# Characteristics of a Portable Neutron Generator

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## 1. Introduction

Neutron generators can be excellent tools for materials analysis, explosive material detection, nuclear weapon detection, and high quality radiography [1]. Neutrons are produced by fusing deuterium or deuterium and tritium. The fusion reactions take place in a neutron generator by accelerating deuterium or tritium into a metal target which contains deuterium or tritium. The yield of the DT reaction is ~100 times higher than that of the DD reaction.

D + D : 3He + n (2.5 MeV)
D + T : 4He + n (14 MeV)

Recent commercial neutron generators, fast neutron yield from $10^7$ to $10^{11}$ n/s, are produced by several companies and research groups around the world. But limited life time, high price, and frequent troubles make it difficult to develop related application systems by domestic companies or research groups. To remove such problems, it is necessary to develop our own domestic neutron generators.

In this presentation, the design and experimental results on the developed small neutron generator are summarized.

## 2. Design of a Portable Neutron Generator

The movable neutron generator is composed of an ion source, an accelerator, a target, and a fuel supply and vacuum system. Depending on neutron strength of the generator, different type ion sources should be used. For a high flux neutron generator, an added accelerator tube is needed to increase the beam energy higher than 200 keV. Getter is usually used as a fuel controller for a portable neutron generator, but for a high flux one vacuum pump and gas feeding system is introduced. As a target, a titanium coated drive-in target is used, but for a very high flux one gas target is needed because of the heat load on the target.

### *2.1 Penning Ion Source*

Penning ion source [2] is a low current ion source, but it is simple and stable in a low power operation condition. Therefore a penning type ion source is suitable to be used in a portable neutron generator, and we select this type as an ion source. Fig. 1 shows the designed prototype neutron generator including ion source and vacuum pumping system for the test of developed components for a portable one such as ion source, feedthru, and drive-in target. The penning ion source is designed to be operated continuously in an arc power of less than 1 Watt. Fig. 2 shows the modified vacuum chamber with view port.

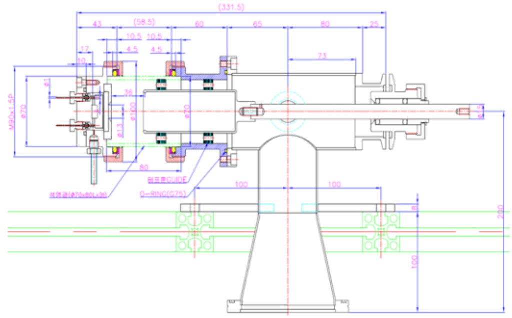

Fig. 1. Prototype of a portable neutron generator to test the developed components.

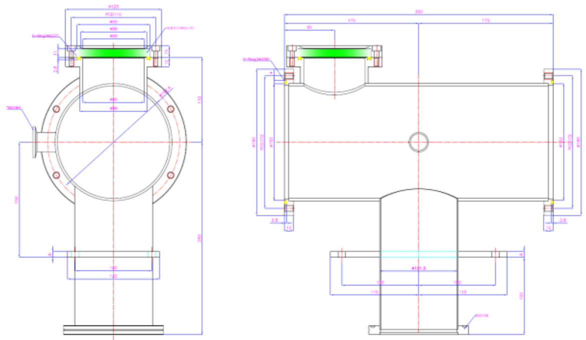

Fig. 2. Modified vacuum chamber with view port.

### *2.2 Drive-in Target*

Fig. 3 shows the expected neutron yields depending on the energy of the incident particle. The drive-in target is a solid target for a mixed fuel beam such as D and T. 14 MeV neutrons are produced from the DT (D+T→n(14.1)+ $^4$He(3.5)) interactions of impinged fast D and/or T ions with T and/or D atoms embedded in the lattice of the target material. Drive-in target is designed and fabricated by titanium coating (2 μm) on a 30 mm copper disc.

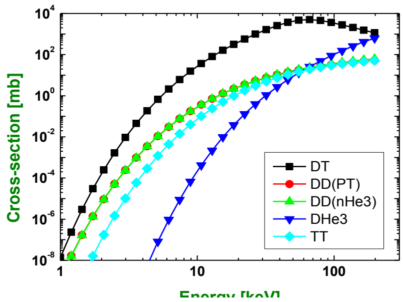


Fig. 3. Major fusion reaction cross-sections as a function of the beam energy, where the target is fixed. [3]

### *2.3 High Voltage Feedthru*

To be an effective neutron generator in a view of ratio of the input power to the neutron yield, the beam energy should be higher than 70 keV as shown in Fig. 3. For stable ion beam extraction without surface flashover on feedthru insulator, metal cover which reduces the effect of metal-vacuum-insulator triple junction [4] is introduced as shown in Fig. 4. The stable ion beam with energy higher than 100 keV was achieved.

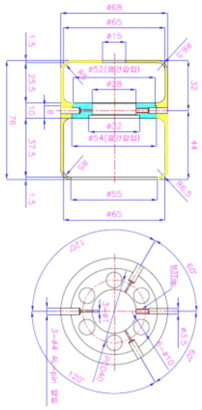

Fig. 4. Advanced high voltage electrode which reduces the effect of triple junction.

### *2.4 Fuel supply system*

The neutron generator is a D-D (deuterium - deuterium) neutron generator and for easy maintenance, we adopt the fuel supply system as open vacuum system. Deuterium is supplied through the mass flow controller (MFC) and vacuum-pumped as shown in Fig. 5. The pressure of the vacuum chamber in which the ion source and target installed is controlled by adjusting the flow rates of the MFC.

