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§15. Anisotropy of Proton Velocity Distribution Function in Argon Plasma Analyzed by Means of Plasma Polarization Spectroscopy

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The proton (or deuteron) velocity distribution function (PVDF) in a magnetically confined fusion plasma can be anisotropic in the velocity space on a certain condition. The PVDF in low density plasma heated with neutral beam injection (NBI) is expected to be anisotropic. The magnetic dipole (M1) transitions between the levels of ground state configuration of multiply ionized ions are observed in a visible spectral region and the population of the upper level of M1 transitions are created due to the collisional excitation by protons[1]. Anisotropic collisional excitation produces population imbalance or alignment on the upper level. The emission form the aligned level is polarized.

Argon gas was puffed into the LHD vacuum vessel then the NBI started plasmas. The emission from the plasmas was resolved into orthogonally polarized components with the polarization separation optics (PSO). Two types of the PSO were used. One consisted of a polarization separation Glan-Thompson prism and a pair of lens couplers. The other consisted of two Glan-Taylor prisms and a pair of lens couplers. The each image of the optical fiber cores of 400 μm diameter for the orthogonal polarization components was coaxially overlapped. The image was 50 mm-diameter circle at R=3.75 m. Ten lines of sight were equipped to cover the poloidal cross section at #1-O port for the poloidal observation as shown in Fig. 1.

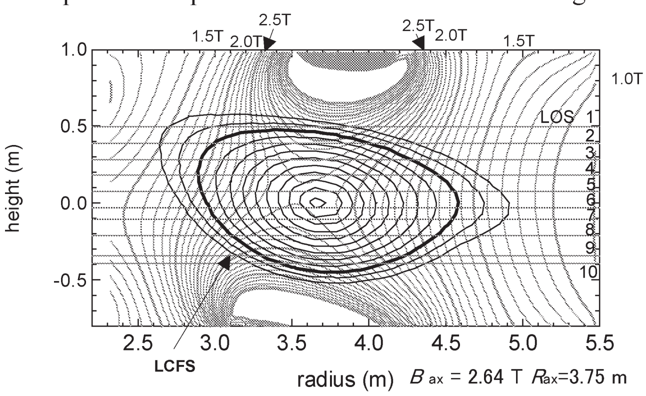
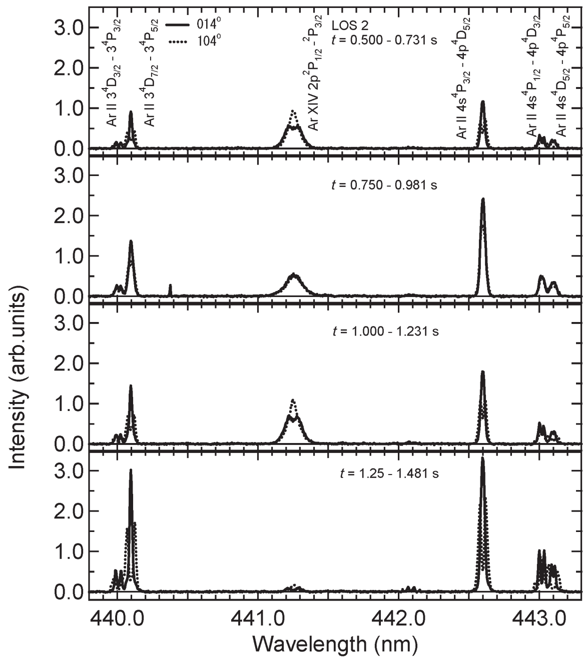


Fig. 0. Ten lines of sight cover the poloidal cross section at #1-O port.

An example of the time evolution of the polarization separation spectra is shown Fig. 2. The observed spectra are M1 transitions in Ar XIV ions and E1 transitions in Ar II ions. The σ components of anomalous Zeeman spectra at λ441.2 nm are dominant in the 104° polarized, close to horizontal direction and the π components are dominant in the 14° polarized, close to vertical direction., while the σ and π components of the E1 transitions are contra-directionally polarized. The anomalous Zeeman components of the M1 transitions calculated at the magnetic field strength of 2.5 T describe the observed line positions.



The relative intensities for 14° and 104° polarized components are calibrated with a standard spectral irradiance lamp and a white diffuse reflectance target. The polarization degree $P=(I_{14^\circ}-I_{104^\circ})/(I_{14^\circ}+I_{104^\circ})$ of the M1 transitions varies -0.026, 0.034 and -0.016 on three sequential exposures started at t = 0.500, 0.750, 1.000 s shown in Fig. 2. The negative polarization degree represents qualitatively that the intensity of the σ components is higher than the π components. The longitudinal alignment A_L of the M1 transition between $^2P_{1/2}$ – $^2P_{3/2}$ terms is expressed as

$$A_L^{M1} = \frac{I_\sigma - I_\pi}{I_\sigma + 2I_\pi} = -\frac{a(p)}{n(p)},$$

where I_σ and I_π are the intensity of σ and π polarized components. The alignment $a(p)$ and the population $n(p)$ are expressed as

$$a(p) = \frac{1}{2}(\rho_{\frac{3}{2},\frac{3}{2}} - \rho_{\frac{1}{2},\frac{1}{2}} - \rho_{-\frac{1}{2},-\frac{1}{2}} + \rho_{-\frac{3}{2},-\frac{3}{2}})$$

and

$$n(p) = \rho_{\frac{3}{2},\frac{3}{2}} + \rho_{\frac{1}{2},\frac{1}{2}} + \rho_{-\frac{1}{2},-\frac{1}{2}} + \rho_{-\frac{3}{2},-\frac{3}{2}}$$

where ρ_{M_J,M_J} is the population of the magnetic sublevel M_J. The negative polarization degree is explained by the negative alignment, or positive A_L, created via the collisional excitation by directional protons. When the PVDF is prolate spheroid or axially dominant in velocity space, the negative alignment is excited by the proton collision. The qualitative analysis is underway with population-alignment collisional-radiative (PACR) model.

[1] S. Suckewer and E. Hinnov, Phys. Rev. Lett. **41,** 756, (1978). K. Sato, et al., Phys. Rev. Lett. 56, 151, (1986).

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