2D Imaging of Small Pellet Ablation Cloud Density in Heliotron J Based on High-speed Spectroscopy for Balmer-β Line Broadening

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1. Introduction

Hydrogen pellet injection is regarded as an effective fuelling tool in fusion-relevant magnetic confinement devices. In many of the pellet ablation models, the ablation cloud surrounding the solid hydrogen can be categorized into the neutral cloud and plasmoid [1]. The latter is the low-temperature high-density partially-ionized plasmas expanding along the magnetic field. However, it is difficult to measure them separately due to the mixture of their emission and different spatial behavior.

We have developed a small pellet injector, 0.6 – 1.2 mm in diameter [2], in Heliotron J, medium-sized helical devices having the major radius R = 1.2 m, the minor radius a = 0.17 m, and the magnetic field at the magnetic axis B_{ax} ~ 1.5 T [3]. We have measured the penetration depth [4] from the arrayed H_α detectors, and have also observed a unique fluctuating behavior of the ablation cloud around the pellet [5] using the fast visible camera (without spectroscopy).

Conventional imaging spectrometry for the plasmoid density for larger devices, such as the large helical device (LHD) [6], is hard to be applied to the low-density plasmoid where the Stark broadening is narrow. The intensity ratio of the H_β line passing through the interference filter having different pass-band widths cannot resolve the narrow Stark width [7], while the fast grating spectroscopy can usually apply for either the measurement with the limited number of channels [8] or the time-integrated measurement over the entire ablation process.

One approach we have made is to use the spectroscopy of Stark broadening of the near-infrared Paschen α line [9] for which the Stark broadening is several times broader for the same density. However, the obtainable spectra were the emission average value over time and space, limited by the spectrometer channel and the detector.

In this respect, we have designed and developed a fast 2D imaging spectroscopy system and have succeeded to measure the intensity, density, and trajectory of the ablation cloud of the especially small hydrogen pellet in Heliotron J.

2. Development of the spectroscopic system for lower-density cloud

The schematic system is shown in Fig. 1. The emission collected from the viewing area, 144 x 144 mm^2 square at the midplane containing the pellet trajectory, is projected onto the 2D-side of the image-to-array optical fiber bundle (200 μm fused silica core/230 μm hard polymer cladding from Fiberguide Industries, Inc.,). The spatial channel of the 2D side is 12 x 12