§2. Plasma Simulation Experiments Using Versatile Highly Charged Ion Sources

Nakamura, N. (Univ. of Electro-Commu.),
Sakaue, H.A., Kato, D.

Using highly charged ion (HCI) sources at the University of Electro-Communications (UEC) and NIFS, we have been obtaining atomic data of highly charged ions such as the cross sections of resonant recombination and ionization processes[1, 2]. Those data are important as fundamental atomic data in non-equilibrium plasmas such as the peripheral plasma in fusion devices and the transition region in the solar atmosphere. On the other hand, the purpose of the present study is to make more active contribution to the understanding of such non-equilibrium plasmas by obtaining experimentally simulated spectra emitted from HCIs interacting with electrons that have an arbitrary velocity distribution.

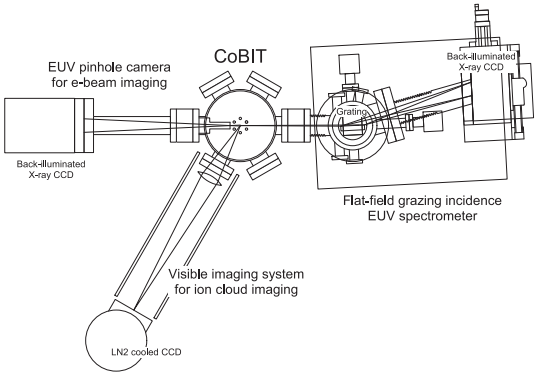

Fig. 1: Experimental setup for the electron density dependence measurement with a compact EBIT (CoBIT).

The experimental setup is shown in Fig. 1. For spectroscopic studies of iron ions relevant to the solar corona, a Compact EBIT[3] was used. It has six ports currently used for an EUV spectrometer, gas injector, pinhole camera, visible imaging system and K-Cell injector. The EUV spectrometer[4] is of a slit-less type especially designed for the present EBIT. Since the trapped ions are excited by a thin electron beam, the EBIT represents a line source so that an entrance slit can be omitted. A laminar-type diffraction grating (1200 gr/mm or 2400 gr/mm depending on wavelength) is used to focus the radiation on the surface of a back illuminated CCD (PIXIS-XO:400B). A pinhole camera is used for monitoring the electron beam shape, which is important for evaluating the EBIT performance and also for determining the absolute electron density. On the other hand, the spatial distribution of the trapped ions is measured by using the visible imaging system.

Fig. 2 shows a typical result for the electron density

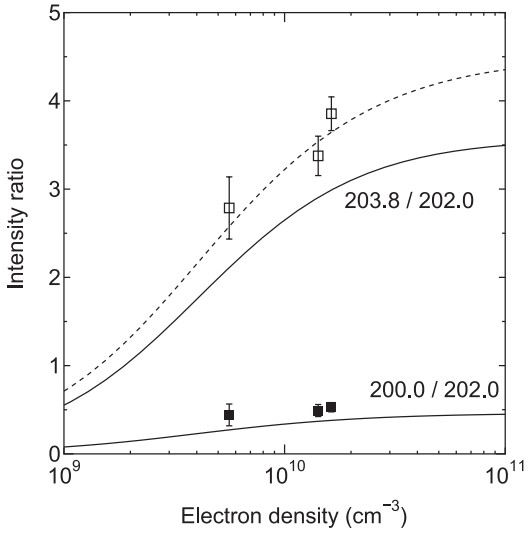

Fig. 2: Line intensity ratio of Fe XIII. The solid squares are the present experimental results. The solid and dashed lines are theoretical results.

dependence of line intensity ratio. The electron density was obtained from the electron beam profile with taking the overlap with the ion cloud into account. The solid and dotted lines in the figure represent the theoretical results calculated by the collisional radiative model[5]. The dotted line is the result obtained by taking the line overlap into account. As shown in the figure, good agreement between the experiment and the theory is found.

In summary, the present results proved that the compact EBIT is a powerful device for simulating the spectra of iron ions in the solar corona. To simulate plasmas with an arbitrary electron velocity distribution, a fast electron beam control system is currently being prepared.

1) H. A. Sakaue, A. Danjo, K. Hosaka, D. Kato, M. Kimura, A. Matsumoto, N. Nakamura, S. Ohtani, M. Sakurai, H. Tawara, I. Yamada, and M. Yoshino, J. Phys. B **37**, 403 (2004).

2) N. Nakamura, A. P. Kavanagh, H. Watanabe, H. A. Sakaue, Y. Li, D. Kato, F. J. Currell, and S. Ohtani, Phys. Rev. Lett. **100**, 073203 (2008).

3) N. Nakamura, H. Kikuchi, H. A. Sakaue, and T. Watanabe, Rev. Sci. Instrum. **79**, 063104 (2008).

4) H. A. Sakaue, D. Kato, N. Nakamura, E. Watanabe, N. Yamamoto, C. Chen, and T. Watanabe, J.Phys.: Conf.Ser. **163**, 012020 (2009).

5) T. Watanabe, H. Hara, N. Yamamoto, D. Kato, H. A. Sakaue, I. Murakami, T. Kato, N. Nakamura, and P. R. Young, Astrophys. J. **692**, 1294 (2009).