§7. Development of RF Plasma Source for Negative Ion NBI

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The high power neutral beam injection (NBI) heating utilizing negative ions have been actively executing in NIFS. Concerning the future plasma source in NBI, key issues to be studied are easier plasma production with a good stability, higher plasma density and higher ionization, and developments of large or compact sources. In addition, developing a neutral beam source with the high particle flux is important in the charge-exchange recombination spectroscopy. The present objective is, first, characterizing a high-density, compact plasma source, using a helicon wave scheme [1] in the range of radio frequency. Then, developing a negative ion source with, e.g., hydrogen gas, will be carried out to apply to the advanced NBI in NIFS.

The construction of the compact helicon plasma source with the strong magnetic field has been completed. The main device parameters are as follows: the discharge chamber uses a quartz tube, which has an outer (inner) diameter of 10 (9.5) cm and 90 cm axial length. The magnetic field B can be applied up to 10 kG, whose main strong field region extends to ~ 30 cm in the axial direction. Here, iron yokes are added to increase the field.

Two parallel plates with 3 cm in the axial direction each used as the rf antenna, are wound around the quartz tube at the midplane. Here, the spacing between two copper plates is 6 cm. By changing the electrical connection between two plates (parallel and anti-parallel current directions), the excitation of the axial wavenumber spectrum can be changed [2,3]. The rf frequency can be varied in the range of 3 - 15 MHz, 145 MHz and 435 MHz (with pulsed as well as continuous operation modes). In order to estimate the antenna loading, a directional coupler monitoring the incident and reflected power is used in addition to measure the antenna voltage and current. A Langmuir probe is scanned radially at the midplane, and two probes inserted from the top and the bottom flanges move axially. For the electron density calibration, 70 GHz microwave interferometer system has also been installed.

We will present the results on the plasma performance using an argon gas [4]. Figure 2 shows an example of the plasma density n_e, changing input rf power P_{rf} (rf frequency is 7 MHz) with argon pressure P_{Ar} of 10 mTorr. A so-called density jump to the range of 10^{13} cm^{-3} was observed with less than 1 kW of P_{rf}. Here, due to the better radial confinement with the increase of the magnetic field, n_e was higher in the high field region before the density jump. This jump became weaker with the increase of this field (see, e.g., B = 3,040 G case). Figure 2 shows the relationship between the electron density and the magnetic field with P_{rf} = 1.6 kW. In both cases of P_{Ar} = 4 and 10 mTorr, n_e was higher near B = 640 G, which corresponds to the condition that the excitation frequency is close to the lower hybrid frequency.

In conclusion, the experiments on the plasma production in the electron density range of 10^{13} cm^{-3} were successfully carried out using a compact, high magnetic field device. The more detailed characterization in a wide range of operating parameters will be done. The optimized condition obtained will be expected to contribute to the advanced NBI system in NIFS.

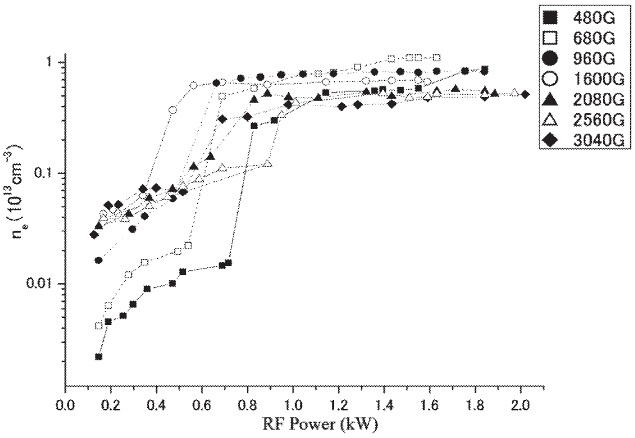

Fig. 1. Electron density as a function of rf power.

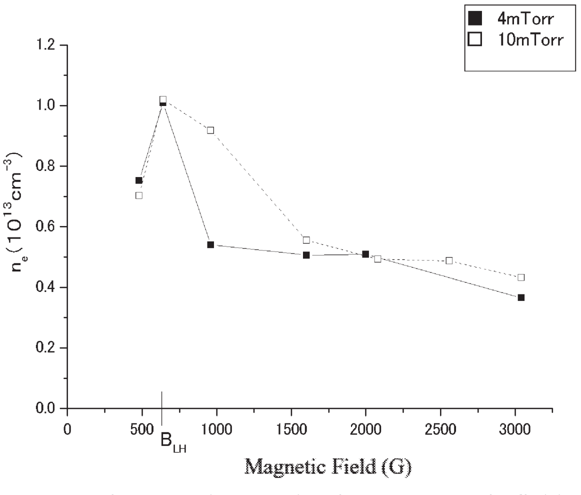

Fig. 2. Electron density vs. magnetic field.

Reference

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2) S. Shinohara *et al.*, Plasma Phys. Control. Fusion **42** (2000) 41 and **42** (2000) 865.
3) S. Shinohara *et al.*, Phys. Plasma **8** (2001) 3018.
4) H. Mizokoshi and S. Shinohara, 21st JSPF Annual Meeting (2004) 25pA30P.