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Reaction of H⁻ Ion Source Plasma to Beam Extraction

H⁻イオン源のビーム引き出しに伴うプラズマ応答

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Negative-hydrogen-ion (H^-) density in the vicinity of the beam extraction surface of H^- source is one of the important parameters for the clarification of the particle dynamics concerning H^- beam extraction. We successfully measured the H^- density and its profile with Cavity RingDown (CRD) method. The linear relations were observed between the H^- density and input arc power to plasma, and between the H^- density and extracted beam current. We observed that the H^- density changes at the moment of the beam extraction. Since variation of H^- density at the moment of beam extraction depends on the bias voltage applied between the arc chamber and the electrode of the beam extraction surface, the bias voltage can affects dynamics of not only electron but also H^-.

1. Introduction

Negative hydrogen ion (H^-) sources are applied and scheduled to be utilized for neutral beam injectors (NBIs) with more than a few hundreds keV of beam energy for nuclear fusion experiment devices [1-3]. In the H^- sources, cesium is seeded for increasing H^- beam current. In the cesium seeded H^- source, it is considered that H^- is mainly produced on the electrode of beam extraction boundary, so-called plasma grid (PG). In this case, the velocity direction of H^- needs to change from the inward of the discharge area to opposite direction (extracted beam direction). The particle dynamics including this phenomenon in the vicinity of the PG has not been clearly understood. The clarification of the particle dynamics is one of the important tasks for the improvement of the H^- source.

The H^- density in vicinity of the PG is one of the most important parameters for the clarification of the particle dynamics. We adopted Cavity RingDown (CRD) method [4] for the measurement of absolute H^- density in the large scaled H^- source which is used for development of NBI on LHD (Large Helical Device) in NIFS (National Institute for Fusion Science) [5].

In this article, we discuss the H^- density measurement with CRD method in the H^- source, the relation among H^- density, extracted H^- beam and parameters of ion source plasmas, and the response of H^- density in the beam extraction.

2. Experimental Setup

Figure 1(a) shows a horizontal cross section of

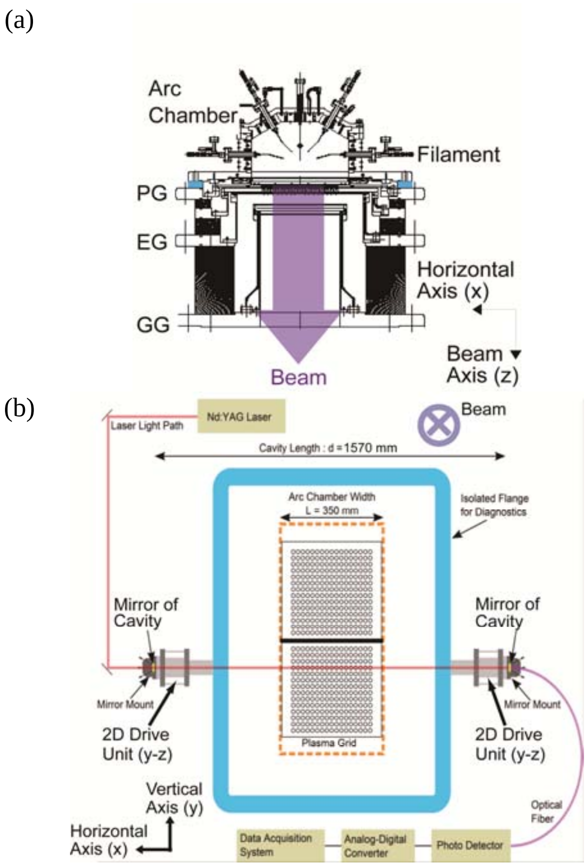

Fig. 1 (a) Short-side cross section of large-scaled H^- source. (b)Schematic view of the CRD system for H-density profile measurement.

the large-scaled H^- source. The large-scaled H^- source consists of an arc chamber, PG, extraction grid (EG) and grounded grid (GG). The size of arc chamber is 350 mm of horizontal width, 700 mm of vertical length, and 220 mm of depth. The H^- source has two PGs with round apertures with 12 mm of diameter. The typical H^- beam energy and current density are 50 keV and ~100 A/m^2, respectively, in this experiment.

