§48. Plasma State in the Carbon Pellet Ablation Cloud

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A carbon pellet has been injected into the plasma from the 1-O port. The trajectory of the injected pellet lies on the equatorial plane and nearly perpendicular to the magnetic axis. The pellet speed is measured to be approximately 200 m/s with the time-of-flight technique.

An end of an optical fibre having the core diameter of 400 μm is placed at the same port as that for the pellet injection and the radiation from the ablation cloud is observed. The other end of the optical fibre is located at the entrance of a Czerny-Turner type UV and visible spectrometer (Chromex 500is) equipped with a 100 grooves/mm grating. A CCD (charge coupled device) detector (Andor UV-420) is used to record the spectrum and the wavelength range of roughly 500 nm is simultaneously observed. The spectra are obtained every 100 μs with the "fast kinetic mode" of the detector function.

Figure 1 shows an example of the observed spectra, where several representative emission lines discretely observed are labeled. All the identified lines are found belonging to the CII and CIII ions.

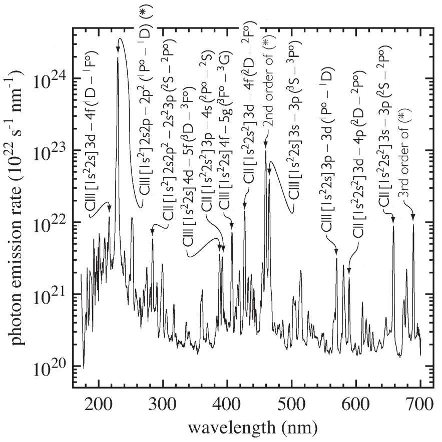

Fig. 1. Example of spectra observed for an ablation cloud of carbon pellet. Several representative lines discretely observed are accompanied by the corresponding transitions.

The volume-integrated population of CIII excited level p, $N_{\mathrm{CIII}}(p)$, normalized by the statistical weight $g_{\mathrm{CIII}}(p)$ is plotted as a function of the ionization potential $\chi_{\mathrm{CIII}}(p)$ in Fig. 2. When the excited level is in local thermodynamic equilibrium (LTE), its population is expressed with the Saha-Boltzmann equation as

$$\frac{N_{\mathrm{III}}(p)}{g_{\mathrm{III}}(p)} = \frac{1}{2g_{\mathrm{IV}}(1)}\left(\frac{h^2}{2\pi mkT_{\mathrm{e}}}\right)^{3/2} \exp\left(\frac{\chi_{\mathrm{III}}(p)}{kT_{\mathrm{e}}}\right) n_{\mathrm{e}}N_{\mathrm{IV}}(1), \tag{1}$$

where h, m, and k have the usual meanings, the subscript IV indicates the CIV ion, and $p = 1$ stands for the ground state, and it is noticed that the relative population distribution over the excited levels is determined solely by the electron temperature. In the present case $T_{\mathrm{e}} = 3.1$ eV is derived from the fitting of the experimental data in Fig. 2. The fitting result is shown with the dashed line in Fig. 2.

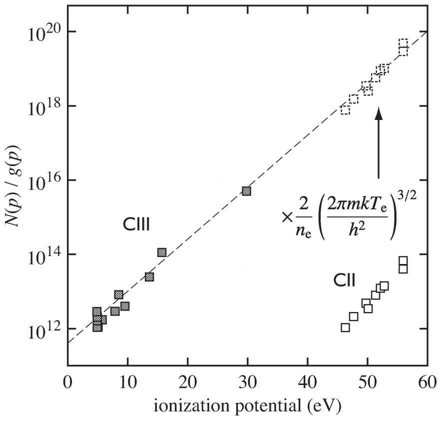

Fig. 2. Volume-integrated population normalized by the statistical weight. The ionization potential for CII ion is measured from the ionization limit of CIII ion. The dashed-line is the fitting result for the CIII data set with the Saha-Boltzmann equation.

Figure 2 also shows the CII excited level populations but the ionization potential is measured from the ionization limit of the CIII ion. It is readily found that the CII population distribution is fitted well with the same electron temperature as determined from the CIII populations. This result indicates that the dominant plasma volumes for the CII and CIII line radiations are overlapped.

Under the LTE condition, the normalized CII populations $N_{\mathrm{II}}(p)/g_{\mathrm{II}}(p)$ should lie on the fitted line for the CIII populations when it is multiplied by a factor $(2/n_{\mathrm{e}})\left(2\pi mkT_{\mathrm{e}}/h^2\right)^{3/2}$. This factor is determined from the fitting and $n_{\mathrm{e}} = 4.6 \times 10^{22}\ \mathrm{m}^{-3}$ is derived with the electron temperature already known.

Equation (1) shows that the excited level population is proportional to the ground state population of the upper ionized stage ion. Since most of the observed emission lines originate in the CII and CIII ions, the ion density abundance is expected dominated by the CIII and CIV ions in the present plasma condition. Under such circumstances a relation $n_{\mathrm{e}} = 2n_{\mathrm{III}}(1) + 3n_{\mathrm{IV}}(1)$ should be valid, where $n_{\mathrm{III}}(1)$ and $n_{\mathrm{IV}}(1)$ are the ground state densities of the CIII and CIV ions, respectively. Their ratio $n_{\mathrm{III}}(1)/n_{\mathrm{IV}}(1)$ is obtained from eq. (1) and then $n_{\mathrm{III}}(1) = 1.6 \times 10^{22}\,\mathrm{m}^{-3}$ and $n_{\mathrm{IV}}(1) = 4.5 \times 10^{21}\,\mathrm{m}^{-3}$ are obtained. With the derived plasma parameters and the absolute emission line intensities, the plasma volume of the ablation cloud, which corresponds, for example, to $N_{\mathrm{III}}(1)/n_{\mathrm{III}}(1)$, is evaluated to be $1.3 \times 10^{-4}\ \mathrm{m}^3$.