Characteristics of a FET-based RF negative ion source

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Negative ion neutral beam injection (NNBI) system is one of the most powerful and effective plasma heating methods in fusion devices. ITER requires a 1 MeV negative deuterium (D⁻) beam with pulse length of 3600 s and 40 A in current intensity. A radio frequency (RF) negative ion source was chosen for the ITER NBI reference source for maintenance free operation and low Cesium (Cs) consumption [1].

Industrial applications often use 13.56 MHz RF wave for plasma production. However, as for high-density plasma production, lower frequency waves are feasible because of large skin depth. We have utilized the metal oxide semiconductor field effect transistor (MOSFET) for DC switching in RF power supply with lower frequency RF waves (<1 MHz). This FET-switching inverter power supply has several advantages of higher efficiency of RF generation, easier matching system than conventional vacuum tube based RF sources, and no high voltage part in the power supply [2].

The schematic of the FET-based negative ion source is shown in Fig. 1. RF plasma was produced in the driver region. A RF antenna coil was wound around a ceramic tube (Al₂O₃). The outer Helmholtz coil forms an axial magnetic field in the driver region. A high-density plasma with electron density \( n_e \) of \( \sim 10^{18} \text{ m}^{-3} \) was achieved with the help of the magnetic field [2].

In order to separate energetic electrons which deteriorate negative hydrogen (H⁻) ions in the expansion region, a set of permanent magnet attached outside of the chamber. It forms magnetic filter field that enables only low temperature electrons (~ 1 eV) flow into the area near the plasma grid (P.G.). In the expansion region plasma parameters (electron density \( n_e \) and temperature \( T_e \)) were measured by Langmuir probes and laser photo-detachment. Fig. 2 shows the radial profiles of \( n_e \) and \( T_e \) observed near the P.G. When the magnetic filter field was applied, \( T_e \) decreased to 1.5 eV and its spatial distribution became flat. In order to enhance H⁻ ion production, cesium vapor was injected into the expansion region. It attached onto the P.G. and formed a thin layer on it. Cs layer lowers the surface work function, and H⁻ ions can be produced effectively by surface production.

The effects of the filter field and Cs injection on the characteristics of the ion source will be discussed. Results of H⁻ beam extraction (~10 keV) experiments will be also presented.

![Fig.1 Schematic of the experimental set up.](image)

![Fig.2 Radial distribution of \( n_e \) and \( T_e \) with or without magnetic filter (\( f_{\text{RF}} = 343 \text{ kHz, } P_{\text{RF}} = 14 \text{ kW, } 1.08 \text{ Pa, } B_{\text{EXT}} = 187 \text{ G}.\))](image)