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

Shikama, T., Ogane, S., Hasuo, M. (Dept. Mech. Eng. Sci., Kyoto Univ.), Zushi, H. (RIAM, Kyushu Univ.)

For the spatially resolved diagnostics of the atomic density, temperature, and flow velocity in the SOL, a passive emission spectroscopy technique which utilizes the magnetic field effect on the spectral line shape has been developed. The technique determines the emission location from the magnitude of the Zeeman splitting. In particular by adopting a radial viewing chord near the mid-plane, emissions which originate from the inboard and outboard SOLs can be separated by using difference in the spectral line shapes. The local values of the emission intensity and Doppler broadening and shift can then be evaluated from the separated spectral lines [1].

Application of this technique requires a larger Zeeman splitting than the spectral line broadening. It is, hence, advantageous to observe a spectral line with longer wavelength, 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 the wavelength. In the fusion relevant plasmas, one should also consider the effect of the black-body radiation emanated from the plasma facing components whose surface temperature can increase up to nearly 1000 K and locally over 1000 K. Thereby the effect of the radiation can be large in the mid- and far-infrared regions. Based on this restriction and the above mentioned wavelength proportionalities, we have developed a near infrared (NIR) interference spectrometer optimized for the observation of the HeI 2^3S-2^3P transition (1083 nm). The helium atom is an intrinsic element in the fusion relevant plasmas, and for the observation of the Zeeman splitting, it is advantageous compared to the hydrogen atom, since we can neglect the heating processes of atoms through the molecular dissociation and consequently expect smaller Doppler broadening.

A schematic drawing of the spectrometer is shown in Fig. 1. The light is transferred via a quartz optical fiber following which the ejected light is collimated by an objective lens (Mitsutoyo M Plan Apo NIR 10x). After reduction of the beam diameter, the beam is injected into a tunable Fabry-Perot etalon (Light Machinery OP-1986-64; wavelength 1083 nm, FSR 0.6 nm). The gap length of the etalon is adjustable by applying voltage to the piezoelectric element, where a scanning frequency up to 10 kHz is attainable for one FSR. For typical measurements, a low-frequency triangular voltage (20 V_{pp}, 10 Hz), which corresponds to about two FSRs, is applied by a function generator. The beam transmitted through the etalon passes through an interference filter (Omega Optical XB173-1080BP10; 1080 nm, FWHM 10 nm) to exclude the other emission lines. Finally the intensity of the beam is measured by a cooled photomultiplier tube (PMT) (Hamamatsu Photonics R5509-43). The PMT current is converted into voltage by a transimpedance amplifier, and the signal is recorded by a digitizer (NI USB-4431; 24 bit, 102.4 ks/s). All the optical components are enclosed in a housing made of aluminum with black alumite coating so as to minimize the temperature fluctuation and to reduce the stray light. In a laboratory with a typical air-conditioning system, we confirmed reproducibility of the measured spectrum at least within several hours.

The applied voltage to the etalon was converted into the wavelength with observing helium atom emission from a commercial discharge tube (Electro-Technic Products Spectrum Tube). The conversion coefficient was estimated to be 67.4 pm/V. The instrumental function of the spectrometer was measured with light from a single-mode laser-diode (Thorlabs L1060P200J; 1060 nm), the spectral line broadening of which is negligibly small compared to that of the transmittance profile of the etalon. During measurements, the temperature and injection current of the laser-diode were controlled with respective drivers (Thorlabs TED200, LDC202). The observed spectrum shown in Fig. 2 was fitted with the Lorentzian function, and the FWHM was found to be 15.1 pm [2].

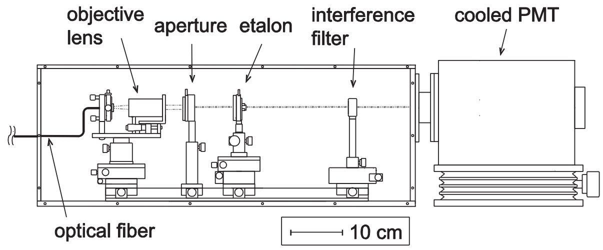

Fig. 1. A schematic diagram of the spectrometer.

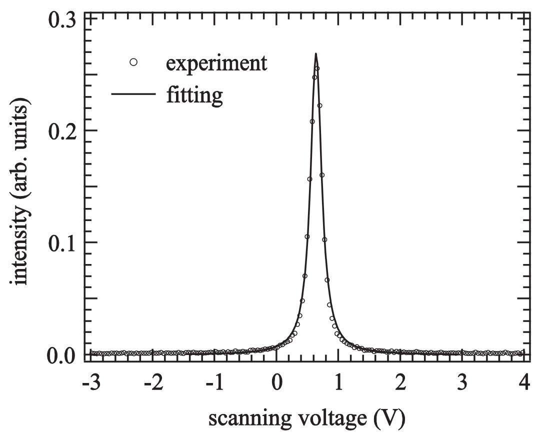

Fig. 2. Spectrum of 1060 nm single-mode laser-diode.

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