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Spatial Distribution of Negative Hydrogen Ions in the Extraction Region of a Negative Hydrogen Ion Source for NBI

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Measurement by means of Photo-detachment (PD) and single Langmuir probe are applied to investigate the distribution of charged particles in a negative hydrogen ion source on NBI-test stand at NIFS. Profile of negative hydrogen ion density along the direction parallel to the plasma grid is obtained. It is shown that negative ion density has a quasi-symmetrical profile. The plasma profile is measured by a single Langmuir probe. The result shows a slight shift in the profile of the probe saturation current.

1. Introduction

Negative-ion-based neutral beam injection (N-NBI) is a most reliable heating method for plasma heating and current drive. In N-NBI system, negative ion source is an important and effective device to improve the performance. However, there are many unknown issues relevant to the dynamics of charged particles in a negative ion source. Especially, understanding on production and extraction mechanisms of H^- ions, which are strongly affected by the plasma state in the beam extraction region, are the essential part of these issues. Therefore, photodetachment and single-Langmuir probe are applied to the experiment to investigate the spatial distribution of charged particles.

The photodetachment[1] is a diagnostic technique, by which a laser beam is irradiated into the plasma, to measure negative ion density. In this process, the excess electron detached from a negative ion (H^-) by a photon conserves the charge neutrality, and thus the detached electron is not affected by the additional field caused by this process. The detached electrons are collected by a DC biased probe tip. Then a current increase named PD current is observed from the probe and it is proportional to the local H^- density.

In addition, a single Langmuir is applied in this experiment to obtain the information of spatial distribution of electrons and positive ions by measuring the saturation current.

2. Experimental Setup

The experiments are carried out in the negative hydrogen ion source on the NBI-test stand at NIFS.[2] The schematic drawing of the PG and the position of the probe is shown in Fig. 2. The probe has an "L-shaped" tungsten tip which is 4 mm in length and 0.5 mm in diameter. For photo-detachment experiments, a Nd:YAG laser beam with a diameter of 4 mm and energy density of 40 mJ/cm2 is irradiated into the plasma and a DC bias of 40 V is applied to the probe to collect the PD electrons. The PD current is acquired by a high-speed oscilloscope and each waveform is stored. For single Langmuir probe experiment, the laser is switched off and the DC bias is replaced by a sweeping voltage to obtain the time evolution of the plasma parameters.

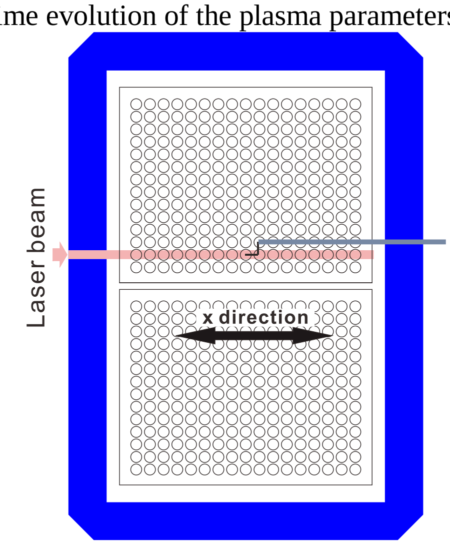

Fig. 1. Schematic view of the plasma grid and the position of the probe. The "x" direction is oriented parallel to PG surface and filter magnetic field.

3. Experimental Results

3.1 Overall Profile

The spatial distribution of PD current is obtained by moving the probe along the laser beam in x direction, and then the H^- ion density is calculated from the PD current by comparing its overall profile with the line-averaged H^- density obtained from cavity ring-down according to

$$k \cdot \int \Delta I \cdot dx = n_{CRD} \cdot L \,. \qquad (1)$$

Where ΔI is the PD current, n_{CRD} is the line-averaged H^- density obtained from cavity ring-down results and L is the plasma length. The coefficient k is derived from equation (1), and the local H^- density is calculated by $n_{H-} = \Delta I \times k$. The overall profile of H^- density in x direction is shown in Fig. 2, and it is almost Gaussian with a slight drift to the negative direction.

