§16. Development of a Large Negative Ion Source and a Photo-neutralizer for the Continuous Operation

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Neutral beam injection (NBI) system is one of the powerful and fruitful heating tools in fusion researches. A high power hydrogen negative-ion (H^-) source has been successfully developed for a beam source and operated as a major heating device in LHD. For a long pulse or continuous operation, it is requisite to develop radio-frequency (RF)-driven H^- sources.

Our previous studies have shown that a field effect transistor (FET)-based high power RF amplifier with the frequency below 0.5 MHz enables us to operate RF ion sources. As a next step, we have developed a large-scaled ion source consisting of Alumina ceramic tube with 230 mm in inner diameter and 300 mm in length, which are wound by a RF loop antenna. Characteristics of plasma production in the source were measured in hydrogen gas in order to clarify the high density plasma production with this source. Figures 1 and 2 show the experimentally obtained axial distributions of electron density and temperatures with hydrogen gas. Cusp magnetic field around an expansion chamber give good effect in obtaining high density plasmas even in the operating pressure of 0.3Pa.

In addition to the experiments, we have performed a numerical simulation for a photo-neutralizer. We modeled different types of neutralizers (gas neutralizer and photo neutralizer) and studied the difference in neutralization efficiency. A negative deuterium ion beam is passed through a gas neutralizer filled with background gas and laser light (λ=1064nm) with the power of P_0 is applied in the neutralizer..

Figures 3 and 4 show the simulated maximum neutralization efficiency in a single beamlet with two beam energy of 180 keV and 1 MeV, respectively. The efficiencies are shown as a function of background gas density in various laser power. For the ion beam with 1 MeV energy, the combined system is effective even with P_0 <20 kW. It is necessary to optimize neutralizer with different ion beam energy by considering the effects of gas, photo, and their combined effects.

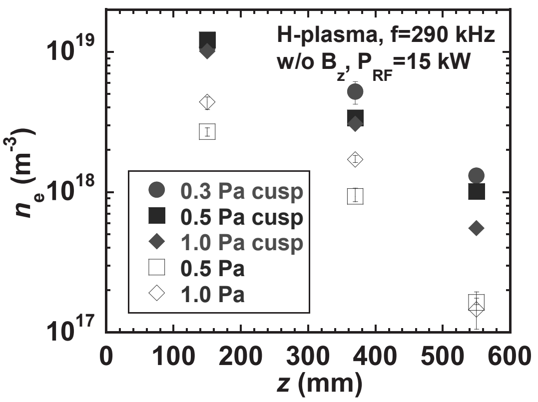

Fig.1 Axial distributions of an electron density.

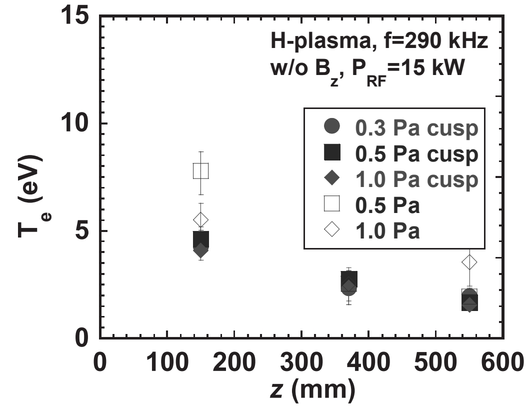

Fig.2 Axial distributions of an electron temperature

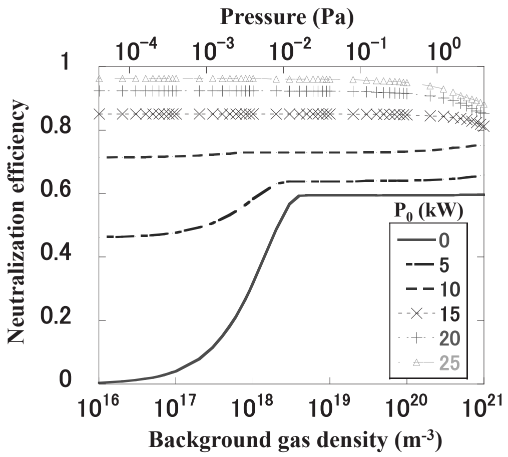

Fig. 3 Maximum neutralization efficiency with 180 keV negative deuterium ion beam as a function of background gas density and laser power.

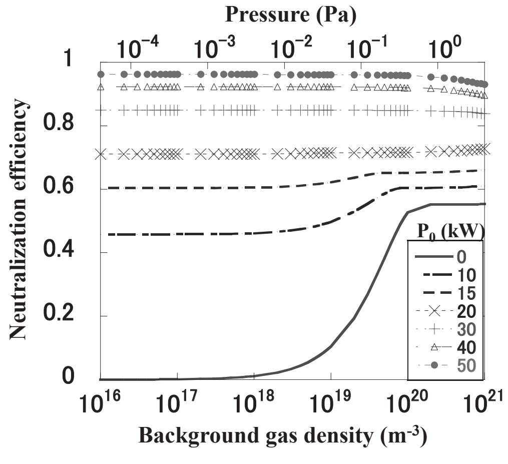

Fig. 4 Maximum neutralization efficiency with 1 MeV negative deuterium ion beam as a function of background gas density and laser power.