§2. Determination of the Electron Temperature and Density at Plasma Edge with Helium Spectroscopy

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Spectra of neutral helium in the visible wavelength range are measured for a discharge with $R_{\mathrm{ax}} = 3.9\,\mathrm{m}$ and $B_{\mathrm{ax}} = 2.54\,\mathrm{T}$, where R_{ax} and B_{ax} are the magnetic axis radius and the magnetic field strength on the magnetic axis, respectively, and derivation of the electron temperature T_{e} and density n_{e} from the measured spectra is attempted. Figure 1 shows the temporal development of the discharge. The discharge is started with the electron cyclotron heating and then is taken over by three neutral beams (NBs) so that the plasma is sustained. (Fig. 1(a)). During the injection of the NBs, helium gas is continuously puffed as shown with the dashed-line in Fig. 1 (b) which indicates the gas-puffing rate in arbitrary units. Accordingly, the line-averaged electron density $\bar{n}_{\mathrm{e}}$ keeps increasing monotonically while the central electron temperature T_{e0} is lowered. The T_{e} profile is peaked at the magnetic axis all the time in the present discharge, while the n_{e} profile changes from flat to hollow.

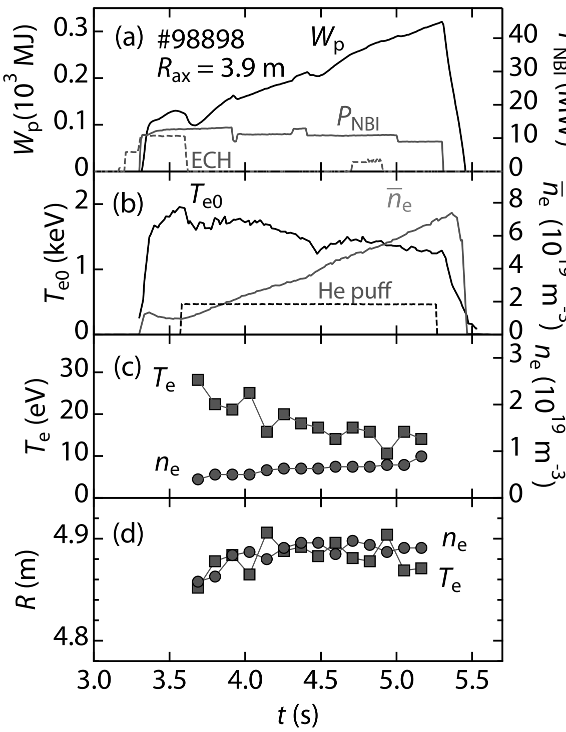

Fig. 1: Temporal development of the discharge for the present observation; (a) and (b), T_{e} and n_{e} derived; (c), and the radial locations of line emission determined from the results in (c); (d).

The spectroscopic observation is carried out with single line-of-sight which passes through the center of a poloidal plasma cross section elongated horizontally. An example of the measured spectra is shown in Fig. 2. Nine emission lines of neutral helium in total are identified as indicated in Fig. 2 and the all lines are used in the following analysis. First, the excited level populations are derived from the observed spectrum. Since the level population distribution is generally dependent on T_{e} and n_{e}, it is expected that we can reversely infer those parameters from the measured population distribution data. We have actually attempted derivation of T_{e} and n_{e} with a help of the collisional-radiative (CR) model, namely, the parameters are determined so that the calculated population distribution with the CR-model gives the best fit to the measured one. Figure 1(c) shows the results. Here, the CR-model developed by Sawada et al.[1] which takes the reabsorption effect into account is used. Indeed, incorporation of the reabsorption effect is found to be indispensable to obtain a set of parameters giving a line intensity distribution consistent with the measurement.

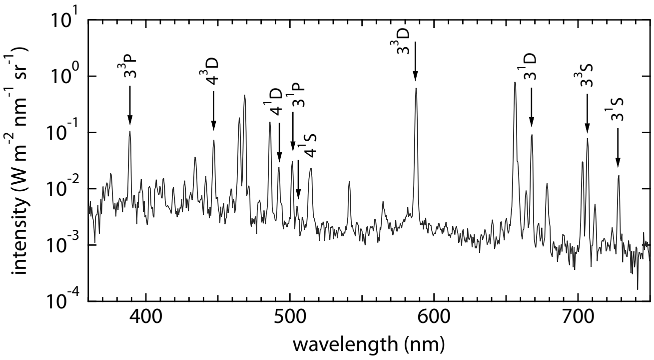

Fig. 2: An example of the measured spectra. The lines used for the present analysis are indicated with arrows and labeled with the upper term of the transitions.

The position where the helium line emission dominantly takes place is located with the T_{e} and n_{e} profiles measured by the Thomson scattering system. The results are shown in Fig. 1(d). The fact that the positions derived independently from T_{e} and n_{e} almost coincide with each other implies validness of the present measurement method. It is found that the emission position is approximately fixed while the T_{e} and n_{e} vary in the course of discharge time, and that the fixed position corresponds to the location where the connection length of the magnetic field lines to the divertor plate leaps beyond approximately 10 m. Because intense neutral atom line emission suggests the vigorous ionization of neutral atoms, the helium line emission location determined here can be regarded as the effective boundary of the plasma.

1) K. Sawada et al.: Plasma and Fusion Res. **5** (2010) 001.