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

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The objective of this Cooperation Research Program is to develop PPS as a plasma diagnostic technique by making *polarization* the keyword. In this fiscal year we examined the following subjects.

1. Anomaly of Balmer alpha line profile from tokamaks

At Kyushu University, a Zeeman (or Paschen-Back) split line was observed on the TRIAM-1M. In the majority of discharges, the profile showed the usual Zeeman pattern with the stronger central π component and the weaker σ components on the both sides. 1 or 2 shots out of ten showed a profile with the central π component significantly weak or almost absent. If we assume the equal populations among the magnetic sublevels of the $n = 3$ level, the anomalous profile is interpreted that the magnetic field makes an angle about 45 degrees with respect to the toroidal direction. Since this assumption is quite unlikely, we have to explore another possible interpretation. One possibility is that the strong microwave creates resonant population transfer among the magnetic sublevels resulting in strong alignment.

2. Studies of the electric field from the polarization of emission lines

At Hiroshima University, a unique electric-field diagnostic method has been developed in which the degree of Stark mixing of the optically allowed transition component to the forbidden transition is determined from the polarization degree of the line. At Kanazawa University, the Langmuir turbulent state is being investigated which is produced by the injection of a strong relativistic electron beam into a plasma. So far, the electric field strength inside the caviton has been estimated from the Stark shift and the intensity of a neutral helium emission line. An oscillating electric field of the order of 100 kV/cm with the frequancy of 10 GHz was concluded. A possibility was discussed to determine the direction of the field on the basis of the polarization observation of the optically forbidden transition.

3. PPS on the WT-3 tokamak

By the image reduction optics of 1/8 the image of the WT-3 plasma was focussed on the entrance slit of the monochromator. The two polarized components were resolved by the calcite plate located just behind the entrance slit. Thus, the space (poloidal direction) resolved and polarization resolved spectra were obtained on a CCD detector. The quality of the image was improved by compensating the change in the focal plane position owing to the introduction of the calcite plate. The transitions from the $J = 1$ and 2 levels of berylliumlike oxygen of $2s3p^3P_J$ showed polarization. The two weak components of heliumlike carbon $2^3S_1 - 2^3P_{0,1,2}$ lines were barely resolved.

4. Directional electron collisions on rydberg atoms

Yoneda *et al.*[1] showed that heliumlike fluorine lines from the laser produced plasma are polarized. The line intensity distribution in the spectrum clearly indicates that the plasma is recombining. This conclusion is consistent with the presence of the recombination continuum, which is also polarized, indicating that the continuum electrons have an anisotropic velocity distribution. Highly excited ions are produced by three-body recombination of ions with the directionally indident electrons. Ditmire[2] presents a formula of three-body recombination rate, but this formula is based on the two assumptions which are not justified.

A classical Monte Carlo calculation of directional electron collisions on $n = 10$ hydrogen atoms is performed. For elastic collisions the populations tend to drift to $m_l = 0$ sublevels, suggesting positive polarization for the resonance-series lines, which is consistent with Yoneda's experiment. In ionization events the two electrons leave the proton with relative angles larger than 60 degrees. This suggests reduced rate for three-body recombination in comparison with the isotropic velocity distribution.

5. X-ray spectroscopy of highly-ionized ions by Tokyo-EBIT

From the direction perpendicular to the electron beam the Lyman alpha line of hydrogenlike titanium was observed with the quartz crystal spectrograph. From the apparent intensity ratio of the Lyman alpha 1 and alpha 2 lines, polarization degree of the latter line was estimated. The polarization degree against the excitation energy was significantly smaller than calculation. A thorough examination of experimental uncertainties will be made.

References

1) Yoneda, H. *et aj.*, Phys. Rev. E **56**, 988 (1997).
2) Ditmire, T., Phys. Rev. E **54**, 6735 (1996).