§16. Characteristics of rf-based Hydrogen Negative Ion Source with Cs Additive

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Neutral beam injection (NBI) system is one of the powerful and fruitful heating tools in fusion researches. NBI involves injecting a high-energy beam of neutral atoms, a hydrogen isotope such as deuterium, into the core of the plasma. A hydrogen negative-ion (H-) source has been developed for a beam source with beam energy more than 100keV, where the charge exchange probability gets worse for positive hydrogen ions. Successfully, a large H- source has been operated as a major heating device in LHD.1),2) For a long life operation, it is requisite to develop radio- frequency (rf)-driven H- sources. They have no electrode like a filament, usually used in DC-arc driven sources, which limits a source lifetime by its erosion and fatigue.

A number of rf ion sources for H- beam extraction have been investigated so far.3),4) They utilize a few MHz – tens of MHz as an input rf frequency. A matching system is necessary to couple with a low impedance antenna. Auto-matching is also difficult at the plasma ignition.

Our purpose of this research is to develop an H- ion source by using a FET-switching inverter power supply as an rf source and an improvement of the rf-driven H- ion source. An operation pressure and power efficiency are investigated.

The inverter power supply has many advantages of higher efficiency of rf generation and easier matching system than conventional vacuum-tube based rf sources. Figure 1 shows a schematic of the experimental devices. Circuit of the FET-based inverter rf source is shown in Fig.2. It can deliver an rf power of more than 10kW. Matching can be obtained by changing a capacitance or a switching frequency. An rf-driven plasma is produced by the FET-based source with a frequency of 0.5MHz matched with a 6-turn antenna. The plasma production region is attached at a back plate of the source, and an rf antenna is set outside of a ceramic tube of 8cm in diameter.

Figure 3 shows typical waveforms of antenna current and other signals. When rf power supply was on, rf frequency was changed automatically to keep the matching condition by a phase-locked loop (PLL) circuit. Within 1 ms, a plasma was produced, and an antenna current decreased because an antenna loading resistance increased. As shown in the figure, rf frequency did not change at the plasma production. This indicates that reactance of antenna was almost constant in spite of the plasma production. Although an input power decreased due to the increase of antenna resistance, constant power operation can be realized by primary voltage control.

Hydrogen rf plasma was produced in a low pressure region of 1- 3 Pa. In a low pressure, higher input power was necessary. Electron density and temperature were measured by a Langmuir probe with a filter. Electron temperature was around 5eV, and density was still lower than 10^{18}m^{-3} in the diffusion area of the source. We are going to improve an antenna design and coupling methods further for more efficient rf plasma production.

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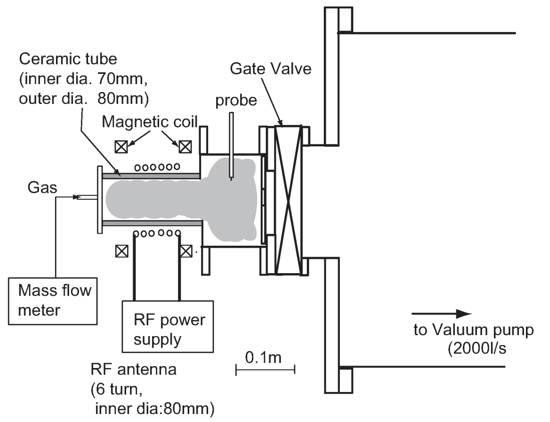

Fig. 1 Schematic of an ion source and RF antenna..

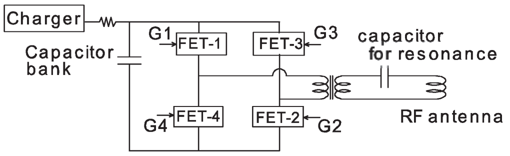

Fig. 2 Circuit of an FET inverter and matching..

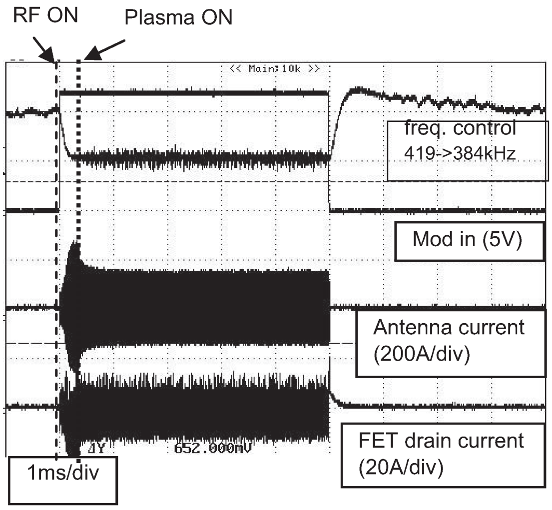

Fig. 3 Typical waveform of RF plasma production by the FET power supply..