In the CRD system (Fig. 1(b)), from intensity decay of laser injected to an optical ring-down cavity by photo detachment reaction, line-integrated H^- density along the laser path is evaluated. The system consists of Nd-YAG laser (wave length: 1064 nm, pulse width: 5 ns, repetition frequency: 50 Hz), high reflective mirrors for the optical cavity, optical fiber for output light transmission, photo detector, analog digital converter, and data acquisition system. The lengths of the optical cavity and effective plasma along the cavity axis are 1570 mm and 180 mm, respectively. A base laser path is the center of PG apertures and 9 mm from the PG. To measure density profile, the optical cavity axis is able to move y-z plane by mounting mirrors for optical cavity on 2D drive unit [6]. A measurable range is 5 mm to 17 mm from the PG and -22 mm to 22 mm in y direction from the base laser path. The photo detachment cross section of H^- by the laser is $3.5x10^{-21}$ m^2.

3. Results

Figure 2(a) shows decay signals, so-called ringdown signals, of the CRD system using base laser path with and without the ion source plasma. From these decay times (ringdown times), the H^- density is evaluated as $3.2x10^{17}$ m^{-3}. And the H^- density is proportional to input arc power and extracted H^- beam current measured with water calorimeter equipped in beam line [5]. This can indicate that measured density reflects both effects of H^- production and beam extraction.

Figure 2(b) shows time evolutions of the H^- density, input arc power, and drain current of acceleration power supply. The H^- beam is extracted for 1 sec from 0 sec. The input arc power enhances during beam extraction by the back streaming which is a positive charged beam into the arc chamber produced in downstream of the PG. The H^- density drops at the moment of extracting the H^- beam. We found that an amount of the density drop depends on a bias voltage applied between the arc chamber and the PG, and on distance from the PG. The bias voltage, by controlling electron dynamic in the vicinity of the PG, has been mainly used for suppressing

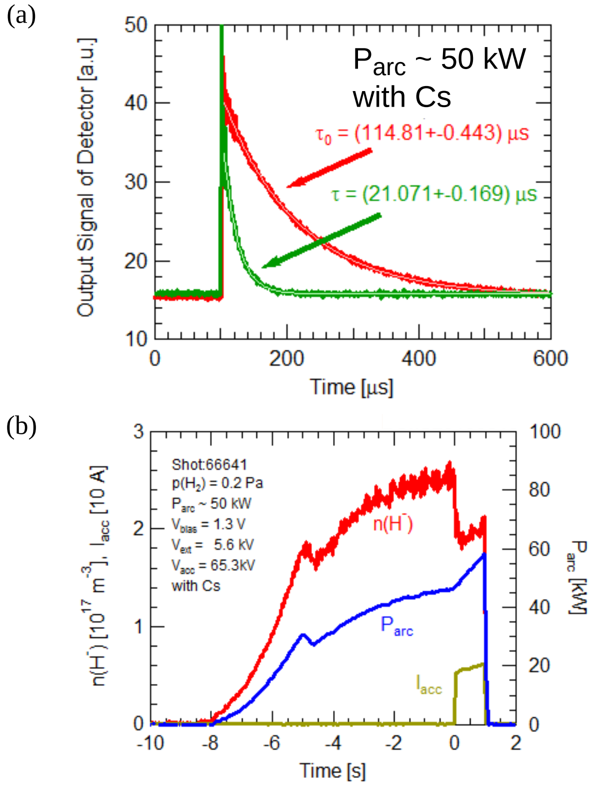

Fig. 2 (a) Ringdown signals with and without the plasma. The waveform with ringdown times of smaller and larger numbers are with and without the plasma. (b) Time evolution of H- density ($n(H^-)$), input arc power (P_{arc}), and drain current of acceleration power supply (I_{acc}).

simultaneous extracted electron with H^-. However, it is confirmed that the H^- dynamics is affected by the bias voltage.

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