22C05

Ion-Ion Plasma in a Large-Scaled Hydrogen Negative Ion Source
大型水素負イオン源内のイオン性プラズマ

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Ion-ion plasmas including quite low electron density are observed in a caesium (Cs) seeded negative hydrogen ion (H^-) source. The voltage-current curve (V-I curve) monitored with Langmuir single probe shows quite symmetric with respect to the inflection point of the curve. The symmetric feature breaks during beam extraction, and electron density increases. That change indicates the negative charge density of extracted H- is compensated with electron density. The spatial distribution of the changes suggests the extraction field affects deep region of ion-ion plasma.

1. Introduction

Negative-ion-based neutral beam injectors (NBI) have contributed to improve the performances of recent plasma confinement devices in the nuclear fusion research [1,2]. To enhance the H- current, small amount of Cs is seeded in the plasma chamber of the negative ion source. Although intensive R&D have been carried out to increase the H- current in some laboratories, there are some unclear parts in the mechanisms of the production and extraction of the H- ions. In order to investigate the mechanism, we started the measurement of the particle dynamics in the beam extraction region using a diagnostic system combining with a Langmuir single probe, a CRD system, a millimeter-wave interferometer (MWI), and optical emission spectroscopy [3-6]. The experimental setup, the results on the ion-ion plasmas, the response of the H- and electrons with and without applying the beam extraction field, and on the spatial distribution of the saturation currents and their changes during beam extraction in the following sections.

2. Experimental Setup

A Cs seeded negative ion source is applied for this experiment, and the source is a multi-cusp one characterized with a pair of filter magnets as shown in Fig. 2. The source plasma is generated with filament-arc discharge, and the primary electrons decrease their energies via diffusion in the filter magnetic field. Near the plasma grid (PG), diffusing electrons are trapped with another strong magnetic field of ~ 10 mT induced by an array of the permanent magnets embedded in the

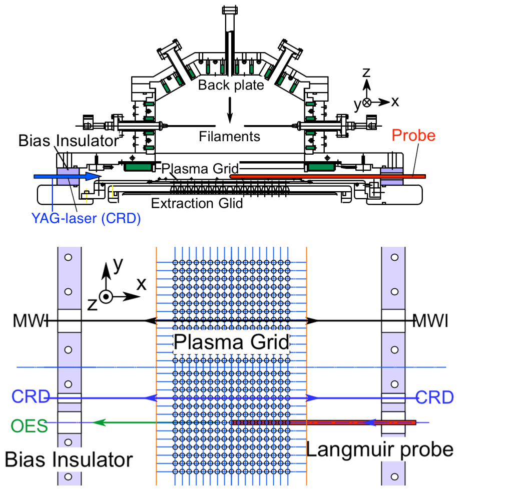

Fig.1. Negative ion source and diagnostic configuration

second electrode called extraction grid (EG). An insulator spacer is inserted to apply positive bias potential to the PG with respect to the source chamber. The spacer is called bias insulator, and diagnostic ports are installed through the insulator. The Langmuir probe and the CRD unit are time resolved system and the systems are able to scan in the horizontal and vertical directions to the PG plane.

3. Experimental Results

3.1 *Positive-Ion and Negative-Ion Plasmas*

The electron saturation current (ESC) measured with the Langmuir probe is much larger than the ion saturation one in a pure hydrogen discharge. The ESC drastically decreases after Cs seeding, and quite symmetric voltage-current (V-I) curve is observed as shown in Fig. 2. The ion-ion plasmas are reproducible in relatively high filling gas pressure and bias voltage. The electron density is crossly checked with the MWI [3], and the electron density can be quite small of the order ~10^{-2} to that of H^-.

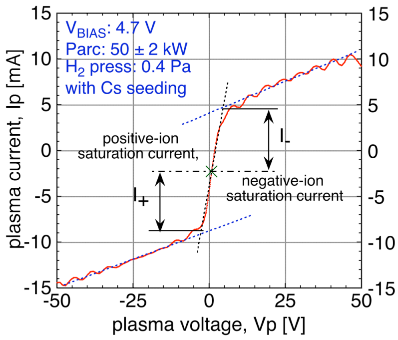

Fig.2. Ion-ion plasma observed in a negative ion source

3.2 *Response of H- and electron with and without Beam extraction.*

With and without beam extraction, the density changes of the charged particles in the ion-ion plasma have been compared. The Langmuir probe and CRD measurement, which can estimate the absolute H- density [4], are applied for the monitoring. As shown in Fig. 3, the probe signal

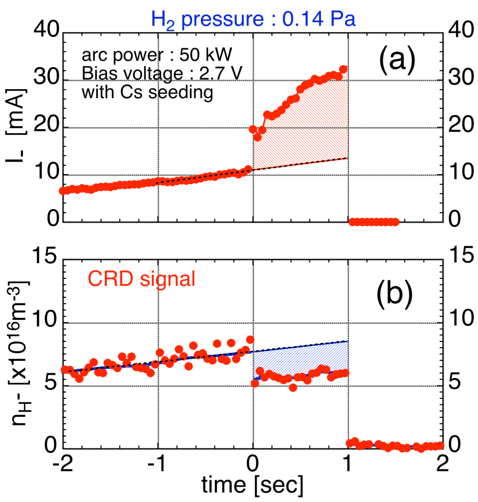

Fig. 3. Waveforms of (a) negative probe current and (b) H- density with and without beam extraction.

jumps up (a) during beam extraction, and the H- density steps down (b) at the same time. There is no negative charge except for H- and electron, so that the jumping-up of the probe signal is interpreted to indicate the electron charge compensating the positive ion background remaining after H- extraction.

3.3 *Spatial Distribution of Electron Increments*

As the next step, the partial distribution of the increments of the compensating electron is investigated. Figure 4 shows the distribution of the

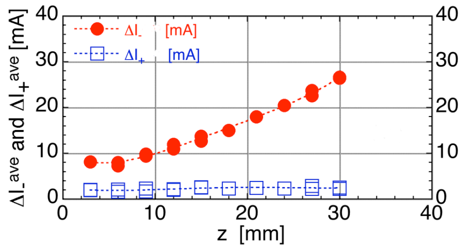

Fig. 4. Spatial distributions of the increments of negative (●) and positive (□) probe signals with and without beam extraction.

increments of the positive (ion) and negative (electron) probe signals with and without extraction. The z direction is set in the direction separating from the PG surface. The distribution suggests the extraction field affects even deep region of the ion-ion plasma.

Acknowledgments

The authors would like to express their acknowledgements to the Director Generals Prof. Dr. A. Komori, for continuous support and encouragement of the development and the operation of our neutral beam injectors. They also would like to express their sincere acknowledgement to the LHD experimental group for excellent execution of the LHD experiments. This work is supported by National Institute for Fusion Science grant administrative cord, NIFS-ULRR702.

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