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多段反射光モデルを考慮したトカマクプラズマの可視光トモグラフィ
Tokamak plasma tomography of visible light considering multiple reflection

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1 Introduction

When we observe tokamak plasma, tomography with a high-speed camera is one of the most useful tools. Cameras with tomographic reconstruction can determin plasma position, shape and fluctuation in tokamak devices[1].

Generally, in order to obtain tomography images, many cameras have to be installed around a poloidal cross section. However, in a small tokamak device, it is difficult to set many cameras because of little room. Therefore, we applied a tangentially viewing camera under the assumption of toroidal symmetry.

Besides, reflection light has to be considered in visible light tomography[2]. In PHiX, which is a small tokamak device in Tokyo Tech, the vessel wall is very specular. To solve this problem, we applied multiple reflection light models and calculated multiple lines of sight (LoS).

2 Numerical Model

Visible radiation emitted from plasma can be detected along LoS. Assuming pinhole camera model, one pixel imaging sensor has one LoS. It is calculated as follows:

$$\boldsymbol{x}_{\mathrm{p}}(t) = \boldsymbol{x}_{\mathrm{s}} + \boldsymbol{V} \cdot t, \tag{1}$$

where $\boldsymbol{x}_{\mathrm{p}}$ is a LoS position, $\boldsymbol{x}_{\mathrm{s}}$ is a LoS start position, $\boldsymbol{V}$ is a LoS directional vector and t is absolute value of $\boldsymbol{x}_{\mathrm{p}} - \boldsymbol{x}_{\mathrm{s}}$. When we take account of a lens effect, $\boldsymbol{x}_{\mathrm{s}}$ and $\boldsymbol{V}$ must be changed into a randam point on lens $\boldsymbol{x}'_{\mathrm{s}}$ and focus direction $\boldsymbol{V}_{\mathrm{focus}}$.

Multiple reflection light is considered as a reflected LoS on the vessel wall or internal structures which are flux loops and limiter and so on. They have two reflection parameters of reflectance (albedo) and diffusivity. The number of LoS reflection is determined by Monte Carlo method.

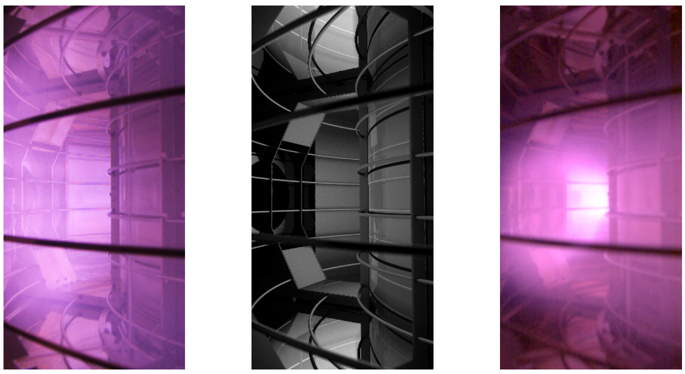
When cross section image and camera image are defined as $\boldsymbol{f}$ and $\boldsymbol{g}$, respectively, the relationship is represented by a following liner equation:

$$\boldsymbol{g} = (\mathbb{H} + \mathbb{M})\boldsymbol{f}, \tag{2}$$

where $\mathbb{H}$ is a geometrical matrix without reflection, and $\mathbb{M}$ is reflection matrix.

3 Result

A high-speed camera was Phantom LAB110 which is a lens camera whose focus distance and F value are 50cm and 3.5, respectively. The numbers of camera image resolution and reconstructed resolution are 512×256 pixels and 165×90 pixels, respectively. And we used a truncated SVD methods to solve Eq.(2)[1].



(a) ECR discharge (b) Reflection light (c) shot#3840

Fig1 Calculated and captured images. Both (a) and (c) are measured data. (b) is a calculated wall reflection image on assuming that plasma emissivity is uniform ($f_i = 1$)

References

[1] I. Naofumi and O. Satoshi, J.Plasma Fusion Res. **92**, 743 (2016).
[2] M. Odstrčil and et al., REVIEW OF SCIENTIFIC INSTRUMENTS **85**, 013509 (2014).