§ 23. Plasma Polarization Spectroscopy on the LHD

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When collision frequency between electrons is low, the electron velocity distribution function (EVDF) may deviate from the thermal equilibrium Maxwellian distribution function. For instance, when the electron cyclotron resonance (ECR) wave heats electrons, when the lower-hybrid current-drive (LHCD) is applied to a tokamak plasma resulting in the run-away electrons, or in low density RF discharges, the EVDF could even be anisotropic.

The excitation levels of ions (hereafter the word "ions" includes atoms) are excited by electron impacts in the plasma. If the electron impacts are anisotropic, the alignment, i.e., the population imbalance among the magnetic sublevels of the excited level, is created. The aligned excited ions produce polarization in the emission line originating from this level. From the observation of polarization of the emission lines, we can deduce the information about the anisotropy of EVDF in the plasma. Polarization resolved spectrometry has been performed on the Large Helical Device (LHD).

Emission lines from the plasma were observed with the polarization separating optical fiber system. This system consisted of a 104° beam separation Glan Taylor prism made of calcite and a Glan Taylor prism made of αBBO for the UV region (200-300 nm) or of calcite for the visible region (over 300 nm) and a pair of lens couplers, each of which focused the plasma radiation on a optical fiber for the orthogonal linearly polarized light. The output from the fibers was fed in a line in front of a spectrograph of 50 cm focal length f/8 (Chromex 500is), which was equipped with three plane gratings (100, 1800 and 3600 grooves/mm) on a rotary table and a pair of toroidal mirrors for minimizing aberration. The spectral image was recorded by a back illuminated CCD (Andor DV420-UV equipped with Malconi 30-11, 1024x256 of 26 μm square pixels). For high-resolution observations, we used another spectrograph (McPherson M209) of 1.33m focal length f/9.4 1800 grooves/mm and a frame transfer CCD (Andor DV435-BV equipped with EEV 4720, 1024x2048 of 13 μm square pixels, half of them were masked as a storage area). In order to minimize the smear effect, which is caused by the exposure of the pixels to the light from the other fibers during the charge transfer process on the CCD, we selected only one pair of fibers which corresponding to the line of sight on the equatorial plane of the LHD plasma.

Figure 1 shows the polarization resolved spectra of C II 3s $^2S_{1/2} \leftarrow 3p\ ^2P_{1/2,3/2}$ (658.3, 657.8 nm) from a collapsed plasma. Since the ion temperature is relatively low, Doppler broadening is narrower than the Zeeman splitting. The filled and open circles represent the ordinary- and extraordinary-rays, respectively, the electric-field vector of which oscillated in the direction 10° and 100° with respect to the horizontal direction.

The least squares fitting was performed to the Zeeman profiles and the results are shown with solid curves in Fig.1. It was found that the magnetic field strength was B = 2.6 T and its direction was 5° with respect to the horizontal direction. We calibrated the relative transmittance of the optical system for the two polarized components by using the J=1/2 ←1/2 emission lines. The J=1/2 ←1/2 transition is never polarized. The longitudinal alignment, $A_L = (I_\pi - I_\sigma)/(I_\pi + 2I_\sigma)$, of the J=1/2 ←3/2 was 0.001± 0.006. No polarization was observed in the time evolution of the plasma.

In a discharge of neon gas puff, neon pellets were injected into the main plasma at 1.02, 1.86, 1.94 and 2.02 s. The plasma was started by the injection of neutral beam until 1.9 s and two ECR waves (82.7 and 168 GHz) were injected from 2 to 2.6 s. The time evolution of the polarization resolved spectra of Ne I $1s_2$-$2p_4$ (Paschen notation) 667.8 nm is shown in Fig. 2. At t=2.0 s after the pellets were injected, the emission profiles drastically change their shapes both for the o- and e-rays. The Zeeman profile of the e-ray signal shows $\Delta\lambda$=0.15 nm splitting at 1.8 and 1.9 s; this indicates that the σ components are dominant. From 2.0 s the central π component is superimposed on the split σ components in the e-ray and apparent broadening appears in the o-ray signal understood to be caused by overwrapping of the split σ components. If the emissions are generated from the two groups of atoms at two different locations where the magnetic field directions are different, the variation of the spectra may be explained. The quantitative analysis is underway.

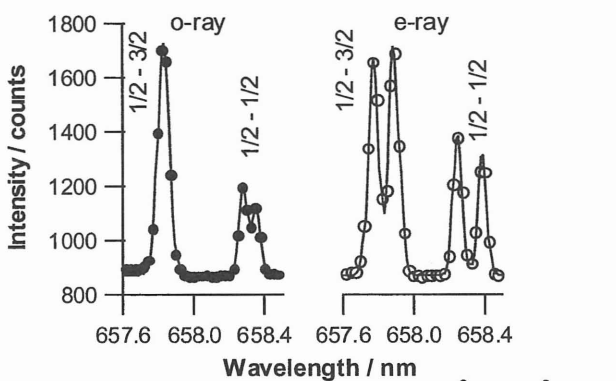

Fig. 1. Polarization resolved spectra of C II $3s^2S_{1/2}$-$3p^2P_{1/2,3/2}$

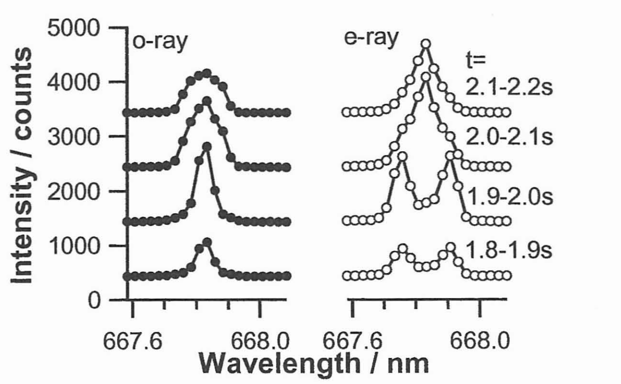

Fig. 2. Polarization resolved spectra of the Ne I $1s_2$-$2p_4$