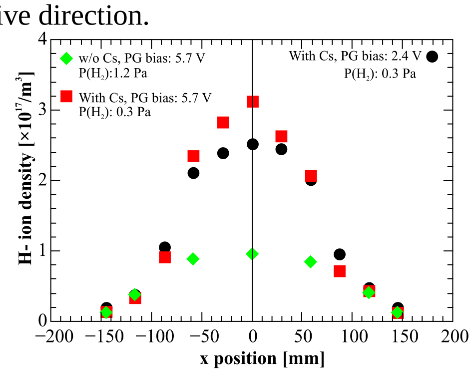

Fig. 2. Spatial distribution of H^- density in x direction at arc power of 50 ±2.5 kW, with and without Cs

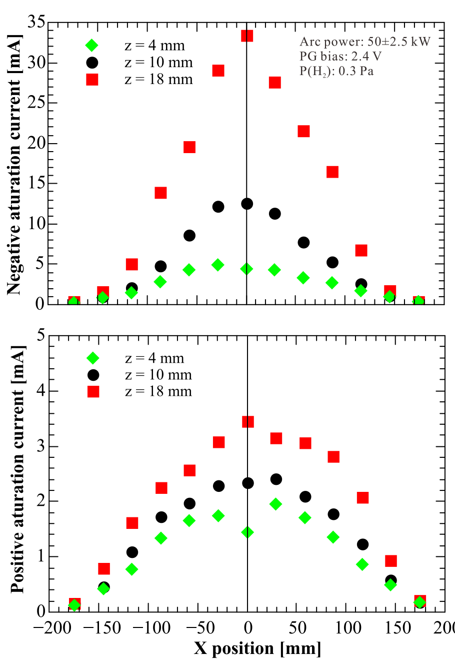

Fig. 3. Negative and positive saturation current of a single Langmuir probe

The slight drift is also observed in experiments by a single Langmuir probe in sweeping mode. The results are shown in Fig. 3 in which z means the distance of the probe tip to the PG surface. Here the "negative saturation current" includes electrons and H^- ion currents, and "positive saturation current" is traditional positive-ion saturation current. The distribution of negative saturation current is more triangular than that of H^- density. The positive saturation current distributes rather close to the negative one, and has some deviations. The shift of the negative and positive distributions is opposite. It, however, does not indicate the charge separation occurs in the plasma because the spatial distribution of plasma potential is uniform in x direction. The cause of the opposite shift of the measured distribution is not clear, and future experiments are required to check the cause of this shift.

3.2 Local Profile

The spatial distribution of H^- ion density, negative and positive saturation currents are shown in Fig. 4. The probe tip is scanned across a PG aperture at 15 mm apart from the PG surface and the scanning distance is 16 mm. The local spatial distribution of plasma is uniform in a short distance due to the uniform magnetic field.

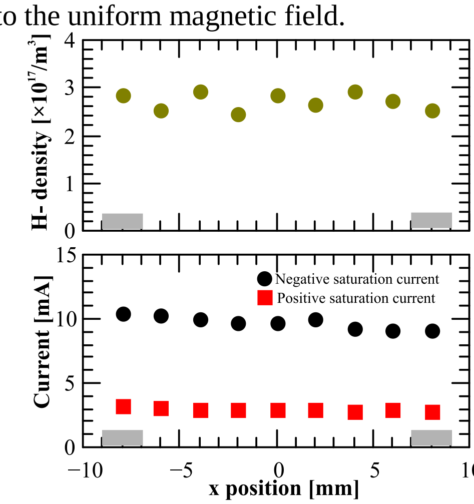

Fig. 4. Local spatial distribution of H^- ion density, negative and positive saturation currents

References

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[2] K. Tsumori, H. Nakano, M. Kisaki, K. Ikeda, K. Nagaoka et al., Rev. Sci. Instrum. **83** (2013) 02B116.