Two categories of spectroscopic measurements and analyses for the fusion plasma diagnosis

M. Goto[a], K. Sawada[b], K. Fujii[c], T. Oishi[a], M. Hasuo[c], S. Morita[a]

[a] National Institute for Fusion Science, Toki 509-5292, Japan

[b] Department of Applied Physics, Faculty of Engineering, Shinshu University, Nagano 380-8553, Japan

[c] Department of Mechanical Engineering and Science, Graduate School of Engineering, Kyoto University, Kyoto 606-8540, Japan

The plasma spectroscopy can be categorized into two groups. One is the detailed analysis of a single emission line profile. The Zeeman effect, Stark effect, Doppler broadening, and Stark broadening are the examples of this kind. Each of these effects is directly connected to a certain physical parameter and the measured line profiles can be used to obtain the corresponding parameters. The other category of the plasma spectroscopy focuses on the line intensity distribution of the same charge state ions or atoms. The line intensity distribution stands for the population distribution of excited states. Since the population distribution generally depends on the plasma parameters such as the electron temperature T_e and density n_e, those parameters can be conversely determined by the measured population distribution.

A recent example of the line profile analysis in the Large Helical Device (LHD) is the Balmer-α line measurement [1]. The observed line profile is found to contain a significant broad component and is never fitted with a single Gaussian function, rather it is understandable to regard the line profile as a superposition of different Doppler components which is mathematically expressed as a Laplace transform. A numerical inversion of the Laplace transform of the measured line profile yields the emissivity distribution function with respect to the atom temperature. The temperature dependence of the line emissivity is well translated to the spatial dependence so that the ionization rate and the atom density of neutral hydrogen in the plasma core region are determined. The atom density at the plasma center is found to be six orders of magnitude smaller than the maximum at the plasma boundary.

An example of the line intensity measurement in LHD is the helium line analysis for the T_e and n_e determination [2]. The temporal variation of spectra in the visible range is measured for a discharge in LHD, where nine emission lines of neutral helium are identified in each spectrum. A collisional-radiative (CR) model, which calculates the excited level populations for a given set of T_e and n_e, is called for and a determination of T_e and n_e is attempted so that the CR-model results give the best fit to the measured population distribution. It is found that the obtained parameters vary as the line-averaged n_e by the laser interferometer is increased in the course of a discharge. The comparison of the results with those of Thomson scattering diagnosis shows that the radial position of helium line emission is almost fixed at the location where the connection length of the magnetic field to the divertor plate is increased beyond 10 m. Because intense line emission implies vigorous ionization of atoms, the radial location obtained here can be regarded as an effective boundary of the plasma.

References

[1] M. Goto, K. Sawada, K. Fujii, M. Hasuo, S. Morita, Nucl. Fusion 51, 023005 (2011).
[2] M. Goto and K. Sawada, J. Quant. Spectrosc. Radiat. Transf. 137, 23 (2014).