§11. VUV Spectroscopy of Detached Plasmas

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Detached plasmas are produced and sustained stably on LHD in order to reduce the heat or particle flux to the divertor. The VUV spectra of such detached plasmas show different feature from those of attached plasmas. This study is intended to clarify the state of the peripheral region or the atomic processes in the detached plasmas by comparing the experimental results with the calculation results of the impurity transport code. The detached plasmas are produced by increasing the electron density with the $m/n = 1/1$ magnetic island [1]. The detachment is found at the electron density $\overline{n}_e \simeq 6 \times 10^{19}\,\mathrm{m}^{-3}$. The localization of the radiation at the X-point is observed by the AXUVD measurement.

The VUV spectrometer of Schwob-Fraenkel type observes from the outer port. The position of the O-point of the $m/n = 1/1$ magnetic island is the upper side in the line of sight of the spectrometer. In the density region of $\overline{n}_e \leq 2 \times 10^{19}\,\mathrm{m}^{-3}$, the iron lines of Fe XXII (114.4 Å), Fe XXIII, Fe XX (132.8 Å) and Fe IX $\sim$ Fe XI are found in the wavelength range of $98 \sim 200$ Å. Figure 1 and 2 show VUV spectra in this wavelength range which are observed before and after the divertor detachment, respectively. When $\overline{n}_e$ exceeds $4 \times 10^{19}\,\mathrm{m}^{-3}$, the iron lines become small and the oxygen lines of O V (193 Å), O VI (150, 173, 184 Å) are observed before the detachment in Fig. 1. In Figure 2, the high-order light of carbon lines of C VI (33.7 Å) and C V (40.3 Å) appeared. On the other hand, in the case of no $m/n = 1/1$ magnetic island, the detachment was not occur and the lines of C VI or C V did not appear clearly.

As the causes of the appearance of the C VI and C V lines after the detachment, the change of the carbon amount in the plasma, the change of the electron temperature T_e, the localization of the radiation and so on can be considered. The emissivity of carbon lines are simulated by using the impurity transport code MIST [2]. The change of T_e in the magnetic island at the peripheral region is from $60 \sim 80$ eV before the detachment to about $10 \sim 20$ eV after the detachment. The C II and C III lines become large after the detachment. An example of calculation results by MIST is shown in Figure 3. A constant diffusivity of the impurity, $D = 0.4\,\mathrm{m}^2/\mathrm{s}$ is assumed in the whole plasma region, and no convection velocity, v, is assumed. In this calculation, the electron density and the carbon density at the peripheral region are increased by factors of 5 and 3, respectively, considering the localization of the radiation at the X-point. Since the C VI and C V lines are become small in the T_e range below 200 eV, the emissivity of C VI and C V lines is also small without such density increment in the peripheral region. Although the calculation results can show the existence of C VI and C V lines, the change of these lines before and after the detachment cannot reproduced yet. However, it may be needed to assume the increment in the electron and carbon density at the peripheral region in order to increase the intensities of the C VI and C V lines.

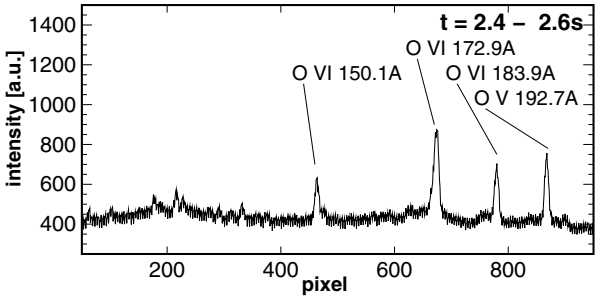

Fig. 1. A VUV spectrum before the divertor detachment in the wavelength range of $98 \sim 200$ Å. O V (193 Å), O VI (150, 173, 184 Å) are observed.

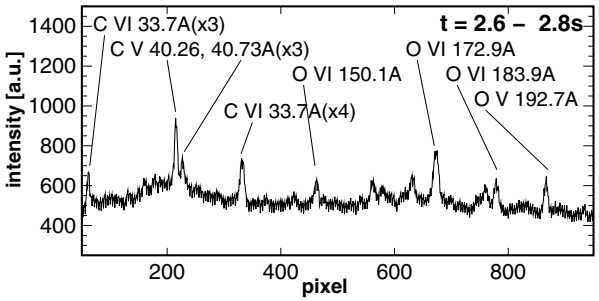

Fig. 2. A VUV spectrum after the divertor detachment in the wavelength range of $98 \sim 200$ Å. The high-order light of carbon lines of C VI (33.7 Å) and C V (40.3 Å) appeared.

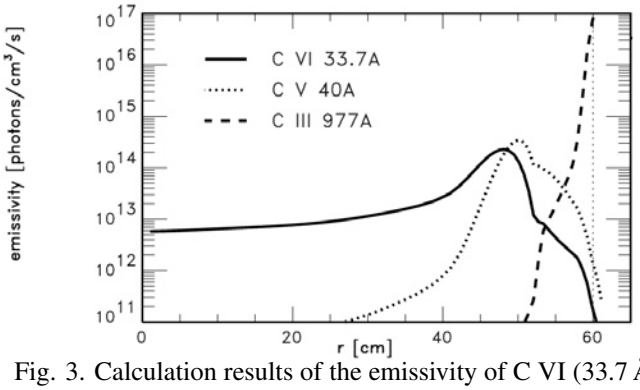

Fig. 3. Calculation results of the emissivity of C VI (33.7 Å), C V (40.3 Å) and C III (977 Å) lines by MIST.

[1] M.Kobayashi, *et al.*, Phys. Plasmas **17**, (2010) 056111.
[2] R.A.Hulse, Nucl. Tech./Fusion **3** (1983) 259.