# §10. 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. A hydrogen negative-ion (H-) source was developed for a beam source with beam energy more than 100keV, and a large H- source has been successfully 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 fragility.

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. As a matching system is necessary to couple with a low impedance antenna, auto-matching is 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. The inverter power supply has many advantages of higher efficiency of rf generation and easier matching system than conventional vacuum-tube based rf sources.

We have investigated an rf-driven hydrogen plasma produced by the FET-based source with a frequency of 0.3-0.5MHz.[5)] A small ion source consists in a cylindrical driver region and a diffusion region. In the driver region a multi-turn loop antenna was wound around a cylindrical tube made of $Al_2O_3$ ceramic (inner diameter: 70 mm, outer diameter: 80 mm, length: 170 mm ). Turn number of the antenna was changed to adjust optimal coupling. Axial magnetic field can be applied in order to enhance plasma production. Electron density and temperature were measured by a Langmuir probe with an RF filter. It was located at the center of the diffusion region, where is 50 mm apart from the exit of the driver region.

Figure 1 shows the dependencies of measured electron density $n_e$ and temperature $T_e$ on the input RF power. Although $n_e$ was lower than $10^{18}$m$^{-3}$ with $P_{RF}$ of 10kW, it drastically increased nearly $5\times10^{18}$m$^{-3}$ with axial magnetic field of 13mT. As the axial magnetic field increased, $n_e$ increased more than one order of magnitude and $T_e$ also increased from 2eV to 5eV as shown in Fig.2. It is probably due to reduction of wall loss of plasma.

Figure 3 shows dependencies of $n_e$ and $T_e$ on the filling gas pressure. Although the high density plasma was produced at more than 1 Pa, the density decreased at lower pressure arround 0.5 Pa. Further investigation is necessary for more efficient rf plasma production in the low pressure region.

We are going to investigate $H^-$ beam extraction with Cs effect.

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2) K.Tsumori, et.al., Rev. Sci. Instrum., **79** (2008) 02C107.
3) T. Takanashi, et.al. Rev. Sci. Instrum., **35** (1996) 1024.
4) P. Franzen, et al., Nuclear Fusion, **47** (2007) 264.
5) A.Ando, et al., Proc. of 1st NIBS, AIP-Conf. No.1097 (2009) 291.

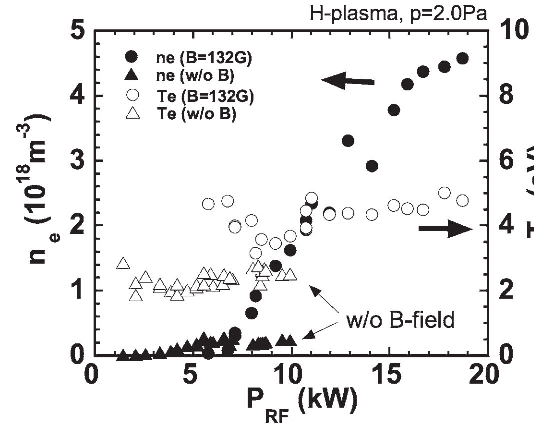


Fig. 1 Dependence of electron density and temperature on $P_{RF}$ with and without the axial magnetic field (B=13mT).

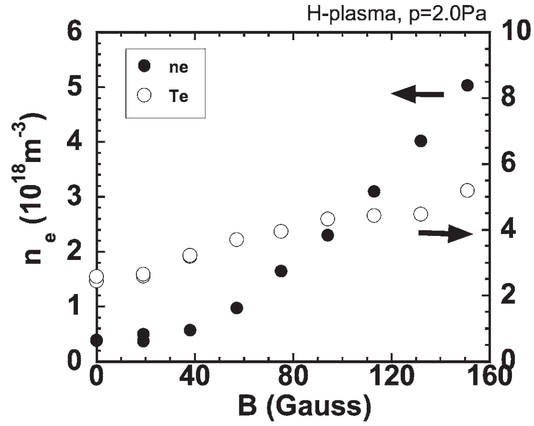


Fig. 2 Dependence of electron density (open circles) and temperature (closed circles) on the axial magnetic field. $P_{RF}$=13kW.

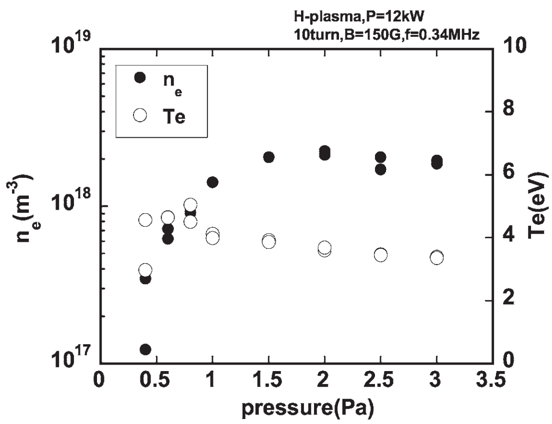


Fig. 3 Dependence of electron density and temperature on the filling pressure. $P_{RF}$=12kW.