§76. Development of a Near-infrared Interference Spectrometer for the Observation of Local Atomic Density and Velocity in the SOL of the QUEST Spherical Tokamak

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For the spatially resolved diagnostic of the atomic density, temperature, and flow velocity in the SOL of torus plasmas, a passive spectroscopy technique utilizing the Zeeman splitting of spectral lines has been developed. By using this technique, emissions originating from the inboard and outboard SOLs can be separately measured by analyzing the difference in their spectral line shapes. The emission intensity and Doppler broadening and shift can then be locally measured from the separated spectral lines[1].

Application of this technique requires a larger Zeeman splitting than line broadening to separate superposed spectra. The observation of a spectral line with a longer wavelength is thus advantageous, since the magnitude of the Zeeman splitting is approximately proportional to the square of the wavelength, while that of the Doppler broadening is proportional to it. On the basis of these proportionalities, we have developed a near infrared (NIR) interference spectrometer to measure an NIR spectral line, HeI 2^3S-2^3P (1083 nm), with a high wavelength resolution.

In order to confirm the feasibility of the diagnostic technique, we conducted experiments in QUEST using a helium discharge. In the operation, only the toroidal field was applied, and a cylindrical plasma was produced by 8.2 GHz ECH. The plasma current was less than 100 A, and the poloidal field was negligible. The emission was localized near the resonance layer at a major radius of 0.29 m.

A radial viewing chord in the mid-plane was adopted. A linear polarizer (Sigmakoki SPFV030C-26; extinction ratio 6.3×10^{-5}) was placed in front of the objective lens, and its transmission axis was sequentially aligned on a shot-by-shot basis to be parallel and perpendicular to the toroidal direction; the two directions correspond to selective measurements of the π and σ components, respectively. The collected light was then transferred via an optical fiber and injected in the spectrometer[2]. The instrumental function represented by a Lorentzian function had an FWHM of 23 pm.

The measured π and σ components are shown in Fig.1. We assumed that the emission was radially localized and performed the least-squares fitting with a magnetic field strength, emission intensity, temperature, and velocity along the viewing chord as adjustable parameters. The fitting results well reproduce the measurements, and a field strength of 0.26 T, temperature of 0.5 eV, velocity of 0.8 km/s were obtained. The field strength is slightly smaller than the resonance field strength of 0.29 T.

The difference between the obtained and resonance

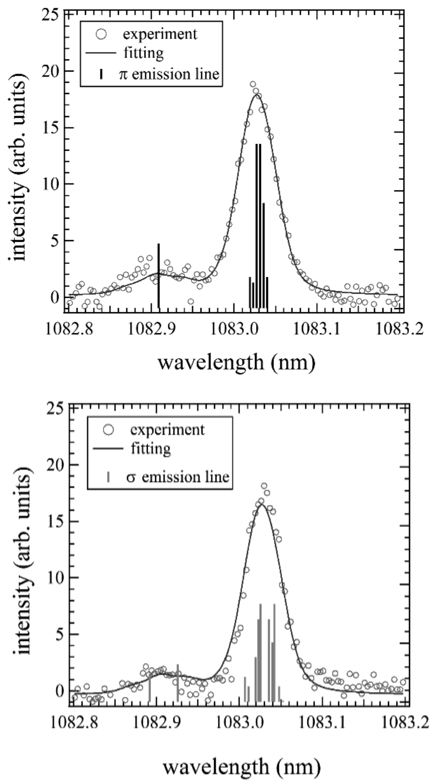

Fig.1. Measured π and σ components of the HeI 2^3S-2^3P spectral line.

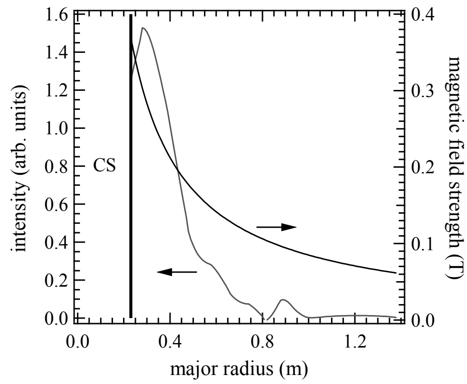

Fig.2. Radial profiles of the magnetic field strength and HeI 2^3P-4^3S intensity obtained by the Abel inversion.

field strengths is caused by the radial expansion of the actual emission region. We evaluated the radial distribution of the emission intensity by applying the Abel inversion to the line-integrated emission intensities of the HeI 2^3P-4^3S spectral line (471 nm) measured using multiple viewing chords in the mid-plane[1]. The result is shown in Fig.2. The intensity reaches the maximum at the resonance layer and expands toward the outboard side. The line-integral of the emission along the viewing chord results in the apparently smaller magnetic field strength.

1) Shikama, T. et al.: Can. J. Phys. 89 (2011) 495, and references therein.
2) Ogane, S., Shikama, T. et al.: Rev. Sci. Instrum. 86 (2015) 103507.