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Collisional-radiative mode of neutral helium and its application to plasma diagnosis

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We have been continuously upgrading a collisional-radiative model for neutral helium [1] considering to apply the model for a diagnosis of the edge or divertor plasmas of magnetically confined fusion devices in particular. An essential element of the model is the atomic data used in it. After a careful examination of cross section data for the electron impact excitation, we decided to adopt theoretical data by the convergent close coupling method [2]. Following a recent analysis of observation data taken in a fusion experiment device, LHD (Large Helical Device), we have incorporated the reabsorption effect for resonance lines into the model. The electron temperature and density derived with the present model for the edge plasma in LHD show agreements with other diagnostic results, which demonstrates high reliability of the present model [3].

Spectra of neutral helium in the visible wavelength range are measured for a discharge with R_{ax} = 3.9 m and B_{ax} = 2.54 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 initiated 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 the arbitrary units. Accordingly, the line-averaged n_e keeps increasing monotonically while the central electron T_e 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.

The spectroscopic observation is carried out with single line-of-sight which passes through the center of a poloidal plasma cross section elongated horizontally. Nine emission lines of neutral helium in total are identified 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 takes the reabsorption effect into account [4]. 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.

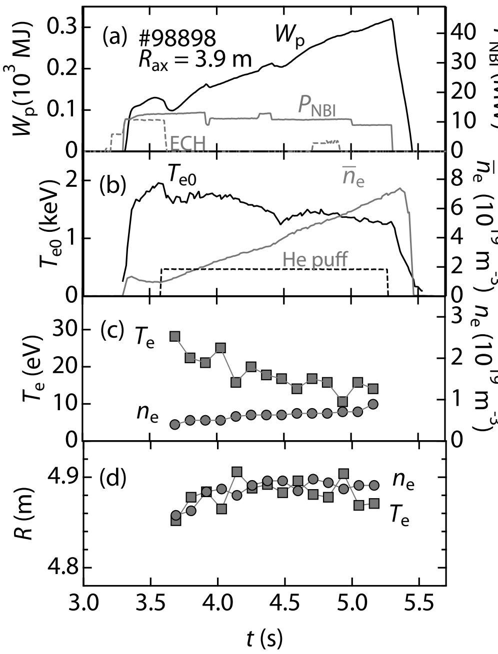

Fig. 1: Temporal development of the discharge for the present observation; (a) and (b), T_e and n_e derived; (c), and the radial locations of line emission determined from the results in (c); (d).

The position where the helium line emission dominantly takes place is determined with the T_e and n_e profiles measured by the Thomson scattering system. The results are shown in Fig. 1(d). The positions independently derived from T_e and n_e, respectively, almost coincide with each other, which implies validness of the present analysis. 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.

References

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