§3. Anisotropic Electron Velocity Distribution Function in GAMMA10 Tandem Mirror Plasma Analyzed by Means of Plasma Polarization Spectroscopy

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The electron velocity distribution function (EVDF) in a plasma is one of the most important attribute of the plasma. When the EVDF is isotropic and Maxwellian, the determination of the EVDF is equivalent to measuring the electron temperature. However, a plateau-shaped electron energy distribution function is observed in the plug region of GAMMA 10 tandem mirror, in the case the electron cyclotron resonance heating (ECRH) is adopted for formation of a plug potential with a thermal barrier [1]. A departure from the Maxwellian velocity distribution is inferred. Since the electrons are accelerated in the direction perpendicular to the magnetic field, the non-Maxwell characteristics may indicate that the electron by ECR microwave in the plasma.

The emission from the plasma in the plug-barrier region was resolved into orthogonally polarized components, π and σ lights, with the polarization separation optics (PSO) schematically shown in Fig 1. The PSO consisted of a lens and a polarization separation Glan-Thompson prism made of calcite. The π light is the linearly polarized component parallel to the quantization axis i.e. magnetic field direction, and the σ light perpendicular to the magnetic field direction. These polarized light components were transmitted through a bundle of twenty optical fibers to the entrance slit of a one-meter focus spectrometer. The dispersed spectra were recorded with a charge coupled device (CCD) of 7.4×7.4 μm 2048× 2048 pixels equipped with a fast mechanical shutter. The dispersion was 0.296 nm/mm. The CCD was cooled and the temperature was kept constant at 275 K.

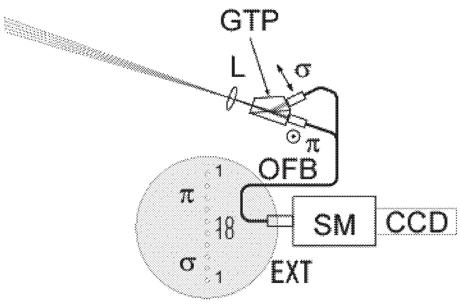

Fig. 1. Polarization Separation Optics.
GTP：Glan-Thompson Prism. OFB：Optical Fiber Bundle. SM ： Spectrometer. CCD. Charge coupled device.

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Figure 2 shows an example of the polarization separation spectra emitted from neutral helium atoms in the plasma during ECR discharge cleaning. Since the upper level of the line of λ504.8 nm is a ^1S state, this line emission is never polarized and can be used as the reference for the polarization determination for other lines. The intensity of the π component I_π of the line λ501.6 nm is higher than that of the σ component I_σ. After averaging over the twelve exposures, the observed polarization degrees $P = (I_\pi - I_\sigma)/(I_\pi + I_\sigma)$ of the lines λ504.8 nm and λ501.6 nm are 0.000(19) and 0.155(9), respectively. The numbers in the parentheses represents statistic errors.

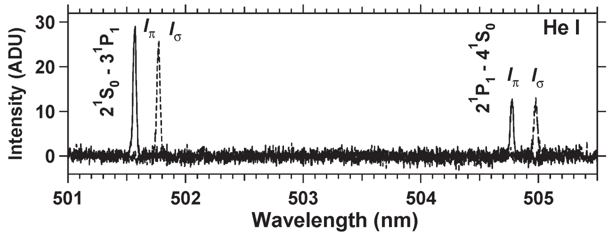

Fig. 2. Polarization separation spectra of HeI lines at λ504.8 nm and λ501.6 nm. The σ component is displaced by 0.2 nm for easier comparison.

The magnetic field direction is perpendicular to the line of sight. Thus the longitudinal alignment $A_L = (I_\pi - I_\sigma)/(I_\pi + 2I_\sigma) = 2P/(3-P)$ for 501.6 nm is 0.109(7).

Population-alignment collisional-radiative (PACR) model [2] for He I is used to estimate the anisotropic electron velocity distribution function (EVDF). We assumed that the EVDF is represented by a model function of two orthogonal temperature parameters

$$f(v,\theta) = 2\pi\left(\frac{m}{2\pi k_B}\right)^{3/2}\left(\frac{1}{T_{rd}{}^2 T_{ax}}\right)^{1/2}\exp\left[-\frac{m}{2k_B}\left(\frac{\sin^2\theta}{T_{rd}}+\frac{\cos^2\theta}{T_{ax}}\right)\right]$$

where T_{ax} and T_{rd} are axial and radial temperature parameters, respectively.

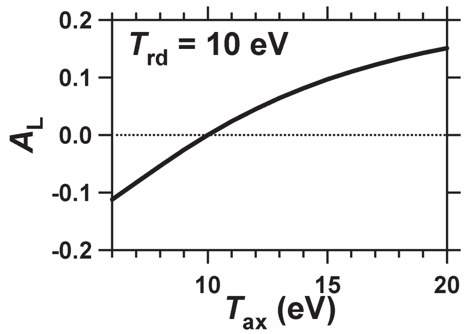

Fig. 3. A_L dependence on T_{ax} of two temperature parameter EVDF. T_{rd} is constant at 10 eV

A_L dependence on T_{ax} is shown in Fig. 3. When the shape of the EVDF is prolate spheroid, A_L is negative. When the shape of the EVDF is oblate spheroid, A_L is positive. $A_L = -0.11$ is obtained at the parameters T_{rd}, T_{ax} = 10, 16 eV.

[1] T. Cho, *et. al.*, Phys. Rel. Lett. **64**, 1373 (1990).
[2] A. Iwamae, *et al.*, in press