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# Detection of anisotropy in the electron velocity distribution produced by electron cyclotron resonance heating using the polarization of helium atom emission lines

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The deviation of the electron velocity distribution (EVD) from isotropic Maxwellian is seen in various interesting plasma phenomena such as electron heating through magnetic reconnection, the non-inductive initiation of torus plasmas, the excitation of a low-frequency drift wave, radio-frequency heating in dual-frequency capacitive coupled discharges, the formation of a current-free double layer, multistep ionization in highly charged ion sources, and so forth, *e.g.*, [1] and references therein. For a better understanding of these phenomena and detailed comparisons between experiments and kinetic simulations, it is necessary to develop a method that can measure the three-dimensional EVD shape (or the two-dimensional shape assuming axisymmetry around the magnetic field). However, this has not yet been established for the existing techniques.

As a possible method, we focus on the polarization of emission lines. This method is based on the fact that the emission lines of atoms, molecules, and ions produced by impact excitation of a monoenergetic and unidirectional electron beam are polarized. In plasmas, electrons have velocity distributions, and when the EVD shape is isotropic, the excitation process occurs isotropically and consequently the emission is not polarized. However, it will be polarized when the EVD shape becomes anisotropic. The polarization degree for a given EVD varies with the type of transition; thus, the EVD shape can be deduced by measuring the polarization degree of multiple emission lines. Figure 1 illustrates a framework of the method for HeI emission lines (T. Fujimoto and A. Iwamae, *ed.*, "Plasma Polarization Spectroscopy", *Springer* (2008)). We previously confirmed the feasibility of the conventional CR model analysis (the green arrow in Fig.1) under an assumption of the isotropic and thermalized EVD [2, 3]. In this study, as a next step toward the evaluation of the anisotropic EVD, we measured the polarization of two HeI emission lines, $2^1P$-$3^1D$@668 nm and $2^3P$-$3^3D$@588 nm.

Experiments were performed using a helium ECR plasma produced with 2.45 GHz and 0.8 kW microwaves. The polarization of the HeI emission lines was measured using a temporal modulation spectroscopy system [1, 4], which can evaluate the normalized Stokes parameters and thus the polarization degree and direction.

Figure 2 shows the helium pressure dependence of the chord-integrated polarization degrees measured on differently oriented two viewing chords. For the $2^1P$-$3^1D$, the difference in the polarization degrees obtained on the two viewing chords can be explained if we assume that the polarization localizes at the ECR surface and its local degree is approximately twice to that detected on chord 1. The observed polarization direction is consistent with this picture. Furthermore, the difference in the polarization degrees between the $2^1P$-$3^1D$ and $2^3P$-$3^3D$ suggests that an anisotropic EVD having larger average kinetic energy in the perpendicular direction than in the parallel direction is produced at low pressures and it becomes isotropic at high pressures. These features seem to be consistent with an anisotropy in the EVD expected to be produced owing to the ECR heating.

References

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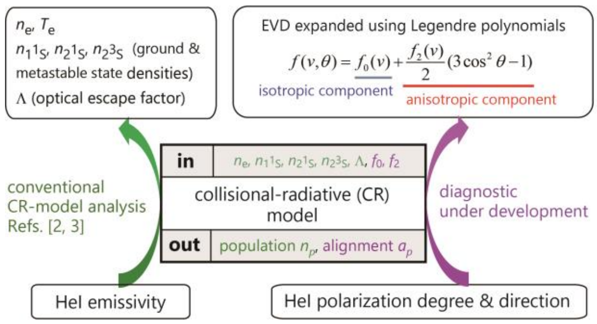


Figure 1. A framework to evaluate anisotropy in the EVD using CR model analysis of the HeI emission lines.

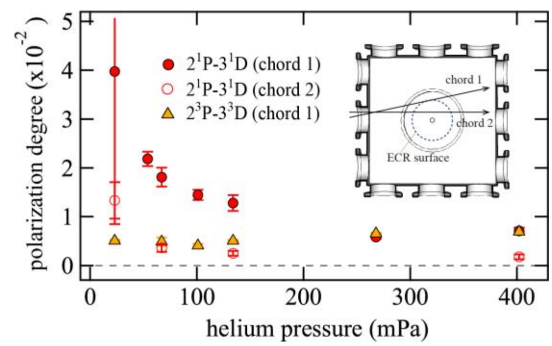


Figure 2. Pressure dependence of the polarization degrees for the $2^1P$-$3^1D$ and $2^3P$-$3^3D$ emission lines [1].