§4. Observation of Reduction Structure of H$^-$ Ions at Extraction Region in a Hydrogen Negative Ion Source

Ikeda, K., NBI Group

We have developed a H_α imaging spectroscopy diagnostic tool to obtain extraction behavior of H^- ions. This system is consisted of optical filters, an aspherical lens and a glass-fiber image conduit. A spectral image with 16-bit monochrome resolution is acquired by a CCD detector. The line of sight was arranged parallel to the PG surface and passed through a viewing port. The center of the line of sight was set beside the PG apertures at $z = 11$ mm from the PG. The viewing angle covers the area from the magnetic filter flange to the PG surface. Both sides of the image field comprise the invisible area behind the flange. A row of the PG's apertures appears as a quadrangular shape on the image. To understand the positional relationship, we superimposed a wire frame on the spectral image to show the envelope of the major components inside the ion source.

Figure 1 shows the waveform of H^- density, H_α and H_β emissions in 38kW arc discharge after Cs conditioning with a 0.2 Pa hydrogen gas pressure and 0.2 V (i.e., low) bias voltage. We applied negative extraction voltage during 1 sec as shown in gray color. The H^- density close to the PG (z = 2mm) measured by cavity ringdown spectroscopy increased to $1.25 \times 10^{17}\mathrm{m}^{-3}$ during arc discharge, and then it is dropped by beam extraction. We found similar signal reduction on the H_α emission measured at z = 11mm by a visible spectrometer. The H_β signal, however, did not decrease by beam extraction. In the extraction region with low electron temperature (~1 eV), main excitation mechanisms for H_α emission are dissociative recombination between an electron and H_2^+, and the mutual neutralization between H^+ and H^-. As the percentage of negative ions is increased, H_α emission caused by the mutual neutralization process becomes dominant. Here the reduction in the H_α intensity due to beam extraction is defined as ΔH_α, which is the key value for understanding the H^- behavior.

Figure 2 shows the two-dimensional image of the ΔH_α structure produced by subtracting the image acquired before beam extraction from that image acquired during beam extraction, here the reduction area is represented in black. In the region close to the PG surface ($z < 10$ mm), the reduction in the H_α signal beside the apertures is much larger than that beside the surface. We also found that the reduction in the H_α intensity is observed inside the plasma, farther than 20 mm from the PG surface. A large reduction in H_α appeared on the upper side of the image, where is the center of the ion source.

We speculate that the neutral hydrogen and positive hydrogen ion densities were not affected by the negative extraction voltage in the constant arc discharge condition. The effect of the electrons due to the extraction voltage is negligibly small in a rich H^- condition, since the H_β emission caused by dissociative recombination H_2^+ and electrons is not affected by beam extraction. Thus, the ΔH_α was caused by the decrease in the excited hydrogen population that resulted from the mutual neutralization processes, which in turn were due to the decrease in H^- density. This result clearly shows that the motion of extracted negative ions generated at the PG surface is widely distributed in the extraction region. Therefore, H_α imaging spectroscopy, which is a powerful tool for experimentally determining the behavior and distribution of negative ions, will contribute to NBI with stable high-power operation.

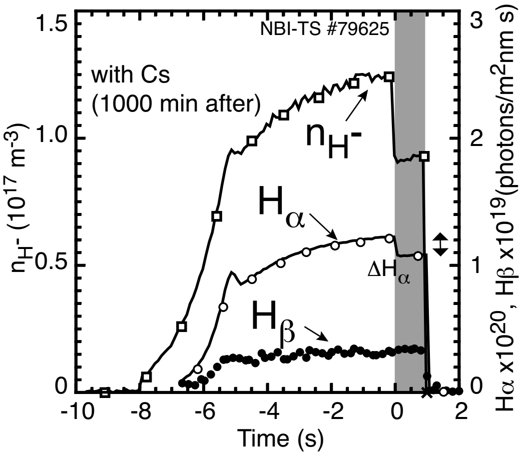

Fig. 1: Waveform of H^- density, H_α and H_β emissions in 38kW arc discharge after Cs conditioning. Negative extraction voltage is applied during 1 sec drown in gray.

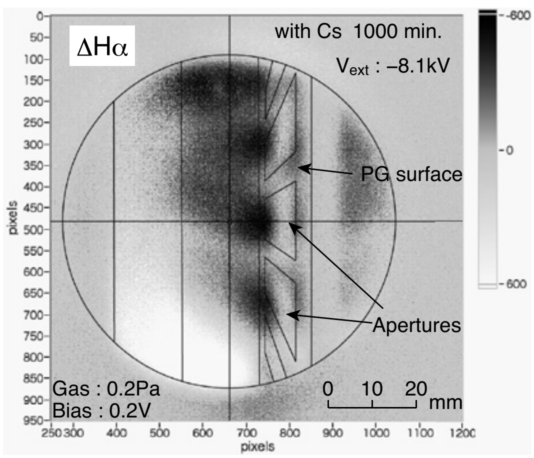

Fig. 2: Image of the reduction structure of H_α emission during beam extraction. Wire frames are superimposed on the spectral image to show the envelope of the major components inside the ion source.