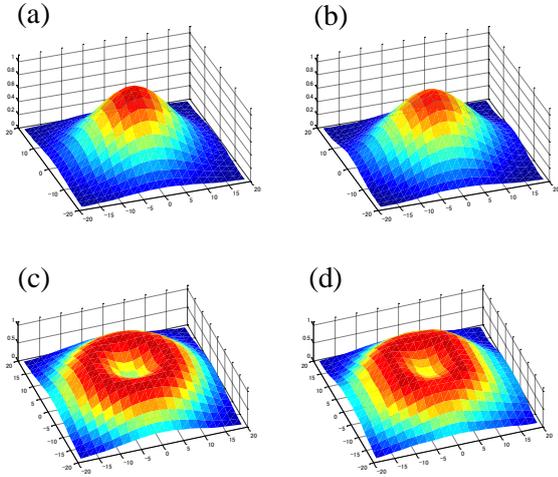

Fig. 3. (a) Model distribution (Gaussian). (b) Reconstruction result (Gaussian). (c) Model distribution (hollow like). (d) Reconstruction result (hollow like).

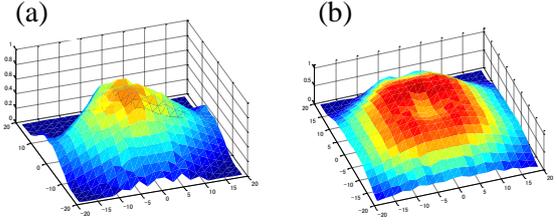We show reconstruction results using ART in Fig. 4.

Fig. 4. (a) Reconstruction result by ART (Gaussian). (b) Reconstruction result by ART (hollow like).

Reconstruction results are rough. The calculation error χ^2 defined in Eq. (1) was used for the comparison of the accuracy with the two techniques.

$$\chi^2 = \frac{\sum_k (E_k^{cal} - E_k^{model})^2}{k} \qquad (1)$$

Where k, E_k^{cal}, E_k^{model} are the cell number, and the intensity of the reconstruction at the k-th cell, and the intensity of the model distribution at the k-th cell, respectively. PT technique indicates numerically better results than ART as shown in Table 1.

χ^2	ART	PT technique
Reconstruction of the Gaussian	0.0074	0.00044
Reconstruction of the Hollow	0.0051	0.0016

Table 1. Calculation error of reconstruction simulation test using ART and PT technique.

4. Summary

We constructed new tomography calculation code using PT technique. We carried out reconstruction simulation test using two model distributions. Simulation results showed good agreement with the model distribution by using PT technique than that by ART. In this presentation we introduce detailed description of the PT technique and application to the actual measurement, and measurement of hydrogen neutral particle in the cross section of plasma.

References
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