§6. Development of High-Density Helicon Plasma Source with Large Diameter and Short Axial Length for Negative Ion NBI

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High power neutral beam injection (NBI) heating utilizing negative ion source has been actively executing in NIFS. As to the advanced, future plasma source in NBI, one of critical issues is easier plasma production by rf wave such as a helicon wave [1] with a good stability, higher plasma density and higher ionization. It is also important to develop a large area plasma source with a short axial length. In addition, a low magnetic field operation is desirable due to the small effect on the ion source as well as from the viewpoints of the small necessary power supply and light weight. Here, the present objective is to characterize large area, high-density, low-field plasma sources [2-7] developed by shortening the axial plasma length, leading to a small aspect ratio A, by the use of the helicon wave scheme. Here, A is the ratio of the axial length to the diameter.

Experiments are carried out using the Large Diameter Device (LDD) [4-6] with 40 cm diameter, and the Large Helicon Plasma Device (LHPD) [2,3,6,7], the largest helicon volume in the world of 2.1 m^3. Here, the high-density plasmas are produced by applying a RF wave of 7 MHz to the spiral antenna with a fill pressure P (argon) of 0.75-10 mTorr and the magnetic field of < 150 G. The axial plasma length L is limited by the movable stainless steel termination plate. Plasma parameters (rf wave structures) are measured by Langmuir probes (magnetic probes). Typical electron density n_e and electron temperature were 10^{12}-10^{13} cm^{-3} and 3-5 eV, respectively. Plasma light is monitored by the high speed (up to 1,200 fps) digital camera（CASIO EX-F1).

Figure 1 shows the dependence of the plasma production efficiency N_e / P_{rf} on L. Here, N_e and P_{rf} are total number of electrons in the whole plasma and input rf power, respectively. In the range of L = 5.5–30 cm, the observed scalings are consistent with the expectations [7], $N_e / P_{rf} \propto L$, based on the classical diffusion, and the obtained proportional coefficients also agree with this theory within a factor of 3.

Figure 2 shows the excited wave field (z component of the rf magnetic field) normalized by the antenna current I_A as a function of the z axis with L = 5.5 cm, corresponding to A of 0.075, which is the smallest in the world. Here, one quarter of wavelength is excited. In the case of the short L, the following discrete wave is obtained: $L/\lambda = (1+2p)/4$, where λ and p are excited rf wavelength and an integer.

In conclusion, we have successfully produced the large diameter (40-74 cm), high-density (10^{12}-10^{13} cm^{-3}) helicon plasma with a short axial length L down to 5.5 cm, which corresponds to A = 0.075. The good plasma production efficiency is obtained, which is consistent with the expectation. These studies must be continued to have the optimum conditions to meet the real ion source requirements.

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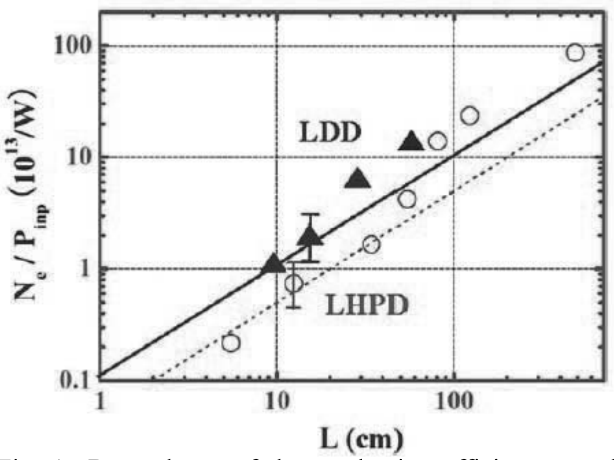

Fig. 1. Dependence of the production efficiency on the axial length.

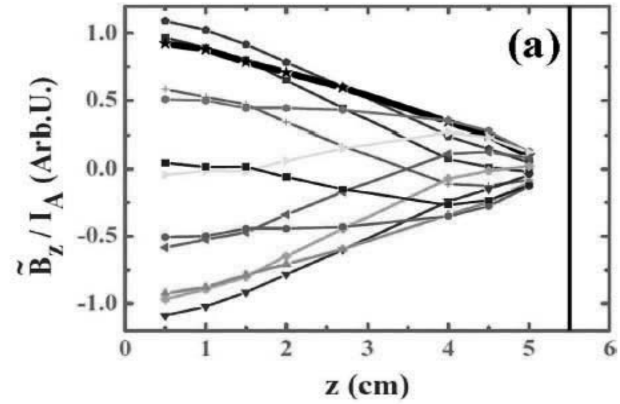

Fig. 2. Axial profiles of the excited rf waves.