§4. Fundamental Processes in H⁻ Ion Source Plasma

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Neutral beam heating based on electrostatic acceleration of negative hydrogen ions (H^-) is one of the most promising candidates to heat magnetically confined plasmas up to temperatures necessary to realize thermonuclear fusion conditions. The optimization study of the H^- ion source and that of the acceleration system are being carried out at the National Institute for Fusion Science, and a reliable plasma heating system for Large Helical Device has already been achieved. However, a further development to improve reliability of the heating system is desirable for extending the operation time of a plasma confinement device. Fundamental processes influential upon the H^- ion extraction is being studied by measuring the perturbation in the extracted H^- beam caused by destroying local H^- by pulse laser photodetachment.[1)]

The experimental setup is schematically illustrated in Fig. 1. The spacing between the plasma electrode and the laser beam, z, is changed to investigate the relative importance of the local H^- density on the laser path to the extracted laser beam. A 9-cm diameter, 11-cm long magnetic multicusp ion source is equipped with a magnetic filter to realize an efficient extraction of H^- ions. Local plasma parameters and an H^- density are measured with a movable Langmuir probe. A beam of H^- is formed with a single gap extraction system. The beam current is measured by a Faraday cup after separating electrons with a permanent magnet electron suppressor unit.

Typical oscilloscope traces of the H^- current signals at the time of photodetachment of H^- in the near plasma electrode region of the ion source are shown in Fig. 2. As shown in the figure, the signal amplitude is smaller and the delay time for the signal to reach its maximum is larger for larger z. Through conducting a series of precise experiments, the probability for an H^- ion to be extracted from an aperture of radius R is found to be expressed by the following equation.

$$P(z) = \frac{1}{2}\left(1 - \frac{z}{\sqrt{z^2 + R^2}}\right)\exp\left(\frac{3}{2}\frac{\Delta\Phi(z)}{K(z)}\right) \qquad (1)$$

Where $\Delta\Phi(z)$ and $K(z)$ are the local potential and the H^- kinetic energy, respectively.

Necessary conditions for equation (1) to be valid are negligible effects of collisions and a weak intensity of the magnetic filter field. These effects upon the H^- transport toward the extraction aperture have been investigated with the present device. The filter field effect is qualitatively understandable, while the effect due to collision is not straight forward to interpret. A particle trajectory based numerical simulation model was developed to clarify the effects of ion-neutral collisions near the plasma electrode. Results of the model reasonably agree with ones obtained from experiments for near collision free conditions. Modification of the model is being made to properly simulate plasmas of high collision frequencies.

Other factors affecting the extractable H^- current are studied with various methods. These include VUV spectroscopy,[2)] and the dc laser photodetachment diagnostics, which has revealed the transport velocity of negative ion containing plasma is substantially slower than the ion acoustic speed of H^-.[3)] The enhanced H^- cooling effect due to neutral collisions will be further studied so as to realize better extraction geometry for H^- ion sources.

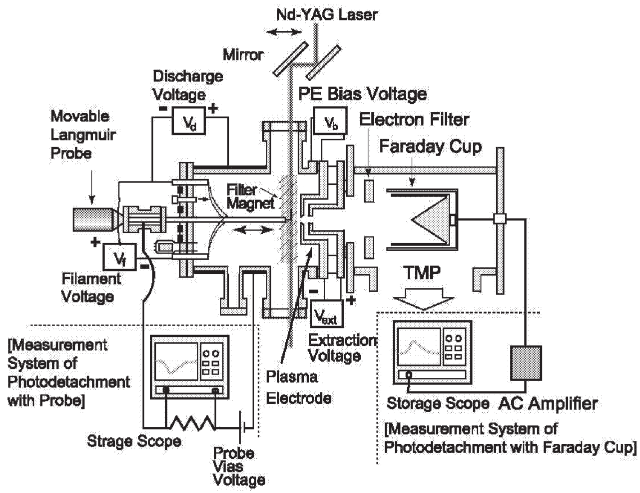

Fig. 1. Experimental setup.

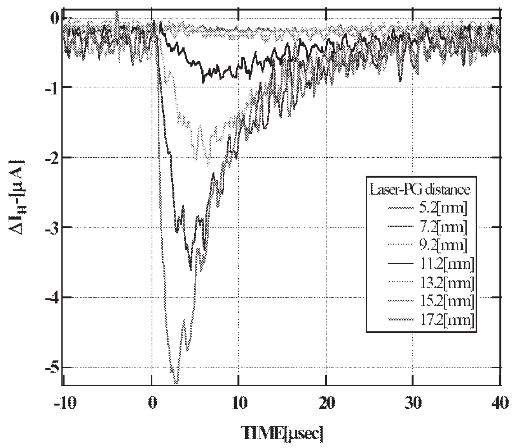

Fig. 2. Typical oscilloscope traces showing the change of H^- beam current induced by laser irradiation into the extraction region of a H^- ion source.

References
1) Matsumoto, A., Nishiura, M. *et al.* Rev. Sci. Instrum. **75**, 1757 (2004).
2) Bacal, M. *et al.* Rev. Sci. Instrum. **75**, 1699 (2004).
3) Takahashi, H. *et al.* Rev. Sci. Instrum. **75**, 1780 (2004).