§3. Local H⁻ Ion Density Measured by Laser Photo-detachment in a Negative Hydrogen Ion Source

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The negative-ion-based neutral beam injector system is an indispensable device to heat plasma and drive current due to the high neutralization efficiency at high beam energy. One of the important subjects for the improvement of the negative hydrogen ion source is to increase the H^- ion density (n_{H-}) for high beam current density. As a fundamental parameter of the negative-ion-rich plasma, the measurement for local H- ion density is required. Laser photodetachment technique [1] is available for this purpose.

In laser photodetachment technique, a laser pulse (1064 nm) is irradiated into the plasma. H^- ions in the laser beam are detached by the photons ($h\nu + H^- \rightarrow H^0 + e$). The charge neutrality of the plasma does not change during photodetachment since the density of the detached electrons is equal to the original H^- ion density. If a positively biased probe is located into the laser beam, the detached electrons are collected by the probe and a current increase (ΔI), which is proportional to the local H^- ion density, is introduced to the probe.

The experimental setup is schematically illustrated in Fig. 1. A Nd:YAG laser beam with wavelength of 1064 nm, beam diameter of 4 mm and pulse energy density of 40 mJ/cm^2 is irradiated into the ion source through a quartz window installed on the ion source. On the opposite side, a Langmuir probe is installed. A 40 V bias is applied to the probe to collect the electrons. The current increase is acquired by data acquisition system. The typical photodetachment signal is shown in Fig. 2.

Traditionally, the local H- ion density can be obtained by

$$\frac{n_{H-}}{n_e} = \frac{\Delta I}{I_{e-sat}}, \quad (1)$$

where n_e is the electron density and I_{e-sat} is electron saturation current of the probe at positive DC bias voltage. However, equation 1 is invalid at high H^- ion density because the probe electron saturation current is contaminated by H^- ions. The error will be significant.

A new method is developed to obtain local H^- ion density with assistant of cavity ring-down (CRD) which is a laser absorption method to obtain line-averaged H^- ion density. By moving the probe along the laser beam (x direction), the profile of photodetachment current is obtained. The profile is integrated along x direction and the integral is compared with cavity ring-down result according to Eq. 2:

$$k \cdot \int \Delta I \cdot dx = n_{CRD} \cdot L, \quad (2)$$

where k is a coefficient, ΔI is photodetachment current, n_{CRD} is line-averaged H^- ion density from cavity ring-down method and L is the length of the plasma. The coefficient k is derived from Eq. 2, and then the local H^- ion density can be obtained by $n_{H-} = k \times \Delta I$.

Figure 3 shows the global profile of H^- ion density in x direction which is parallel to the laser beam and defined in Fig. 1. H- ions are concentrated in the central region of the ion source. This is attributed to the mirror-like structure of the filter field.

In conclusion, a new method for local H- ion density by laser photodetachment with assistant of cavity ring-down is developed. The local H^- ion density is obtained.

[1] M. Bacal, Rev. Sci. Instrum. **71**, 3981 (2000).

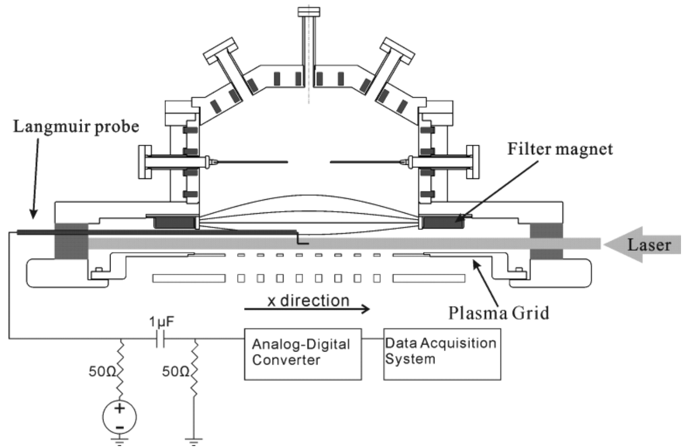

Fig. 1 Schematic illustration of photodetachment system on the negative ion source for development.

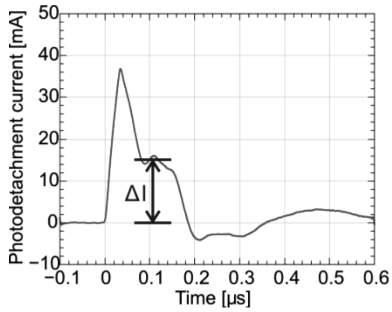

Fig. 2 Typical photodetachment waveform.

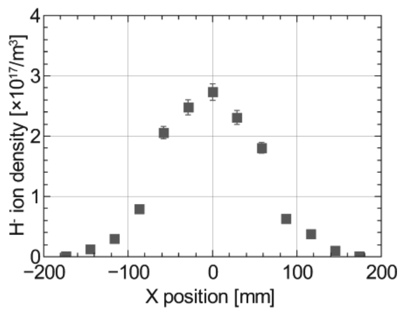

Fig. 3 Global profile of H- ion density in x direction.