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Hα イメージング分光計測による大型負イオン源内の水素負イオン挙動の解明
Evaluation of H^- Behavior in Large Negative Ion Source by H_α Imaging Spectroscopy

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Hydrogen negative ions have been effectively produced on a cesium-covered metal plasma grid (PG) surface faced to arc discharge in an ion source for neutral beam injectors on LHD [1] and JT-60U [2]. For the international thermonuclear experimental reactor (ITER), high current D^- source using RF discharge is developing now [3]. It will be required to involve operating stable 1-hour beam generation with high energy (1 MeV) and uniform beam extraction from a wide grids with a lot of apertures. In contrast, behavior of negative ions in the extraction region near the PG surface is a key issue for such severe conditions, but it is not well understood. We developed H_α imaging spectroscopy to investigate H^- dynamics during beam extraction, and was installed on the 1/3 scaled development negative ion source in NIFS. A combination with three optical filters and an aspherical lens has been set on the bias insulator sandwiched between the arc chamber and the PG flange as shown in Figure 1. Spectral images were transferred to a CCD detector by a glass fiber image conduit for high voltage insulation. The center of the sight line set on the right above extraction apertures at z = 11 mm from the PG, and the viewing angle covered from the magnetic filter flange to the PG. We took a 16-bit monochrome image data with the 80 ms exposure time during arc discharge.

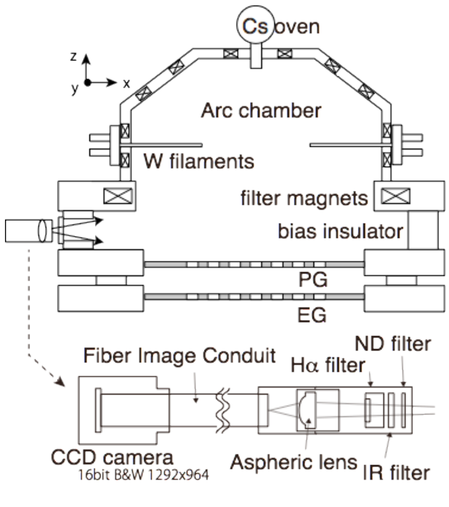

Fig. 1 Schematic drawing of a hydrogen negative ion source. Hα imaging system has been installed on the bias insulator.

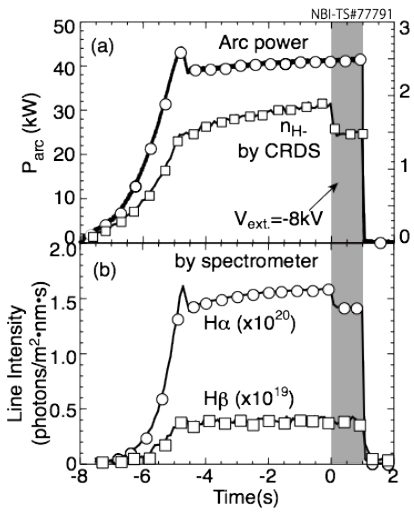

Fig. 2 Waveform of the hydrogen arc discharge power and the H^- density (a), and the signal intensity of hydrogen emissions (b).

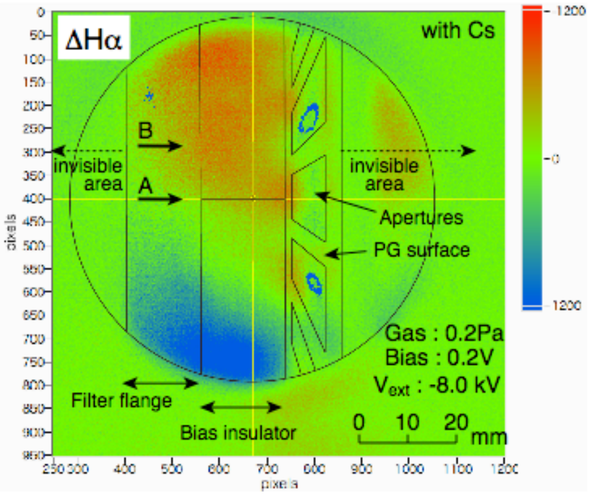

Fig. 3 Two dimensional image of the reduction Hα signal between before and after extraction voltage applied.

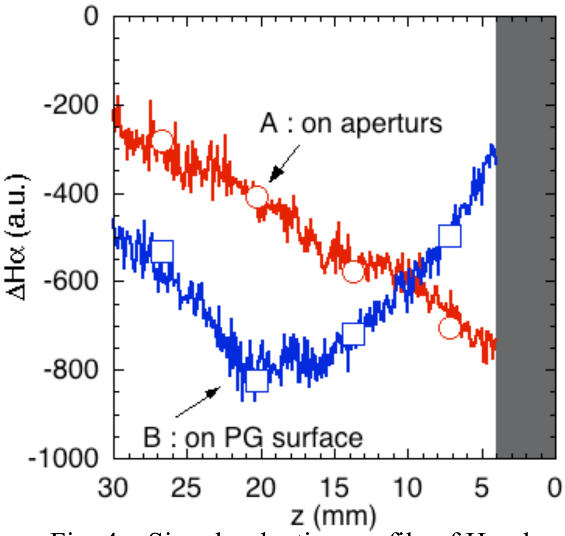

Fig. 4 Signal reduction profile of Hα along the z-axis perpendicular to the plasma grid surface on the apertures (a) and on the PG surface (b).

Figure 2(a) shows the waveform of the arc discharge power and the H^- density measured by a cavity ring-down spectroscopy [4] under the condition of Cs seeding with 0.2 Pa hydrogen gas pressure and 0.2 V low bias voltages. Discharge condition was constant before and after beam extraction applied V_{ext} = -8 kV high extraction voltage between the PG and the extraction grid (EG) which was short-circuited by the grounded grid. The H^- density at the position of z = 9 mm was reduced during beam extraction. We observed same signal drop on the H_α line intensity measured by a visible spectrometer at z = 11 mm as shown in Fig 2(b). The reduction of H_α signal (ΔH_α) was mainly caused by the reduction of excited hydrogen population from the mutual neutralization processes expressed as ; $H_m^+ + H^- \rightarrow H(n=3) + H_m$ (m=1,2,3), due to the decreasing of H^- density. We found an amazing 2D structure of the reduction ΔH_α between before and after applied extraction voltage in the extraction region as shown in Figure 3. In the region closed to the PG (z < 10 mm), the reduction of the H_α signal near the apertures is much larger than that near the PG surface. Reduction of the H_α intensity is observed toward the plasma inside farther than 20 mm from the PG surface as shown in Figure 4. This result indicates that H^- ions produced at the PG surface is penetrated to the depth of the extraction region, which is consistent with the H^- distribution measured by CRDS [4]. It is considered that H^- ions accumulated at a position away from the PG are flowing toward the PG apertures.

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