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Preliminary Performance of Long-Pulse Operation for a Multi-purpose Compact Fast Neutron Generator

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1. Introduction

A Multi-purpose Compact Fast Neutron Generator (MCFNG) was equipped in the Korea Atomic Energy Research Institute (KAERI). The MCFNG device was developed originally by the Plasma and Ion Source Technology Group at Lawrence Berkeley National Laboratory (LBNL) for material analysis group at the KAERI for the purposes of neutron activation analysis (NAA) and prompt gamma activation analysis (PGAA) applications [1]. The NAA/PGAA system of MCFNG device equipped with a compact D-D neutron generator was developed in the KAERI [2]. The MCFNG device was built with a fully high-voltage shielded and axially assembled D-D neutron generator including a radio frequency (RF)-driven ion source [3]. A hole diameter of beam extraction in the ion source was enlarged from 4 mm to 5 mm in order to increase the extracted ion beam current. The performance of long-pulse operation (from 10 minutes to 1 hour) was conducted preliminarily for the MCFNG device with the characteristics of hydrogen ion beam extraction prior to the collision of deuterium ion beams on a TiD drive-in target for the production of fast neutrons.

2. Structure of MCFNS Device

Fast neutrons can be produced by the D-D nuclear fusion reactions in an axially assembled D-D neutron generator (called as the MCFNG) composed of three main components: a radio frequency (RF)-driven ion source with an external antenna for the ICP (inductively coupled plasma) generation (a maximum RF power of 2.0 kW), an electrostatic D^+-ion beam accelerator column (an expected maximum beam power of 100 kV/10 mA through a single hole for the ion beam extraction), and an explosively bonded titanium drive-in copper target including a water-cooled path [3].

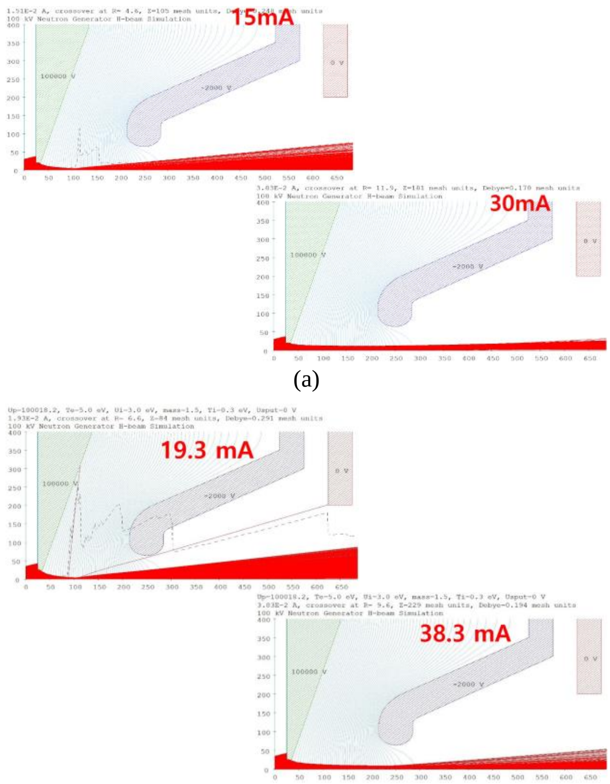
Atomic and molecular deuterium (or hydrogen) ions are produced by an RF discharge in the MCFNG device. The ions are accelerated on the titanium target through a single gap accelerator column to produce the mono-energetic fast neutrons of 2.5 MeV by the reaction shown in the following equation:

$$^2_1H + ^2_1H \rightarrow ^3_2He + ^1_0n \ Q\text{-value} = 3.27\,\text{MeV}$$

Main body of the MCFNG device placed in the center of a radiation shield/moderator structure consisting of three layers of 300 mm-thick polyethylene, 7 mm-thick polyethylene doped with 9% boron, and 1.5 mm-thick lead sheet in order to shield both neutrons and secondary gamma-rays.

3. Simulation of Ion Beam Trajectory

Hydrogen ion beam trajectories were simulated by using the commercial IGUN code in order to compare the beam extraction characteristics of accelerator column with a hole diameter of 4 mm and 5 mm, as shown in Fig. 1 [4]. Maximum ion current density of 150~200 mA/cm^2 can be extractable, in usual, through the accelerator column of ion source. And then, the ion beam trajectory is estimated up to the beam currents (reached to the surface of TiD drive-in target) of ~30 mA and ~40 mA for the hole diameters of 4 mm and 5 mm, respectively, as shown in Fig. 1.



