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Electron temperature anisotropy in magnetically confined fusion plasma

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Anisotropy in the electron velocity distribution function, EVDF, is thought to play a key role for characterizing the plasma confinement state both in the core and edge regions of the fusion plasma. For example, the so-called density cramping which is induced by high power electron cyclotron heating is thought to be due to increase of trapped electrons. On the other hand, in the edge region where the magnetic fields are open, trapped electrons could stay longer in the plasma than passing electrons, and such characteristics could be related to the formation of edge plasma structure. However, no measurement method regarding the anisotropy in EVDF has been established to date.

The polarization spectroscopy is a promising technique for a quantitative measurement method for the anisotropic EVDF. Excited states of atoms or ions in fusion plasma are dominantly created by electron collisions. When EVDF has anisotropy, excited states may have an inhomogeneous population distribution among the magnetic sublevels, and emission lines from such a state could be polarized as a result.

We have succeeded to detect polarization of the hydrogen Lyman-α line in the Large Helical Device. As shown in Fig. 1, the linearly polarized light components in the vertical (red) and horizontal (blue) directions have different intensities which indicates that the line emission is polarized. This is the first observation of a clear polarized atomic emission line in magnetically confined fusion plasma devices.

We have also constructed an atomic model, the so-called, population-alignment collisional-radiative (PACR) model, which calculates the longitudinal alignment as well as the population of energy levels considered in the model and then evaluates the polarization degree of the target emission line with a given EVDF. Here, we assume EVDFs such that the electron temperature, T_e, is different between the parallel and perpendicular directions to the magnetic field.

With a help of the PACR model, the EVDF anisotropy in terms of $T_{/\!/}/T_{\perp}$ is evaluated for a number of discharges with different plasma conditions, where $T_{/\!/}$ and $T_{\perp}$ represent T_e in the parallel and perpendicular directions to the magnetic field, respectively.

The results are shown in Fig. 2. The ratio of $T_{/\!/}/T_{\perp}$ takes a value of roughly 0.1 at the lowest collision frequency, ν, evaluated at the Lyman-α emission location. This ratio increases with increasing ν and reaches 0.5 at the highest ν. It is found that there is no clear dependence on the electron density n_e at the emission location of $T_{/\!/}/T_{\perp}$ is observed

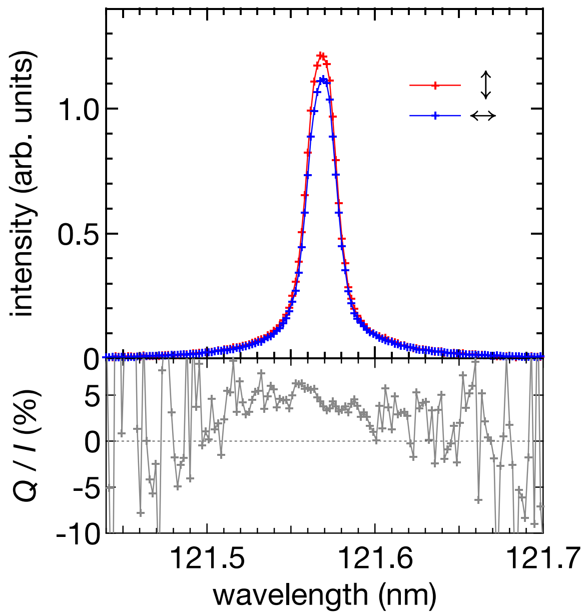

Figure 1. Linearly polarized light components in the vertical (red) and horizontal (blue) directions of the hydrogen Lyman-α line.

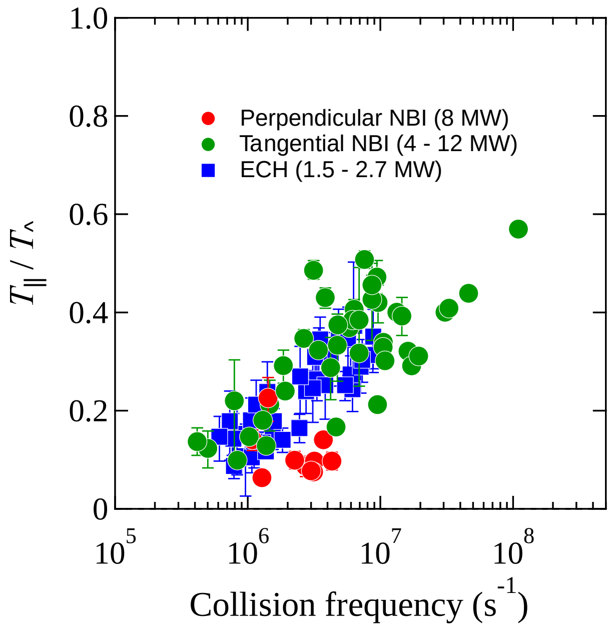

Figure 2. Linearly polarized light components in the vertical and horizontal directions of the hydrogen Lyman-α line.