§19. VUV Spectroscopy in Impurity Gas Seeding Experiment for Divertor Detachment in LHD

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The enhancement of the radiated power in a scrape-off layer by seeding impurity gases is one of the promising scenarios to mitigate heat/particle loads onto divertor plates[1]. From this viewpoint, impurity gas seeding experiment has recently been carried out in LHD using neon (Ne), argon (Ar) and nitrogen (N_2) to achieve the divertor detachment. Though spatial and temporal trends of the radiated power have been extensively studied so far, spectroscopic analyses of the trends of spectral lines from each impurity ions have not yet been performed well. In this study, vacuum ultraviolet (VUV) spectroscopy is applied to this kind of experiment to measure the trends of spectral lines because it is useful to guess where specific ion stages emit in a plasma, and to investigate the mechanism of radiation loss in a detached plasma. In this experimental campaign, the VUV spectra were recorded by a 2 m Schwob Fraenkel grazing incidence spectrometer[2] in Ne and N_2 seeding experiments. The grating with 600 mm^{-1} groove density was used for better wavelength resolution. The frame rate of the detector was fixed at 50 ms. Figure 1 shows temporal variations of the intensities of the three prominent Ne VIII spectral lines at 9.8 nm (2p-3d), 8.8 nm (2s-3p) and 10.3 nm (2p-3s) in a Ne seeding experiment as well as the intensity ratios for the two combinations (8.8 nm/9.8 nm and 10.3 nm/9.8 nm). The Ne line intensities in this shot rapidly build up following Ne gas injection during 3.8–3.9 s. The intensity ratios for 8.8 nm/9.8 nm and 10.3 nm/9.8 nm are almost kept constant at 0.75 and 0.40, respectively, until the termination of the heating power at 5.3 s.

In order to derive the electron temperature where these Ne VIII lines are emitted, we have calculated the temperature dependence of the intensity ratios using collisional-radiative modeling based on ADAS atomic database. The results are different between ionizing and recombining plasmas, as shown in Fig. 2. The electron temperatures corresponding to the measured intensity ratio for 8.8 nm/9.8 nm are around 250 eV and 20 eV in pure ionizing and recombining plasmas, respectively. On the other hand, it is difficult to interpret the measured intensity ratio for 10.3 nm/9.8 nm in pure ionizing plasma because the calculated ratio is above the measured one in the entire range of the electron temperature. Therefore, contributions of both the ionizing and recombining phases should be considered to interpret the experimental results consistently. In addition, the effect of the spectral sensitivity of the spectrometer should be taken into account because it is ignored in the above discussion. We will plan similar analysis for the N_2 seeding experiments in the near future.

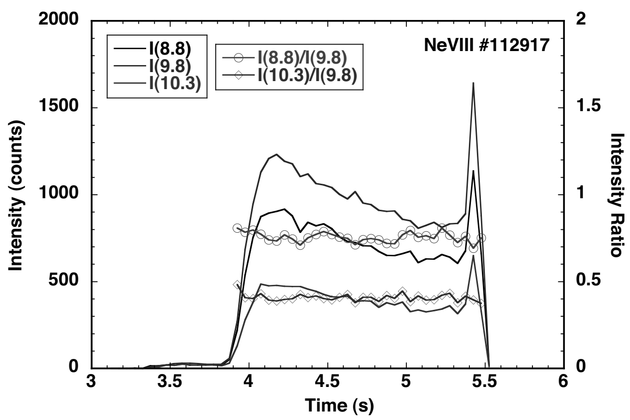

Fig. 1: Temporal variations of the intensities of Ne VIII lines at 9.8 nm (2p-3d), 8.8 nm (2s-3p) and 10.3 nm (2p-3s) in a detached plasma using neon gas seeding at 3.8 s. The line intensity ratios for 8.8 nm/9.8 nm and 10.3 nm/9.8 nm are also plotted.

1) Asakura, N. et al.: Nucl. Fusion **49** (2009) 115010.

2) Schwob, J. L., Wouters, A. W. and Suckewer, S.: Rev. Sci. Instrum. **58** (1987) 1601.

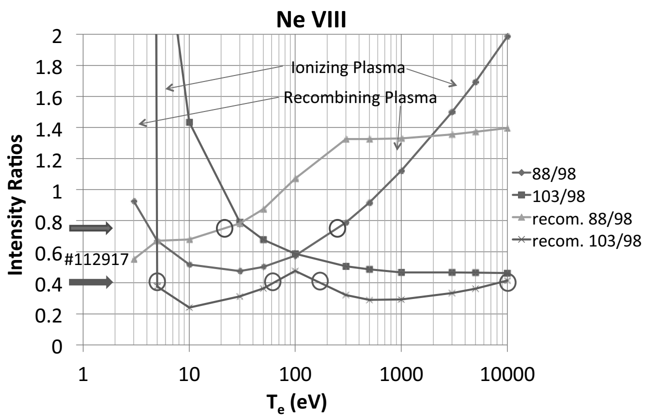

Fig. 2: The electron temperature dependences of the Ne VIII line intensity ratios in pure ionizing and recombining plasmas calculated by collisional-radiative modeling based on ADAS database. The temperatures corresponding to the measured intensity ratios shown in Fig. 1 are marked by circles.