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Python ライブラリ Raysect を用いた小型トカマク装置における可視光トモグラフィー
Visible light tomography on small tokamak device using python library Raysect

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1 Introduction

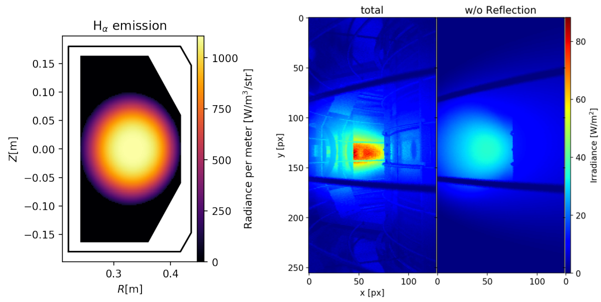
To realize steady-state fusion operation, we need to know the spatial distribution of the neutral and impurity particles. Notably, the investigation of visible light emission around the edge regions of plasma enables us to understand the mechanism of transport of neutral and impurity particles. To find out these issues, the tomographic reconstruction technique is useful. In this study, we conducted the tomographic reconstruction using a high-speed camera which is installed to the small tokamak device PHiX in Tokyo Institute of Technology, and successfully obtained 2-D visible light distributions on a poloidal cross section.

2 Synthetic Diagnostics

The high-speed camera captures the visible light emitted from plasma including the reflection light. At first, in order to evaluate the amount of reflection light, we simulated camera images on a constructed synthetic diagnostic platform, in which synthetic data of plasma emission is produced by following theoretical and empirical assumptions, and a captured image is computed by a ray-tracing technique. Raysect, which is an object-oriented programming ray-tracing framework in Python, can consider the physical light effect such as reflection, refraction, scattering, etc[1]. The synthetic plasma emission data and camera image are shown in Fig.1

3 Tomographic Reconstruction

The Raysect's ray-tracing algorithm allows us to calculate the Ray Transfer Matrix (RTM) which is mandatory for the tomographic reconstruction.



(a) A synthetic plasma emission (H_α) data

(b) Total irradiance(left), without reflection irradiance(right)

Fig. 1: The results of synthetic diagnostic

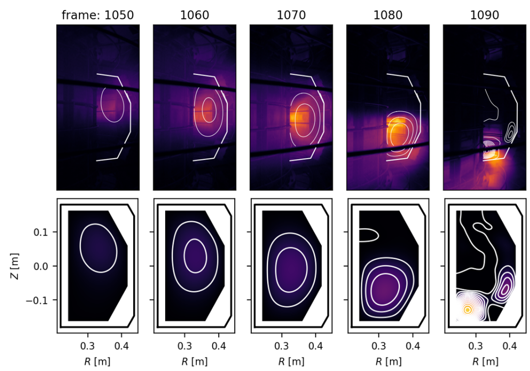


Fig. 2: Top pictures are captured images at each frame, while bottoms are reconstructed ones. To make it easy to compare them, the contours of reconstructed images are reprojected onto upper pictures.

The cross-section image $\boldsymbol{x}$ can be estimated by Tikhonov-Phillips regularization[2] as:

$$\boldsymbol{x}_\lambda = \arg\min \left\{ \|A\boldsymbol{x} - \boldsymbol{b}\|^2 + \lambda \|L\boldsymbol{x}\|^2 \right\}, \quad (1)$$

where A: RTM, $\boldsymbol{b}$: camera image, λ: regularization parameter, L: laplacian operator.

References

[1] M. Carr et al., Rev. Sci. Instrum. **90**, 043504 (2019).
[2] N. Iwama et al., J. Plasma Fusion Res. **82**, 399 (2006).