§40. Plasma Polarization Spectroscopy

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In magnetically confined plasmas, like those in tokamak or helical devices, electrons in their cyclotron motion are subject to various perturbations, for example ECR heating and LHCD. In these circumstances, an anisotropic distribution may develop in electron velocities.

Until recently, emission lines have been assumed to be unpolarized. In other words, one was indifferent to the polarization of the "ordinary" emission lines, except in the case of the observation of Zeeman or Stark split lines. It has been found, however, that ordinary emission lines can be polarized [1] and the polarization is attributed to anisotropic electron velocity distributions. This fact suggests that, by observing polarization of emission lines, we can obtain additional information about the plasma concerning its anisotropy or non-thermal component [2].

The WT-3 tokamak at Kyoto University had the major and minor radii of 0.65 and 0.2 m, respectively. The toroidal magnetic field was 1.5 T and the toroidal current was 60 kA. The electron density and temperature were $n_e=1_10^{19}$m^{-3} and T_e=100~300 eV, respectively, near the axis. The plasma image was focused on the entrance slit of a monochromator (f=1000 mm with grating of 3600 grooves /mm) by three mirrors. Just behind the entrance slit, a calcite plate of 5.4 mm-thickness was placed, which separated the polarization components; The toroidal axis was taken as the quantization (z-) axis, and the light component whose electric field oscillating parallel to the z-axis was π light and that perpendicular the σ light. The spectrum image was focused on the image-intensifier-coupled CCD. We observed helium-like carbon (CV) 1s2s $^3S_1$←1s2p $^3P_{0,1,2}$ emission lines in the ultraviolet region. Figure 1 shows an example of the time-resolved spectra.

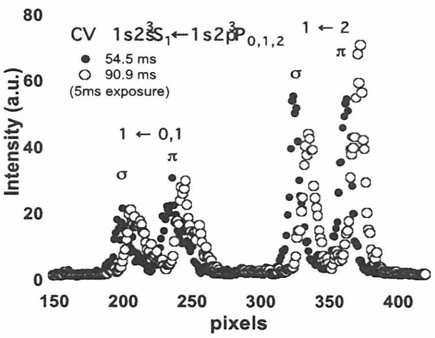

Figure 1. The time-resolved spectra of CV 1s2s $^3S_1$←1s2p$^3P_{0,1,2}$ emission lines.

The J=1←0 and 1←1 lines were blended. The J=1←2 line at t=54.5 ms shows apparently similar signal magnitudes for its σ and π light components, whereas at t=90.9 ms the intensity of the π light components is stronger. The J=1←0 line is never polarized since its upper level has a single m_J = 0 state. For the purpose of increasing the S/N ratio, we summed the spectral data over ten shots and conducted multi-peak least-square fitting to the spectrum. From the J=1←0 line intensity ratio we deduced the efficiency ratio of our detection system for the π and σ components: S =1.24. The resulting longitudinal alignments were $A_L= (I_\pi - I_\sigma)/(I_\pi + 2I_\sigma) = -0.04$ at t=54.5 ms and +0.04 at 90.9 ms.

We developed the population-alignment collisional-radiative (PACR) model code which interprets the observed polarization in terms of the anisotropic electron velocity distribution in plasma. We used the distorted wave approximation results for excitation cross sections. We found that, when the toroidal velocities are dominant over the poloidal ones we have negative A_L for the J=1←2 transition, and *vise versa*.

The cross section data were supplied by Drs. J. Dubau and M. Cornille and by Drs. H. Zhang, G. Csanak and D. Kilcrease.

Reference

[1] T. Fujimoto, H. Sahara, T. Kawachi, T. Kallstenius, M. Goto, H. Kawase, T. Furukubo, T. Maekawa and Y. Terumichi, Phys. Rev E **54**, R2240 (1996).

[2] T. Fujimoto and S.A. Kazantsev, Plasma Phys. Control. Fusion **39** 1267 (1997).