Radial Profile Estimation of Electron Density and Temperature in a Linear Plasma Device NUMBER Using a Single Line-of-Sight He I Line Emission Intensity Ratio

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Plasma spectroscopy can be used to obtain plasma parameters such as electron density and temperature. Since the spectroscopic signals are line integrated, the spatial distribution is usually reconstructed using the multiple line-of-sight signals. However, in the linear plasma device NUMBER, the spatial distribution could not be reconstructed because of the limited measurement line of sight. In this study, we propose a method to estimate the spatial distribution of the plasma from the single line-of-sight spectroscopic signals. Using this method, we estimated the radial profiles of the electron density and temperature in NUMBER [1].

In NUMBER, the cylindrical plasma is generated by electron cyclotron resonance using a microwave [2]. We have measured nine lines of He I line emissions in this device. The line of sight is only in the radial direction.

The collisional radiative model for neutral helium [3-5] was used to calculate the local line intensity. This model requires as input the electron density n_e, the electron temperature T_e, and the photon absorption excitation rate I_{3^1P} from 1^1S to 3^1P, and outputs the line intensity. We assume the radial profiles of n_e, T_e and I_{3^1P} using parameters characterizing the profile. The local line intensity is integrated in the line-of-sight direction and compared with the experimental values.

The parameters characterizing the radial profile are optimized to minimize the objective function such as $\sqrt{\sum_i^n \{(\rho_i^{exp} - \rho_i^{cal})/\rho_i^{exp}\}^2}$, which represents the difference between the measured value of the line intensity ratio ρ_i^{exp} and the calculated value ρ_i^{cal}.

Here, the sensitivity factor of the i-th intensity ratio ρ_i to the j-th parameter x_j is defined as $S_{\rho_i,x_j} = |\partial\rho_i/\partial x_j \cdot x_j/\rho_i|$. The higher the value of the sensitivity factor is, the larger the contribution of the intensity ratio is to the objective function. Therefore, if the intensity ratio ρ_s, which is extremely sensitive compared to other intensity ratios, is used for optimization, the objective function will be dominated by the residual square of ρ_s, and optimization of other intensity ratios will become difficult. To avoid this, it was shown that it is effective to select the pairs of intensity ratios to be used based on the sensitivity factor or to weight the objective function by the sensitivity factor.

When assuming that the n_e profile is represented by 2 parameters and that T_e and I_{3^1P} are uniform, the radial profiles were estimated as shown in Figure 1. In this case, the estimated profiles of n_e and T_e in NUMBER are close to the profiles measured by the Langmuir probe. At the conference, we will report the estimated profiles under several different assumptions about the shape of profiles.

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References

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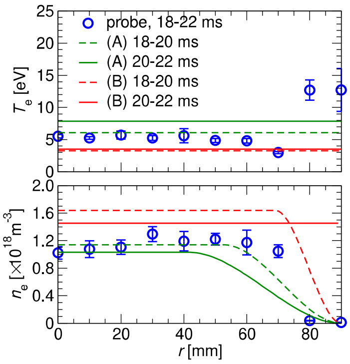

Figure 1. Radial profile estimated by the proposed method and those measured by the probe at a specific time[1]. The blue circle symbol is the value from the Langmuir probe measurement. (A) is the result of using the method to select the pairs of intensity ratios to be used based on the sensitivity factor. (B) is the result of using the method of weighting by sensitivity factor.