## 3. Experimental Results

The prototype neutron generator is fabricated as shown in Fig. 6 and beam extraction experiments with deuterium beam is made to test the ion source and high voltage feedthru. The results are shown in Fig. 7, Fig. 8, and Fig. 9. Fig. 7 shows the relations between ion source voltages vs. plasma currents in various pressures. Fig. 8 shows extraction voltages vs. ion beam currents in various pressures when the plasma currents are 150 uA. Fig. 9 shows the relations between plasma currents vs. ion beam currents when the extraction voltages are -85 kV.

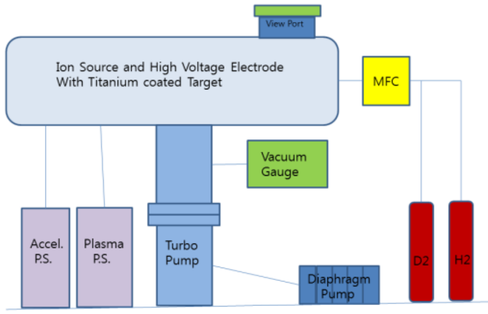


Fig. 5. Fuel supply system of the neutron generator.

The neutron flux of 5 n/s is measured by RadEye GN gamma Neutron (Thermo scientific) detector when the extraction voltage -85 kV, plasma current 250 uA. The detection distance is ~ 200 mm and 40 mm PE plate is inserted between neutron source target and the detector for efficient neutron detection. The precise detector calibration is not carried out yet, so more detailed experimental results will be summarized at the presentation.

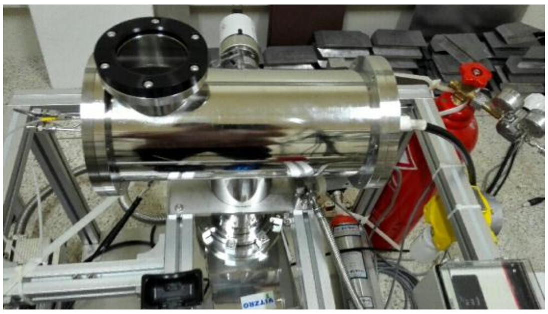

Fig. 6. Photo of the fabricated neutron generator with view port.

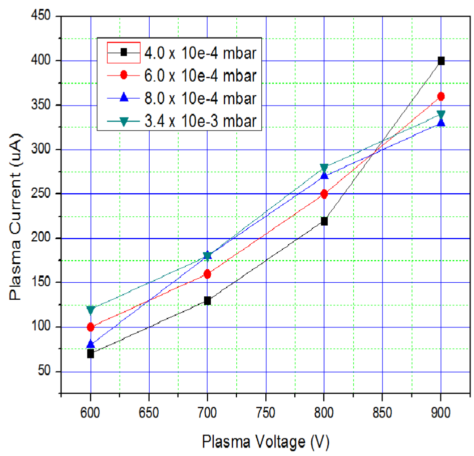


Fig. 7. Ion source voltages vs. plasma currents in various pressures.

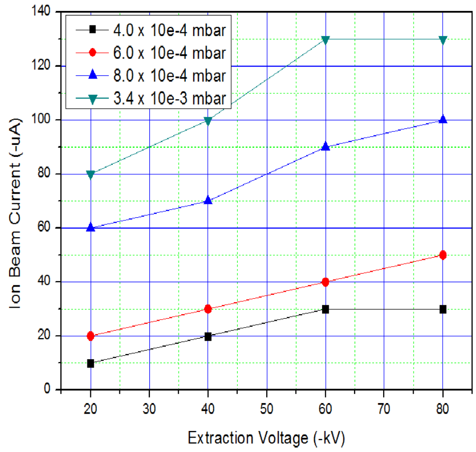


Fig. 8. Extraction voltages vs. ion beam currents in various pressures when plasma currents are 150 uA.

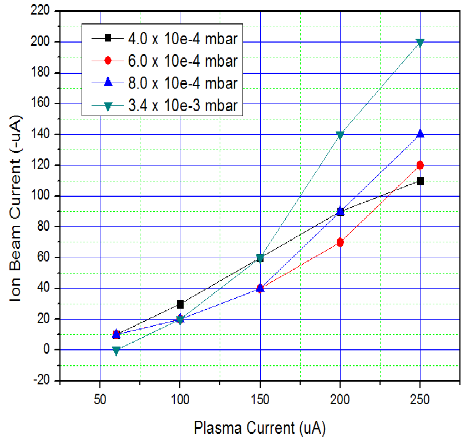


Fig. 9. Plasma currents vs. ion beam currents in various pressures when extraction voltages are -85 kV.

## 4. Conclusions

Experiments on deuterium beam extraction and fast neutron measurement by injecting deuterium beams on a drive-in target are executed. The stable deuterium beam of the energy higher than 100 keV was achieved by introducing metal cover which reduces the effect of metal-vacuum-insulator triple junction.

The neutron flux of 5 n/s is measured by RadEye GN gamma Neutron (Thermo scientific) detector with about 200 mm distance and insertion of 40 mm PE plate between neutron source and the detector. The precise detector calibration is not carried out yet, so more detailed experimental results will be summarized at the presentation.

All of the experimental results on the developed components will be upgraded and combined together as a portable neutron generator. And applying similar technologies and process a high flux D-D neutron generator of the order of $10^{11}$ n/s will be designed and developed.

## REFERENCES

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