§16. Development of High Density Negative Ion Source by Helicon Wave

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In NIFS, intensive studies of the high power neutral beam injection (NBI) heating utilizing negative ions are under way. As to the plasma source in NBI, easier plasma production, higher plasma density and smaller volume are crucial to be studied. In addition, developing a neutral beam source with the high particle flux is important in the charge-exchange recombination spectroscopy. The present objectives are, first, producing 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 very strong magnetic field has been completed in Kyushu University, as shown in Fig. 1, and the initial plasma production experiment was started. 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 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 initial plasma performance using an argon gas with an excitation frequency of 7 MHz. Figure 2 shows an example of the plasma light taken between two coils. In the case of the purely Inductively Coupled Plasma (ICP), where the magnetic field B = 0 G, the electron density n_e with a fill pressure of P = 6 mTorr increased almost linearly with the increase in the rf input power (P_{inp}), and n_e reached to 3×10^{12} cm^{-3} with P_{inp} less than 1 kW. In the case of B = 480 G with P = 3 mTorr, n_e was low of ~ 10^{11} cm^{-3} with $P_{inp} < 0.8$ kW, and above P_{inp} = 0.8 kW, a density jump occurred, leading to $n_e > 5\times10^{12}$ cm^{-3}.

In conclusion, the first experiment on the plasma production was successfully carried out using a compact, high magnetic field device. The detailed characterization in a wide range of operating parameters such as the magnetic field, fill pressure including gas species, excitation frequency and antenna wavenumber spectrum will be tested. The optimized condition obtained will be expected to contribute to the advanced NBI system in NIFS.

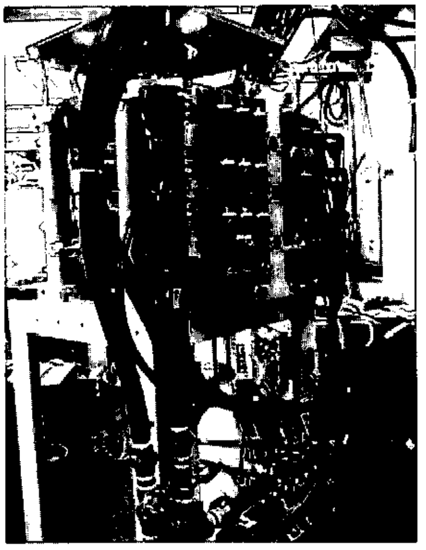

Fig. 1. High field helicon device.

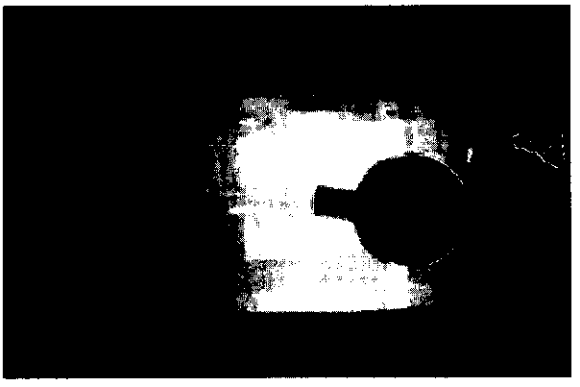

Fig. 2. Example of argon plasma light.

Reference

1) S. Shinohara, J. Plasma Fusion Res. **78** (2002) 5.

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.