§15. A New Measurement Method of Negative-Hydrogen Ion Temperature Measurement with Cavity Ringdown Technique

Nakano, H., Tsumori, K., Shibuya, M., Ikeda, K., Kisaki, M., Nagaoka, K., Osakabe, M., Kaneko, O., Geng, S. (SOKENDAI)

Negative-hydrogen ion sources are utilized in neutral beam injectors for fusion devices and accelerators for particle and nuclear physics and medicine. The negative-hydrogen ion source has been developed with step by step device improvement. The physical understanding in the ion source plasma also contributes the ion source development. The behavior and physical role of the negative hydrogen ion (H^-) in the ion source plasma have not been fully understood. In the ion source with cesium, mostly extracted H^- as beam is produced on boundary electrode between the plasma and the beam, that is Plasma Grid electrode (PG), with opposite velocity component to beam direction. It is not sufficiently understood the dynamics to change the velocity components to the beam direction and the contributions of electric field and other particles (electron, positive ions and neutral atom and molecular) to the H^- dynamics. The studies to clarify the mechanism from H^- production to beam extraction have been performed. In the experimental study, the H^- density is one of the useful measurement values. We have measured the H^- density with Cavity RingDown technique (CRD) which is a sort of laser absorption spectroscopies with high sensitivity[1]. It is known that divergence of the H^- beam from filament arc discharge sources can be several mrad in the case of the beam energy of more than 100 keV. This suggests H^- temperature in the vicinity of the PG is low such as ~1 eV or less. The negative-hydrogen ion temperature may reflect processes of H^- production, emission from PG, relaxation by other particles.

A new measurement method of the negative-hydrogen ion temperature has been developed by modifying the CRD[1]. One of the requirements in the CRD for the density measurement is that the density variation in the optical cavity is sufficient small in the ringdown time. The H^- density decreases by photodetachment reaction by each round-trip laser pulse. Sufficient recovery is necessary before the next pulse returning by H^- with thermal velocity around the laser rod. If the laser intensity is low and the H^- temperature is high, this requirement is satisfied. Otherwise, the H^- density is underestimated. However, if the known high intensity laser is irradiated, the density variation depends on the H^- temperature. Figure 1 shows calculation results of density variation during the ringdown time scale, where the cavity mirror curvature, reflectivity and transparency are 1 m and 0.99994 and 0.00005, respectively. The cavity length is 1.57 m. The H^- temperature is assumed 0.5 eV. There is not clear density variation by low laser pulse energy of 50 mJ. When the high laser pulse energy of 5 J is injected, the H^- density decreases in the initial phase of the ringdown signal and gradually recovers due to the decreasing laser intensity inside the optical cavity.

Based on the above calculations, the H^- density variation was obtained by high laser pulse intensity in the pure hydrogen discharge (Fig. 2). The momentary H^- density along the ringdown signal was evaluated by the decay time constant of the exponential decay curve in each small fraction of the rindown signal. The absorption was saturated by high intensity laser, and the H^- density decrease was observed in the initial phase of the ringdown signal. The H^- density gradual recovery was also observed. Comparing the model calculation and experimental result, the H- temperature was evaluated as approximately 0.1 eV

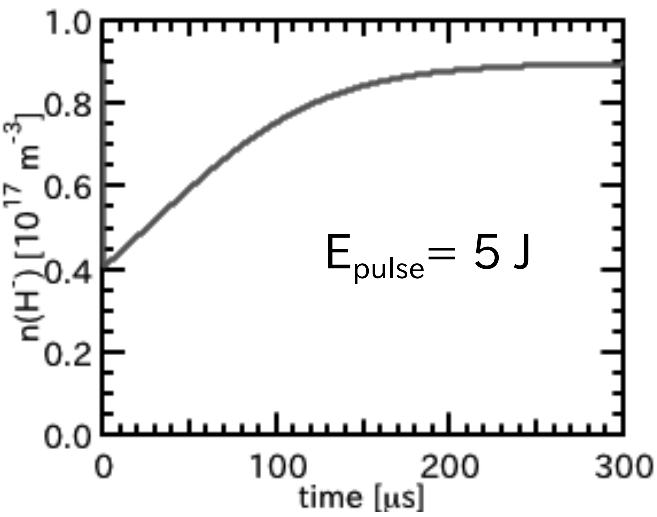

Fig. 1. Density variation calculation during ringdown time scale by high laser intensity.

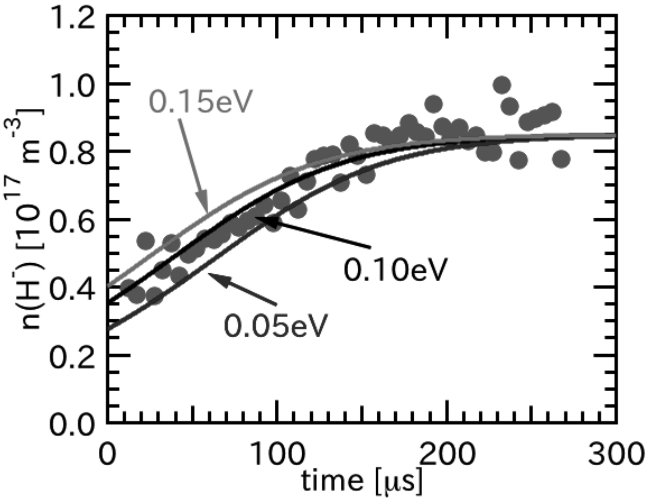

Fig. 2. Experimental results of density variation during ringdown time scale by high laser intensity and H^- temperature evaluation.

1) Nakano, H. et al., AIP Conference Proceedings **1515** (2013) 237-243.

2) Nakano, H. et al.: 17th International Symposium on Laser-Aided Plasma Diagnostics, T1 (LT), Sapporo, Japan, 28th September – 1st October 2015.