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Development of Soft X-ray Stereo Imaging System for High-Energy Electron Distribution Measurement

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We developed a stereo type soft X-ray imaging system that can measure time-evolutions of 2D soft X-ray emissions from two viewing angles. This system enables us to observe the temporal development of high-energy electron distribution in different energy bands over a wide area on the poloidal cross-section of a merging spherical tokamak for the first time.

The soft X-ray emission measurements using microchannel plates (MCP) are widely used for plasma diagnostics. Using 2D image measurement, the entire poloidal cross-section is observed from a single viewpoint in torus plasmas [1]. In this study, we used two MCPs with two filters with different transmission wavelengths, a bifurcated optical fiber bundle, and a high-speed camera to develop a system that realizes 1) high time resolution - the order of μs and 2) two energy-bands measurement of bremsstrahlung radiation. The time evolution of the soft X-ray emission caused by the magnetic reconnection of the merging tokamaks was measured. By applying the Phillips-Tikhonov regularization and GCV [2] to the obtained images, we reconstructed 2D local soft X-ray emission for 2D measurement of high-energy electrons. Measuring the emission in different energy bands, the energy distribution of high-energy electrons can be estimated.

As shown in Fig.(a), the MCP is sealed in two small vacuum chambers (MCP chambers) with pinholes covered with two different filters. The soft X-rays through the pinhole are converted into visible light by the MCP and phosphor. The visible light is focused and transmitted through optical lenses to the fiber bundle whose cross-section is photographed by a framing camera with CMOS camera. The two images of the fiber bundle enable the single framing camera to make simultaneous measurement of the two emission images from two viewpoints every 10μs with the exposure time 5μs. As shown in Fig.(b), the lines of sights through the pinhole extends in three dimensions, but they are projected onto a single poloidal plane by assuming the toroidal symmetry of the tokamak plasma. The emission intensity of each element in the captured image is the line integral value along the corresponding line of sight. If the area to be reconstructed is divided into grid regions, and the local emission intensity in each grid is **E** (vector), and the line integrated emission intensity (measured value) along each line of sight is **I**,

$$\mathbf{I} = \mathrm{G}\mathbf{E} + \mathbf{e}$$

where G is the geometric weight matrix representing the contribution of each line of sight to each grid and **e** is the residual vector.

In the future, we plan to expand the number of viewpoints for 1) more precise estimation of the energy distribution and 2) 3D reconstruction of the spatial distribution.

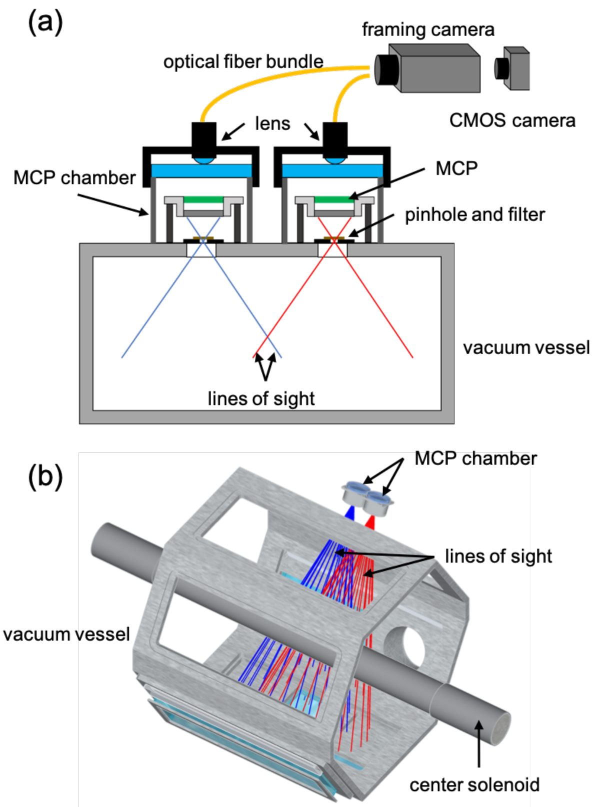

Fig. Soft X-ray measurement system composed of two MCP chambers, a bifurcated fiber and high-speed camera

References
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