§15. Development and Coordination of Plasma Polarization Spectroscopy (PPS)

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The phenomena involved in PPS are divided into three classes; Class 1 is due to the Zeeman (Paschen-Back) effect or the Stark effect. The excitation is isotropic. A spectral line is split into several components and each component is linearly or circularly polarized. These phenomena are well established in atomic physics. Class 2 is due to anisotropic properties of the plasma. An anisotropic velocity distribution of electrons, beam ions, directional photo excitations, all could give rise to polarized light. Class 3 is the combination of Class 1 and Class 2: under an electric and/or magnetic field, the directions of which may be different, an atomic ensemble is excited directionally. This requires very complicated theoretical treatment.

In this collaboration research, the present status of PPS was reviewed from the standpoint of encouraging development and coordination of researches as well as to establish atomic data, including computer codes especially kinetic model codes, which are relevant to PPS.

Class 1: High resolution spectroscopy was made on the LHD, and Zeeman split spectral lines from neutral helium, hydrogen, and berylliumlike carbon ions were observed. Helium lines revealed two sets of clear Zeeman patterns, which were shifted each other due to Doppler effect. From the magnitude of the Zeeman splitting it was concluded that the emissions originate from two locations of the plasma, i.e., just outside the ergodic layer which surrounds the main plasma. The magnitude of the relative shift suggests that helium atoms are moving inward with energy about 1 eV. Hydrogen Balmer alpha line showed larger Doppler broadening and the pi- and sigma-components could be barely separated. Asymmetric patterns, i.e., the shorter wavelength sigma-component is stronger, were observed occasionally. When the plasma changes into the recombining phase, berylliumlike carbon showed a Zeeman pattern, the intensity distribution of which cannot be understood in terms of the ordinary Zeeman splitting. This suggests that the upper level ions have large alignment, which in turn, suggests that the plasma electrons have strongly anisotropic velocity distribution. In the experiment on JT-60 asymmetric Balmer alpha Zeeman pattern has also been observed.

With a JT-60 reverse shear discharge plasma, MSE measurement revealed that in the central region (ρ <0.3) the troidal current almost disappears.

Class 2: In uv-visible spectroscopy on the WT-3 tokamak in Kyoto University berylliumlike oxygen impurity line showed polarization. GAMMA-10 tandem mirror plasma showed that neutral and singly ionized chromium and iron lines are polarized, in the central region and in the anchor region. In the latter plasma the polarization is even more pronounced. For the former polarization a population-alignment collisional-radiative model has been constructed and the cross section data were incorporated. These cross sections were calculated by the distorted wave method by collaborators in France and in the US. Both the calculations give reasonably consistent cross sections each other. For anisotropic velocity distributions of electrons, the polarization degree or the longitudinal alignment, was calculated. The longitudinal alignment for the $2s3p^3S_1$ - $2s3p^3P_2$ line was as low as –0.01, as compared with that from the experiment of –0.07. Quantitative agreement should be improved, but it could be concluded even now that the electron velocity distribution is heavily directed in the poloidal direction for the plasmas that show the negative polarization. Balmer line spectroscopy on the Heliotron-J revealed that the Balmer alpha showed temporal change in its polarization and in the stationaly phase the polarization is negative: longitudinal alignment is -0.07 ± 0.02. Polarization degree decreased for the Balmer beta line and gamma line, which was almost unpolarized. The possible effect by the light reflection from the oblique vessel wall was examined, and it was concluded that the reflection would lead to polarization in the opposite direction.

It was stressed that 1. Polarization can be detected from a wide variety of plasmas if a careful experiment is done. 2. Zeeman patterns sometimes show intensity distributions that cannot be interpreted in terms of normal characteristics of atomic population. These anomaly must reflect some anomalous features of the plasma.

Concerning activities of the Data Planning and Information Center, the following items are suggested; 1. Establishing computer codes for calculation of the Zeeman splitting, especially in the transition region from the Zeeman effect to the Paschen-Back effect. 2. Establishing the population-alignment collisional-radiative model code. At the same time, electron collision cross section data relevant to the polarization phenomena may also be collected as standard atomic data.