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Numerical study of He I 1s^1S-2p^1P radiation trapping in high-ambient gas pressure thermal arc plasma

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The emission spectrum has been utilized to estimate fundamental plasma parameters, such as, flow velocity, particle density and temperature. In magnetically confined fusion plasmas, the spectra emitted from helium atom/ion are widely used for evaluation of the electron density and temperature, because reliable collisional radiative (CR) model incorporated with atomic data for elementary processes.[1] In particular, visible spectra radiated from He atom injected into various plasmas can be analyzed to measure plasma parameters by means of line intensity method.[2] However, the effect of self-absorption (radiation trapping) cannot be disregarded when the plasmas are generated in high-pressure He conditions and dense plasmas. Previous experimental and numerical studies show that population density in the upper levels of resonance transitions, i.e., He I 1s^1S-2p^1P, significantly increased due to the radiation trapping, thus making it impossible to determine the plasma parameters by line intensity ratio. Although quantitative experiment examining the self-absorption has been conducted for plasma region so far, the absorption outside the plasma volume is not investigated. In order to reveal the effect of radiation trapping under high-ambient He gas pressures, we investigated the relationship between He I 1s^1S-2p^1P line spectrum and absorption length from He plasma to vacuum ultraviolet (VUV) spectrometer.

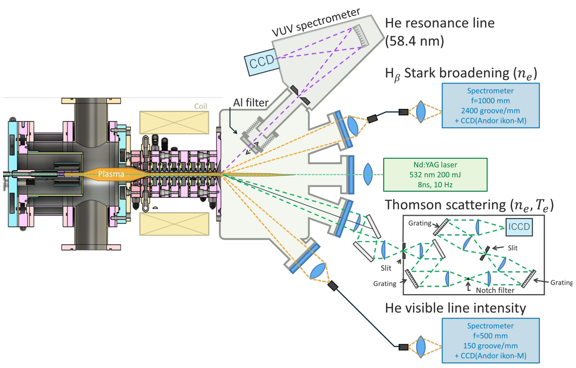

Figure 1. Schematic of the experimental setup.

Figure 1 shows a schematic drawing of the experimental setup. Helium plasma was generated in the cascade arc plasma source and ejected into the vacuum vessel. A VUV spectrometer observed at the anode electrode in the 45degree with respect to the jet axis. The optical path was covered by a metal tube/bellows and pumped by a differential pump, maintaining the pressure in the tube be < 0.1 Pa (see **FIG. 1**). Aluminum filter was attached to the end of the bellows. By varying the tube length (absorption length), we measured He I 1s^1S-2p^1P line spectrum, allowing us to investigate the correlation between He spectrum and the self-absorption due to the residual gas along the optical path.[4]

In this study, numerical simulations were performed to investigate how the He I 1s^1S-2p^1P line shape changed as a function of the absorption length and spatial distribution of atomic temperature and density. Figure 2 shows a typical line shapes for several absorption lengths. As clearly seen, each spectral profile has a strong dip in the line center due to radiation trapping in the ambient gas. Their depths increase with the absorption length and eventually saturates. The width of the depression in the spectral profile is determined by the the absorption spectral profile, depending upon He gas temperature.

In principle, if the relationship between He resonance line intensity and the absorption length can be reproduced by radiation transport simulation assuming that spatial profile of He atom temperature and density

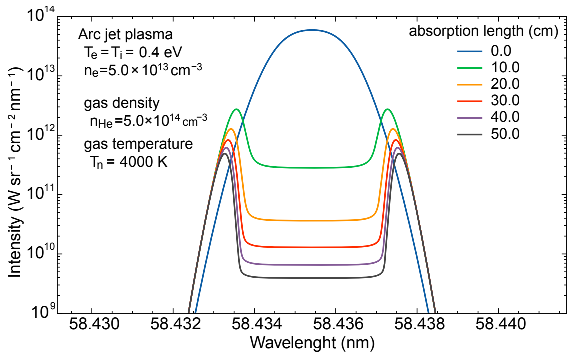

Figure 2. He I 1s^1S-2p^1P line shapes for various absorption lengths.

along the optical path of the spectrometer, we can assess the effect of resonance line absorption. The presentation will include more detailed results and discussion.

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References

[1] M. Goto, J. Quant. Spectrosc. Radiat. Transfer **76**, pp. 331-344 (2003)
[2] S. Sasaki, *et. al.*, Rev. Sci. Instrum., **67** (10) pp. 3521-3529 (1996)
[3] H. Kawazome, *et. al.*, Plasma Fusion Res. **16** 2401012 (2021)
[4] R. Hamada, *et. al*., to be presented at AAPPS-DDP 2025