Near-infrared Stokes spectropolarimetry as a novel local measurement method of atomic line emission in SOL and divertor plasmas

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Stokes spectropolarimetry is a method originally developed for astrophysical plasmas to deduce the magnetic field in plasmas using Zeeman or Hanle effect on emission or absorption line spectra (*e.g.*, [1]). These effects emerge as a wavelength splitting and variations in polarization and the relative intensities of the line spectra. For fusion plasmas, Stokes spectropolarimetry has been applied since 1980s. Different from the astrophysical plasmas, the magnetic field profile is basically given for the fusion plasmas. The method is then used to spatially resolve the viewing chord-integrated emission line spectra by using the correspondence between Zeeman effect and the emission position on the chord. It was initially applied to JET (B = 2 T) for the evaluation of the intensity peak positions near the limiter for atomic and ionic lines [2]. After that it was extended to the separation of the superposed inboard and outboard SOL atomic line spectra in Alcator C-Mod (B = 8 T) [3] and LHD (B = 2.75 T) [4], which enabled independent intensity and Doppler profile analysis of the inboard and outboard line spectra. We played a part in the development of the method by demonstrating the measurements of the poloidal distribution of atomic influx [5, 6], temporal variation in the local recycling flux [6], and a correlation between the limiter hot-spot temperature and the rotational temperature of hydrogen molecules existing near the hot-spot [7] in TRIAM-1M tokamak (B = 7 T).

Since the method adds spatial resolution to passive emission spectroscopy and is implementable with small port area, it has a potential use for the SOL and divertor diagnostics in the future fusion reactors in terms of the evaluations of the radiation peak position and local plasma parameters. However, to realize the use, we need to further improve the spatial resolution. For visible (VIS) emission lines, the magnitude of the wavelength splitting by Zeeman effect is comparable to the line broadening by Doppler effect and the instrumental function, and the latter prevents precise estimation of Zeeman effect. We addressed this issue and developed a near-infrared (NIR) Stokes spectropolarimetry to increase the relative magnitude of Zeeman effect. Zeeman effect is approximately proportional to the square of the wavelength, while Doppler effect and the instrumental function are proportional to the wavelength [8, 9]. In addition, NIR spectroscopy is technically favorable for the fusion reactors for the better tolerances for the degradation of first-mirrors and radiation-induced absorption and luminescence of fused silica optical components.

We have conducted proof-of-principle experiments in a medium-size helical device Heliotron J (B = 1.5 T). Polarization resolved spectra of HeI 2^3S-2^3P (1083 nm) and DI Paschen-α (1875 nm) emission lines in the direction parallel (I_0) and perpendicular (I_{90}) to the magnetic field direction were measured using a high wavelength resolution spectroscopy system. The wavelength splitting by Zeeman effect was observed more conspicuously than VIS lines and the superposed inboard and outboard SOL line spectra were separated more easily. Furthermore, to spatially resolve the line spectra in the inboard and outboard SOLs, we made a comparison of the measured I_0 and I_{90} spectra with those calculated using a Monte Carlo atomic transport code. As a preliminary result, both the Zeeman and Doppler effects on the measured HeI line spectra were reproduced by assuming that all the atoms are produced by recycling from the first wall.

References

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