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

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In NIFS, high power neutral beam injection (NBI) heating with negative ion sources utilizing an arc filament method has been actively executing. Concerning the advanced, future plasma source in NBI, one of critical issues is easier plasma production by an 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 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] by shortening the axial plasma length (changing also the material of the termination plates), leading to a small aspect ratio A, by the use of the helicon wave scheme.

Experiments are carried out using the Large Diameter Device (LDD) [4,6] with 40 cm diameter, and the Large Helicon Plasma Device (LHPD) [2-7], the largest helicon volume in the world of 2.1 m^3. Here, the high-density plasmas are produced by applying an 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 z_E is limited by the movable termination plate. Plasma parameters (rf wave structures) are measured by Langmuir probes (magnetic probes). Typical electron density n_e and electron temperature are 10^{12}-10^{13} cm^{-3} and 3-5 eV, respectively.

Figure 1 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, changing the termination plate material and the input rf power. From this figure, the followings are found. 1) the discrete axial mode number is small in the case of short z_E and/or small rf power. 2) Depending on the end plate material, the boundary condition is changed to cause the different wave structure. 3) Even though the axial plasma length is short (down to 5.5 cm, and thus A is 0.075), the plasma density is as high as > 10^{12} cm^{-3}, and the production efficiency is excellent to be explained by the classical diffusion theory.

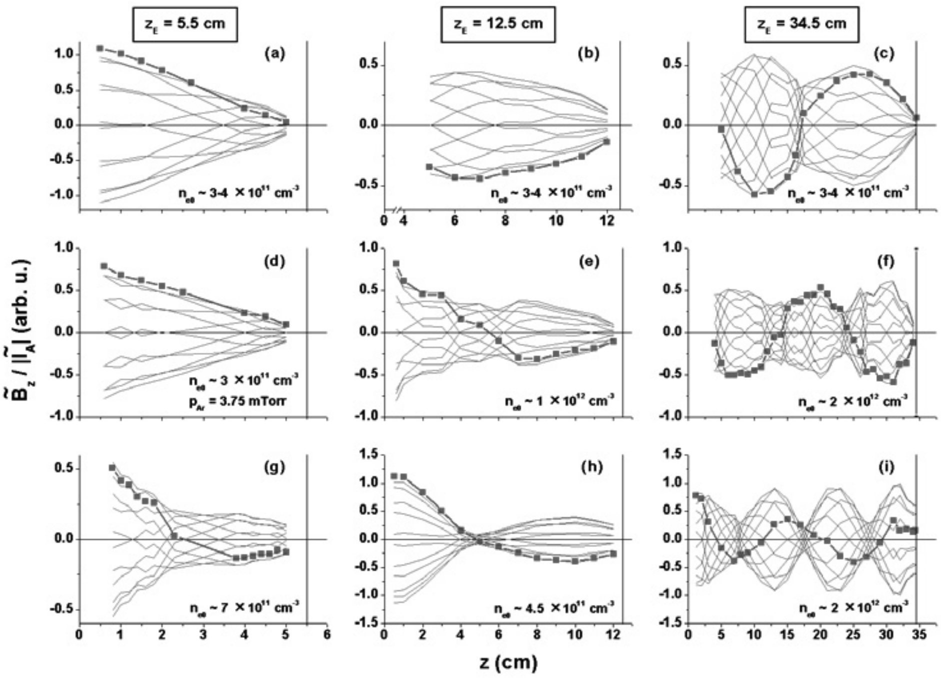

Fig. 1. Axial profiles of z component of the excited rf magnetic field. (left three figs.: SUS plates, middle three figs.: SUS plates with holes, right three figures: mica plates). The input powers from top to bottom are 1, 2 and 4 kW, respectively.

In conclusion, the large diameter (40-74 cm), high-density (10^{12}-10^{13} cm^{-3}) helicon plasmas with short axial length are produced and the wave structures have been characterized. Good plasma production efficiency is obtained, which is consistent with the expected scaling. These studies must be continued to have the optimum conditions to meet the real ion source requirements.

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