§12. Long-pulsed Operation of a Negative Hydrogen Ion Source

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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. It is also required for ITER and DEMO-NBI that the ion source should deliver long pulse H^- or D^- ion beam. For such a long life operation, it is required to develop radio frequency (RF)-driven ion sources. Our purpose of this research is to develop a RF-driven H- ion source by using field effect transistors (FET) as switching devices in a RF power source and to operate it for long time duration.

RF driven H^- ion source using FET has been developed for a NBI source through collaboration with researchers of Plasma Heating Physics Research division in NIFS. Our ion source consisted of a “driver region” and “expansion region”. A driver region consisting of a 70 mm inner diameter and 175 mm long ceramic tube wound by a ten-turn RF loop antenna was contiguously attached to a 165-mm-diameter stainless steel expansion chamber (expansion region). When an axial magnetic field was applied to the driver region by magnetic coil mounted around RF antenna, an electron density over 10^{19} m^{-3} is produced in hydrogen plasma with a frequency of below 0.5 MHz. In addition, H^- beam was successfully extracted for more than 100 seconds from the ion source with cesium evaporation and the characteristics of beam extraction from the source were investigated with optical emissions of cesium and hydrogen atoms and grid temperature during long operation periods [1,2]. However, a further long-time operation was difficult in this ion source because it was too small to insert a Faraday shield into the driver region.

Then we have developed a large-scaled ion source consisting of a 230 mm inner diameter ceramic tube as a driver region and the plasma characteristics in the source were investigated.

Figure 1 shows the schematic of the newly-developed RF ion source. The driver region consists of Alumina ceramic tube with 230 mm in inner diameter and 300 mm in length, which are wound by a RF loop antenna. Figure 2 shows the plasma density measured at the driver region in the source as a function of RF input power. An electron density over 10^{19} m^{-3} is obtained in hydrogen plasma. Figure 3 shows the dependence of produced electron density on the operation pressure. As shown in Figs. 2 and 3, no strong dependence on the number of turns in the RF antenna was observed. High density hydrogen plasma more than 10^{18} $m^{-3}$was obtained at p = 0.3 Pa. The next plan is to perform the experiments for long-time operation and beam extraction with this large-size ion source.

[1] A. Ando, et al., Rev. Sci. Instruments, **81**, 02B107_1-3 (2010).

[2] A. Ando, et al., AIP conf. Proc. **1390**, 322-328 (2011).

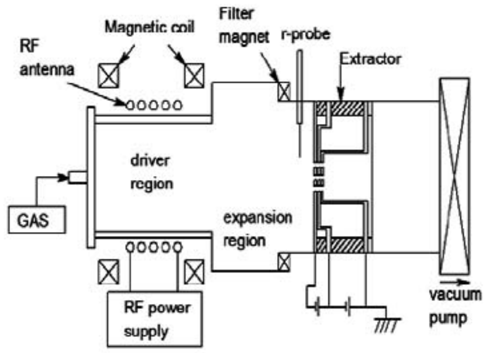

Fig. 1. Schematic of the large-sized RF ion source

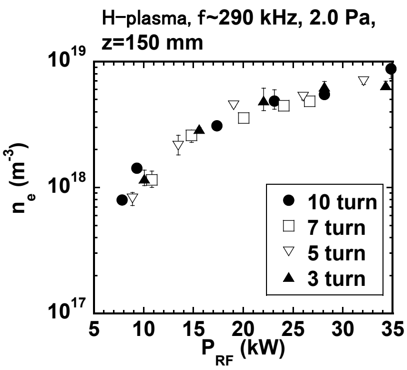

Fig. 2. Plasma density measured at a driver region as a function of RF input power.

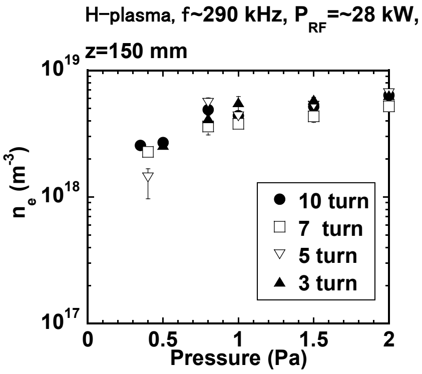

Fig. 3. Plasma density measured at a driver region as a function of pressure.