§4. 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 high power hydrogen negative-ion (H^-) source has been successfully developed for a beam source and operated as a major heating device in LHD.[1),2)] For a long pulse or continuous operation, it is requisite to develop radio-frequency (RF) driven H^- sources. They have no electrode like a filament, usually used in arc-discharge driven sources, which limits a source lifetime by its erosion and fragility.

Our purpose of this research is to develop a compact RF driven H^- ion source by using a FET-switching inverter power supply with a frequency of 0.3-0.5MHz as a RF source and to improve it.[3)-5)] The small ion source consists of a cylindrical driver region and an expansion region. In the driver region a multi-turn loop antenna was wound around a cylindrical ceramic tube (inner diameter: 70 mm, outer diameter: 80 mm, length: 170 mm). Axial magnetic field can be applied in order to enhance plasma production. Electron density attains to 10^{19}cm^{-3} at the driver region (Z=70mm from the end of the driver region), and to more than 10^{18}cm^{-3} at the expansion region (Z=255mm). In order to measure the negative ion density in the RF source, photo-detached electrons were measured by using YAG laser (λ=1064nm) photo-detachment system. In the expansion region magnetic filter can be attached and cesium vapor can be injected to enhance the H^- production.

Figure 1 shows the typical waveform of an electron saturation current with YAG laser irradiation at the expansion region. The sudden increase of I_{es} corresponds to H^- ion density in the plasma. The dependence of increment ratio of electron saturation current I_{es} on the gas pressure is also shown in the figure. The measured position was Z=355mm in the expansion region, 75mm apart from the plasma grid surface. As the filter magnetic field was applied, the ratio increased as is shown in the figure. The ratio was still low with Cs additive. We are going to measure H^- ion density near the grid and to investigate the effect of Cs vapor injection, further.

For the H^- beam acceleration, three grids (plasma, extraction and acceleration grids) were attached on the source. The beam was extracted from a single hole with the aperture of 9mm in diameter. An extraction current and an acceleration current were measured as a function of the filling pressure as shown in Fig.2. When a small amount of cesium (Cs) vapor was injected into the source, I_{ext} and I_{acc} increased as shown in the figure. The source could be operated lower than 0.3Pa with Cs additive. Although electron density decreased with the decrease of pressure, the currents were almost constant. The beam current density was still low at 10mA/cm^2. We are going to increase V_{ext} to investigate H^- beam extraction characteristics with Cs effect.

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3) A.Ando, et al., Proc. of 1st NIBS, AIP-Conf. No.**1097** (2009) 291.
4) A.Ando, et al., Frontier of Applied Plasma Technology, **2** (2009) 67.
5) A.Ando, et al., Rev. Sci. Instrum., **81** (2010) 02B107.

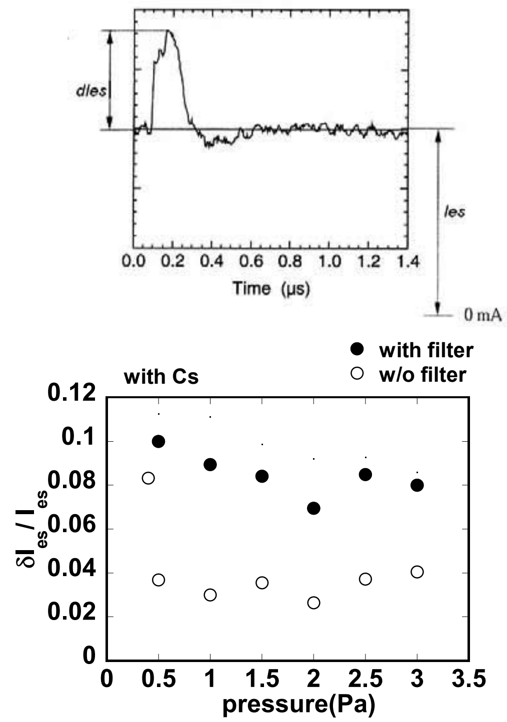

Fig.1 Typical waveform of electron saturation current with YAG laser irradiation. Dependences of the increment ratio of electron density on filling gas pressure. P_{RF}=13kW, Bz = 19mT, Z=355mm.

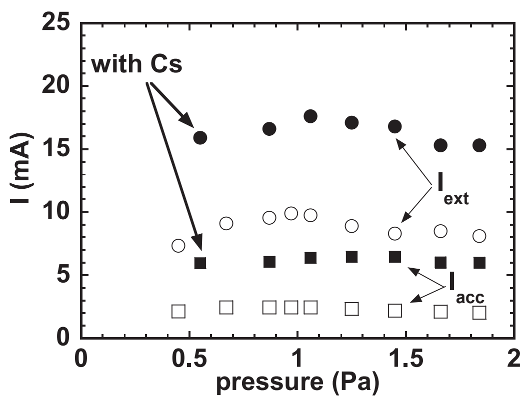

Fig. 2 Dependences of an extraction current (I_{ext}) and an acceleration current (I_{acc}) on filling gas pressure V_{ext}=5kV, V_{acc}=5kV, P_{RF}=13kW, f=0.35MHz. B=3.7mT.