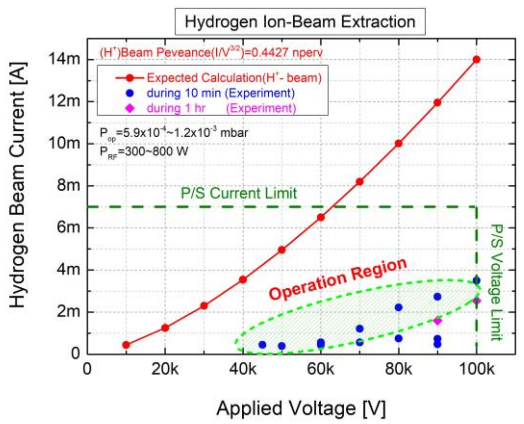
(b)

Fig. 1. Calculated hydrogen beam trajectories from the hole diameters of (a) 4 mm and (b) 5 mm in an accelerator column of ion source.

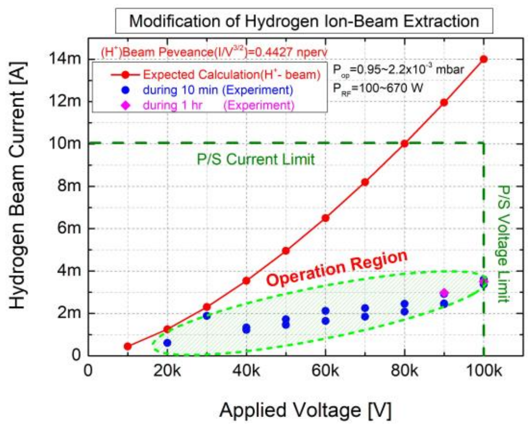
It was found that the extractable beam currents with a similar plasma (ion) density of ion source are increased for a hole diameter of 5 mm, compared to a hole diameter of 4 mm, by the simulation of beam trajectory for the hydrogen ion beams. However, the high-voltage (HV) holding of accelerator column may be more difficult for a hole diameter of 5 mm than a hole diameter of 4 mm. This result means that more stray ion beam particles can be collided on the boundary structure of accelerator grid, and then more back-stream electrons can be produced from the surface of accelerator grid. The frequent breakdown of accelerator column can be arouse from the production of back-stream electrons. Therefore, the high voltage holding of accelerator column including the enlargement of beam extraction hole must be restricted from the back-stream electrons during the ion beam extraction.

4. Results of Long-Pulse Operation

The characteristics of long-pulse operation were investigated preliminarily with hydrogen beam extraction in the MCFNG device. The steady long-pulse operation was conducted during both 10 minutes and 1 hour with the hole diameters of 4 mm and 5 mm on a beam extraction grid. The beam extraction results of long-pulse operation are shown in Fig. 2.



(a)



(b)

Fig. 2. Results of long-pulse operation during 10 minutes and 1 hour with the hole diameters of (a) 4 mm and (b) 5 mm on a beam extraction grid, respectively.

The output power of high-voltage (HV) power supply has exchanged for hydrogen beam extraction with a power of -100 kV/10 mA (from a power of -100 kV/7 mA) in order to increase the extracted beam current, as shown in Fig. 2. It can be found that the stable beam extractions of long-pulse operation (during 10 minutes and 1 hour) are achieved for the extraction of higher beam current at a hole dimeter of 5 mm, compared to a hole diameter of 4 mm, with the lower discharge powers of ion source. And then, this result implies that the beam extraction efficiency of 5 mm-hole diameter is higher than 4 mm-hole diameter. Therefore, more high beam currents can be extracted with a hole diameter of 5 mm than a hole diameter of 4 mm under the same discharge power of ion source.

5. Conclusions

The performance of long-pulse operation (from 10 minutes to 1 hour) was investigated preliminarily in the MCFNG device with the characteristics of hydrogen ion beam extraction prior to the collision of deuterium ion beams on a fast neutron target. The steady long-pulse operation was compared a hole diameters of 5 mm on a beam extraction grid to a hole diameter of 4 mm. It was found that the stable and high current long-pulse operations was expected relatively with a 5 mm diameter compared to a 4 mm diameter, even though the properties of high-voltage holding was degraded in the accelerator column .

Acknowledgments

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