Absorption length dependence of He I resonance line in He arcjet plasma

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Emission spectrum analysis of plasma and neutral particles is widely used to estimate plasma parameters such as electron temperature and density [1]. In estimating plasma parameters using emission spectra, it is assumed that the observed emission from the plasma is not absorbed or scattered until it reaches the detector. However, if the optical thickness cannot be neglected, it is necessary to take into account the absorption of emission by atoms or ions over the optical path, which is termed self-absorption. Therefore, it is essential to quantitatively evaluate the effect of self-absorption to determine plasma parameters using emission spectra accurately. The He I resonance lines, which lie in the vacuum ultraviolet region, are the example where the self-absorption effect cannot be neglected. Since the emission of He I resonance lines is very intense, various information can be expected to be obtained by analyzing the intensity ratio of emission spectra and spectral shape. In this study, the dependence of the He I resonance line intensity on the absorption length was experimentally examined to estimate the self-absorption effect quantitatively. In order to vary the absorption length, we used a vacuum tube installed an aluminum filter, where the VUV light can transmit it, but neutral atom cannot, thus controlling the absorption length.

A schematic diagram of the experiment is shown in Fig. 1. In this study, we measured He I resonance lines ($1s\ ^1S - np\ ^1P$) from the helium cascade arc plasma, whose diameter was 8 mm. A vacuum ultraviolet spectrometer and an X-ray CCD camera were used to measure the emission spectra. A photograph of the vacuum tube used to vary the optical length is shown in Fig. 2. The key feature of the observation system is that the viewing angle remained constant while the length of the absorption region was changed. The internal collimator with an inner diameter of 5 mm determined the solid angle to observe the He I resonance line. In addition, the aluminum filter at the observation window and vacuum bellows tube were placed between the internal collimator and the plasma, so the optical path from the filter to the CCD camera was kept in high vacuum, so that no self-absorption occurred between the filter and CCD camera. The inner diameter of the observation window and filter was 12 mm. The observation window was large enough so that the observation angle did not change when the observation window was moved along the optical axis. The transmittance for 58.4-nm wavelength ($1s\ ^1S - 2p\ ^1P$) is approximately 0.17. The VUV spectroscopic system observed the anode of the He arc plasma within the range of 5.5 × 8.8 mm. The observation window was moved 160 mm by an actuator. By moving the observation window and measuring the He I resonance lines, the dependence of the line intensity on the length of the absorption region was obtained, which represents the effect of the self-absorption length along the optical path.

We will present the details of this measurement system and the obtained data.

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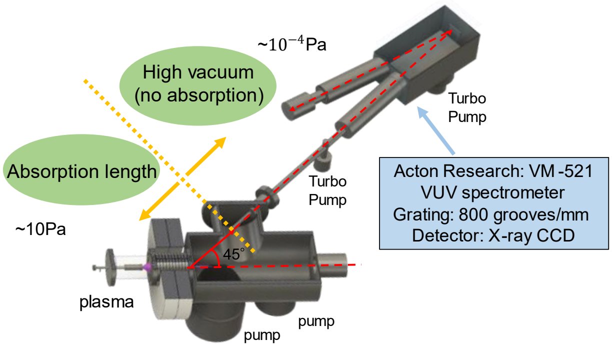

Fig. 1. A schematic of the experimental setup.

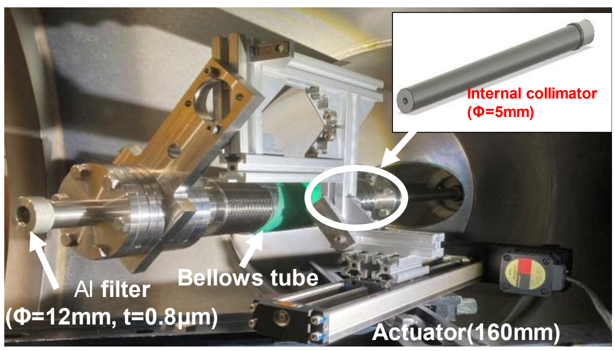

Fig. 2. Photo of the vacuum tube. The actuator was used to vary the optical length.

Reference

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