Development status of a high-flux movable D-D neutron generator at KAERI

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1. Introduction

A high-flux movable D-D neutron generator is being developed at Korea Atomic Energy Research Institute (KAERI). The generator uses the D-D fusion reaction. Positively charged deuteron ions are accelerated up to 200 keV from the ion source and drive into the target. As target saturated, neutrons are generated through the D-D fusion reaction [1,2] .

Recent commercial neutron generators, 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 such as materials analysis, explosive material detection, and neutron radiography [3] by domestic companies or research groups. To remove such problems, it is necessary to develop our own domestic high-flux neutron generators.

2. Design and fabrication of the Neutron Generator

The high-flux movable neutron generator is composed of an electron cyclotron resonance (ECR) ion source, a four stage acceleration tube, a water-cooled target, and a high voltage power supply. Figure 1 is a block diagram of the neutron generator.

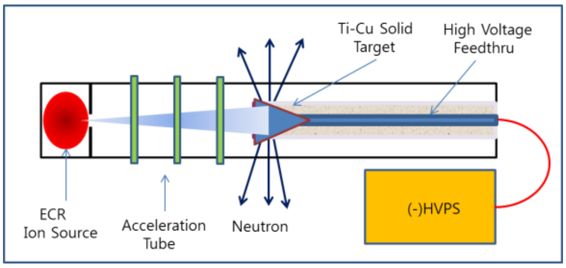


Fig. 1. Block diagram of the neutron generator.

Depending on the neutron yield of the generator, different types of ion source should be used. For a high flux neutron generator, ECR ion source is adopted. An acceleration tube is needed to increase the beam energy higher than ~150 keV. Vacuum pumping and gas feeding system is introduced to reduce pressure in the target chamber for stable operation of the generator. As a target, a titanium coated water-cooled target is designed and fabricated. Figure 2 is a designed drawing of the acceleration tube, titanium coated water-cooled copper target, and high voltage feedthru.

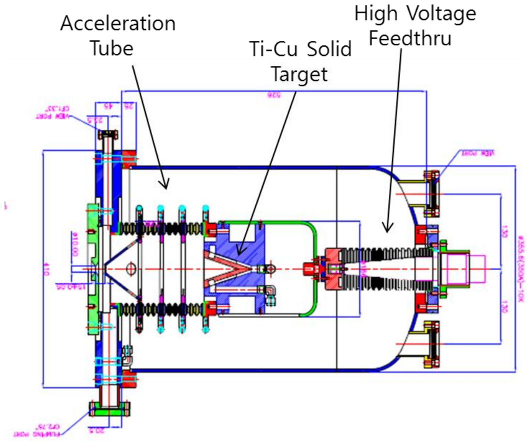


Fig. 2. Drawing of the acceleration tube, water-cooled Ti coated Cu target, and high voltage feedthru.

2.1 ECR Ion Source

ECR ion source is used for the production of high quality ion beam. It is easy to operate and lifetime is also long. It uses solenoid coils or permanent magnets to generate the required magnetic field for electron resonance at the driving frequency [1]. A compact permanent-magnet based ECR ion source is designed and now being fabricated at KAERI for reliable and long lifetime neutron generation. The goal is to extract more than 50 mA deuterium ion beam with low power consumption (less than 1 kW). Table 1 shows design parameters of the ECR ion source. At the driving frequency, 2.45 GHz, the required magnetic field is typically 875 Gauss.

2.2 Acceleration Tube

In a D-D reaction, the neutron production cross-section increases with beam energy (Figure 3). So, for a given beam power on target, it is more efficient to have higher voltage with lower beam current than lower voltage with higher beam current. Here four-stage acceleration tube is designed and manufactured to increase the beam energy higher than 200 keV. Figure 4 shows fabricated four stage acceleration tube. The diameter of the tube is 116 mm, the length of each insulation ceramic is 35 mm. For efficient voltage insulation, the surface of the sintered ceramic insulator has concave-convex surface.

Table 1. Design parameters of the ECR ion source.

Parameters	PM-type
Frequency	2.45 GHz
Power	~ 1 kW
B_{ECR}	875 G
$B_{entrance}$	700 G
B_{exit}	0 G
L	100 mm
D	100 mm
V_{plasma}	785 mm^3
D_{ext}	10 mm
I_{D+}	50 mA

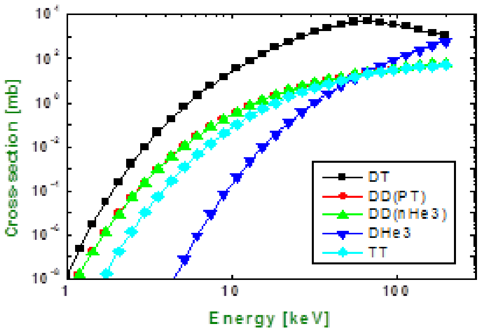


Fig. 3. Fusion reaction cross-section as a function of the beam energy at a fixed drive-in target [4].

