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Characteristics of a RF negative hydrogen ion source with a long pulse operation
高周波水素負イオン源の長時間動作特性

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A radio-frequency (RF) based negative hydrogen ion (H^-) source is investigated for the NBI system in fusion experiments. The RF power supply utilizes a FET inverter circuit operated with the RF frequency lower than 0.5 MHz, which enables a compact and efficient RF system. Until now, we operated RF power supply with the pulse length of several milliseconds. Recently, we introduced new CW RF power supply and cooling systems were attached to the transmission line. They were successfully operated and RF plasma was operated during several seconds. Simultaneously, H^- ion beam was extracted and accelerated up to 15 kV and the beam current was measured with several plasma parameters.

1. Introduction

Neutral beam injection (NBI) system is one of the most powerful and successful heating tools in fusion researches. A hydrogen negative ion (H^-) source has been developed as a beam source with the beam energy of more than 100 keV [1-3]. Recently, negative ion source using RF plasma was chosen for ITER NBI system due to its maintenance free and long pulse (~3600 s) operation [4-6].

Conventionally, RF power was supplied by using a vacuum tube oscillator with MHz frequency range. Recent progress of MOSFET devices enables us to use a FET switching full bridge type inverter circuit, which realizes a compact and flexible RF power supply [7]. Although the operation frequency is relatively low for plasma production (~500 kHz), it can be operated with high efficiency of DC to AC conversion without any high voltage (more than 0.5 kV) part in the source. We have developed the FET based compact RF negative ion source and measured basic plasma parameters. H^- ion beam were accelerated up to 15 kV. The pulse length was limited in several milliseconds because of the power supply's capacity. We introduced a new CW RF power supply and started to operate it with pulse length of several seconds. In this paper, the experimental results of measured basic plasma parameters and accelerated H^- ion beam with longer pulse operation are presented.

2. Experimental setup

Experiments were performed using a small ion source with a cylindrical driver section. An RF coil was wound around the cylindrical tube made of Al_2O_3 ceramic (inner diameter: 70 mm, outer diameter: 80 mm, length: 170 mm). The ceramic tube (driver region) was attached to a cylindrical chamber (expansion region). The schematic of the experimental setup is shown in Figure 1. Axial magnetic field up to 200 G can be applied by Helmholtz magnetic coils attached at the driver region. Electron density and temperature were measured by a Langmuir probe at the driver and the expansion region. The H^- ion beam was extracted and accelerated with extractor attached to the expansion region up to 15 kV.

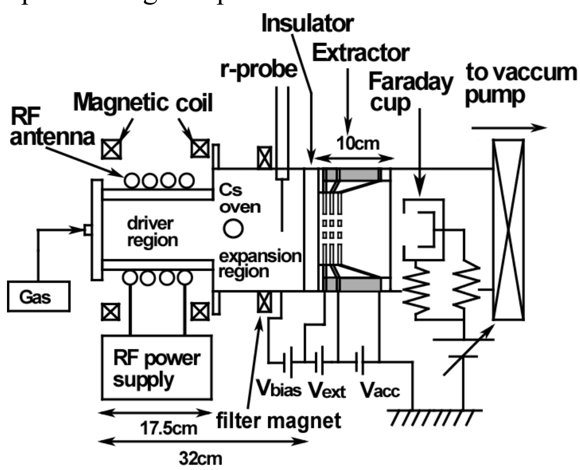

Fig. 1. Schematic of experimental setup.

3. FET inverter power supply

A CW RF power supply with a full bridge type inverter circuit is used for RF plasma production (Fig. 2). A dozen of MOSFET (PDM755HA) is used as a switching device in the inverter circuit. An operation frequency can be adjusted by PLL (phase-locked loop) circuit in the range of 0.2-0.5 MHz. As a matching frequency is chosen by the PLL circuit automatically, a matching circuit is not necessary. Total RF power of more than 20 kW can be delivered to the antenna.

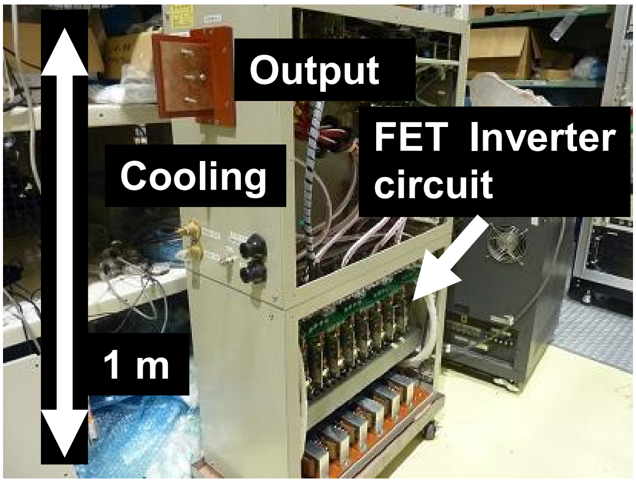

Fig. 2. Photo of inverter unit of the CW RF power supply.

4. Experimental Results

Firstly we tried to produce plasma and extract the beam with the pulse length of 1 second. Fig. 3 shows the time traces in an RF operation. When the RF power was applied, the PLL circuit automatically chose the matching frequency by feedback system using the signal of switching timing of current and voltage. Subsequently, the plasma was produced and H^- ion beams were extracted and accelerated with 3 kV of the extraction voltage (V_{ext}) and 5 kV of the acceleration voltage (V_{acc}). The RF source were grounded and isolated from the source by an isolation transformer. The beam extraction and acceleration can be operated with total applied voltage of 15 kV, which is limited by the isolation voltage of the transformer. The pulse length of the beam can be extended with improvement of water cooling system.

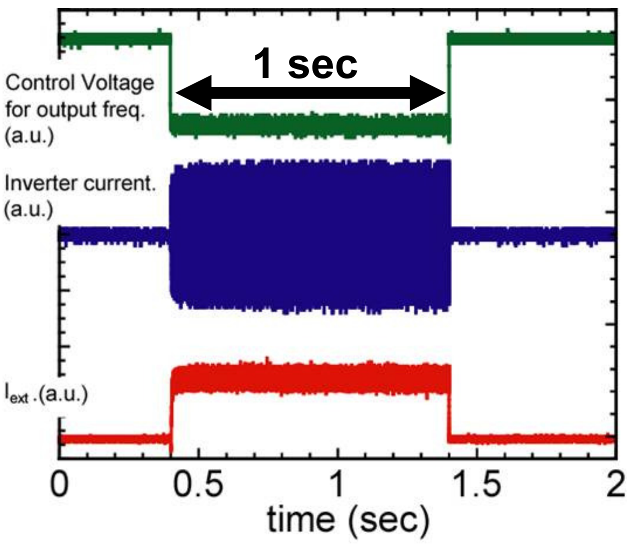

Fig. 3. Time traces of RF operation with beam extraction. p=0.78 Pa, V_{ext}=3 kV, V_{acc}=5 kV, Hydrogen plasma.

5. Summary and future plan

The long pulse operation of FET based RF H^- ion source is on going by using a new CW source. In near future, the pulse length is going to be extended to about 100 seconds by improving the cooling system. The relation between basic plasma parameter, cesium behavior and production efficiency of H^- in the plasma discharge are going to be evaluated in detail with OES [8] and CRD system [9].

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