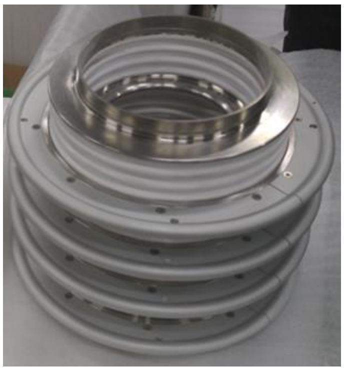
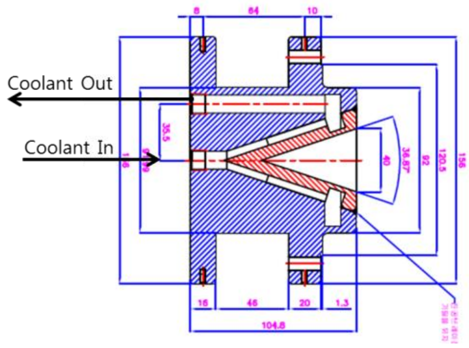


Fig. 4. Fabricated four stage acceleration tube.

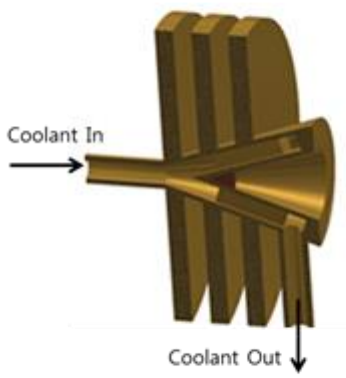
2.3 Water-cooled Drive-in Target

The target is made from titanium coated copper and is water cooled from behind the titanium. The drive-in deuterium ions are overlapped in the titanium and succeeding ions hit with these overlapped ions, creating neutrons through fusion reactions. To maximize the neutron production and life time of the target, the titanium surface needs to remain cool in order to trap the maximum number of ions [2]. Titanium temperatures are maintained by active water cooling.

The corn shaped target is designed and constructed to minimize the power densities at the target surface and effective cooling. The coolant flows from the end of the corn to the bottom with the shape of a fan. Fig. 5 (a) is a drawing of the target and 5 (b) is cross-sectional shape of the target.



(a)



(b)

Fig. 5. (a) Drawing of the target (b) cross-sectional shape of the target.

2.4 Acceleration Power Supply

The acceleration power supply is a switched mode power supply based on a power convert using zero-volt switching. An IGBT bridge circuit in a regulated closed-loop system can supply DC outputs up to (-) 200 kV continuously with currents 60 mA. The output voltage of the main high frequency transformer is 20 kV. This voltage is multiplied 13~14 times by Cockcroft-Walton voltage multiplier circuit. The high voltage parts are silicon molded for insulation.

3. Conclusions

A neutron yield of 1 x 10^{10} n/s neutron generator is designed and being fabricated at KAERI. Fig. 6 shows manufactured parts of the neutron generator. In the preliminary voltage insulation test of the acceleration parts in the air, break-downs were observed at 93~94 kV through the edges of the dividing resistors (Figure 7). The inside of the acceleration tube will be insulated with vacuum and the outside, with vacuum or SF_6, then it will be tested again. Then ECR ion source will be installed, ion beam will be extracted.

At this time, vacuum pumping system and target cooling system are being prepared. More detailed experimental results will be summarized at the presentation.

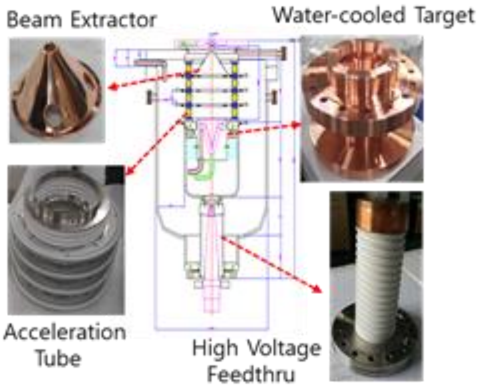


Fig. 6. Fabricated parts of the neutron generator.

Fig. 7. Through the edges of the dividing resistors, a break-down occurred at 94 kV in the air.

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