Development of a D-D Neutron Generator

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1. Introduction

To enhance neutron yield, the ion source of the D-D neutron generator [1,2] is replaced by a large current helicon plasma ion source [3,4]. Current and energy of deuteron beam are increased, and hence neutron yield is enhanced. The maximum neutron yield is 2×10^{8} n/s.

2. Experimental Setup

The reconstructed neutron generator using the new ion source is shown in figure 1. In the figure, the ion source is shown partly by electrodes (suppression, ground) and it is drawn in figure 2, separately. Beam line components and high voltage feed-throughs are modified. The distance from plasma electrode to the target is 337 mm. The base pressure of the target chamber is 4×10^{-7} Torr.

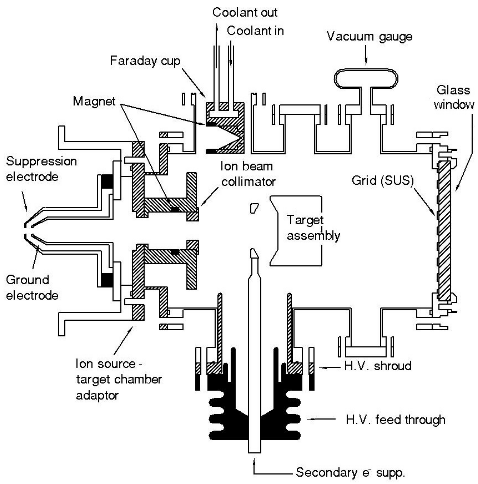

Figure 1. Schematic plane view of the D-D neutron generator

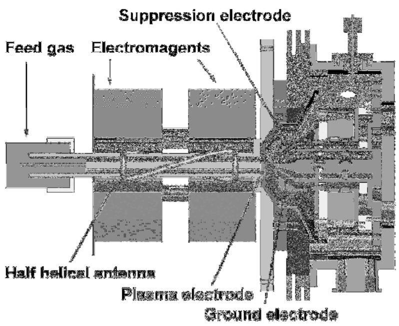

Figure 2. Schematic cross-sectional view of the new ion source.

A Si detector and a He-3 detector are used for the measurement. The Si detector counts protons generated from D(d,p)T reaction, from which neutron yield is derived [5]. The counting efficiency of proton is 7.9×10^{-6} [c/n] (error: 5%) [1,2]. The He-3 detector counts neutrons and monitors the variation of neutron flux [2]. The examples of spectra from the detectors are as shown in figure 3. The spectra retrieved from two detectors are monitored every minute during neutron generation run.

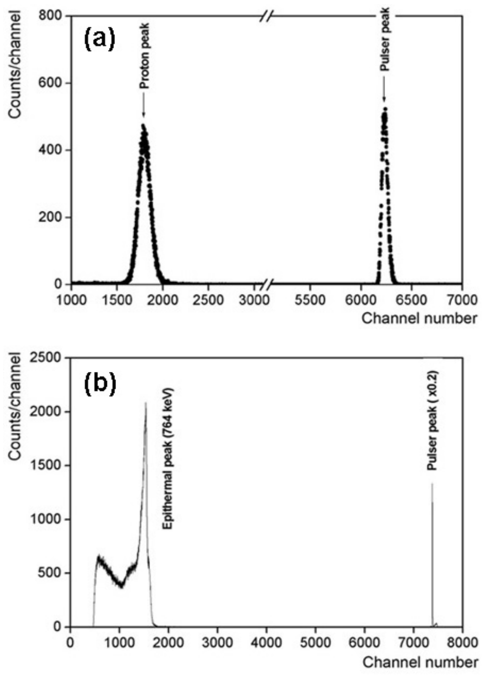

Figure 3. Proton energy spectrum of Si detector (a), and signal spectrum of He-3 detector (b).

3. Experiment and Results

Deuteron beam current is extended to 8.0 mA by adopting the new ion source. It is achieved at RF power of 1,200 W. Only the front-side electromagnet is turned on to make asymmetric B-field, when the maximum B-field strength is 293 G. Gas flow rate is 27 sccm and pressure is 1.8×10^{-4} Torr in the target chamber. The beam is extracted from the ion source by applying 30 kV to plasma electrode, while -3.5 kV is applied to suppression electrode. Also the beam energy is extended to 97.5 keV. It is due to the slight increase of extraction bias voltage and the modified high voltage feed-throughs.

Neutron generation runs are performed at various conditions. The conditions of experimental sets are noted in table 1, and results are shown in figure 4, 5. In figure 4, neutron yields are plotted according to the beam energy. In figure 5, D/Ti ratios [1,2] are plotted according to the beam power.

In the sets of A-C, neutron yield increases drastically in pace with the beam energy, mainly due to the rising cross section of $D(d,n)^3He$ reaction [2]. However, in the set of D, the increment of neutron yield is reduced as the beam energy gets higher. The difference of situation among the sets can be more clearly found in figure 4. In the sets of A-C, D/Ti ratio increases along the beam power. However, in the set of D, D/Ti ratio decreases as the beam power gets higher. The cause is that the cooling of target becomes insufficient for the rising power of the beam. In the sets of E and F, the target cooling performance is improved by increasing coolant flow rate and reducing thickness of the target. Hence, D/Ti ratio is restored and neutron yield is much enhanced. The maximum value of neutron yield achieved is 2×10^8 n/s (at 97.5 keV, in the set of F).

Table 1. The conditions of experimental sets.

	Beam current [mA]	Target thickness [mm]	Target coolant† flow rate [lpm]
A	0.76	1	10
B	2.3	1	10
C	3.8	1	10
D	8.0	1	10
E	7.9	1	25
F	7.6	0.5	25

†Inlet temperature : 17°C.

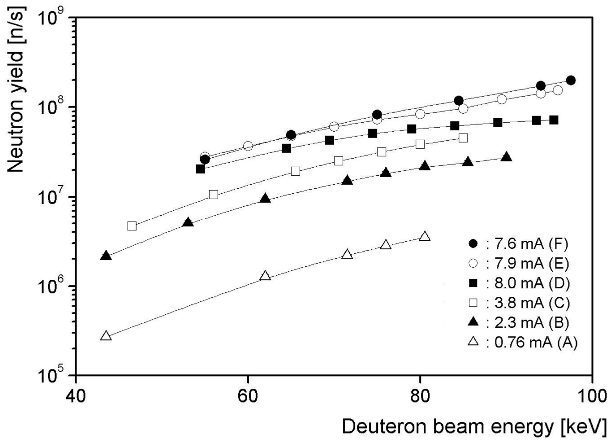

Figure 4. Neutron yields of various experimental sets according to deuteron beam energy.

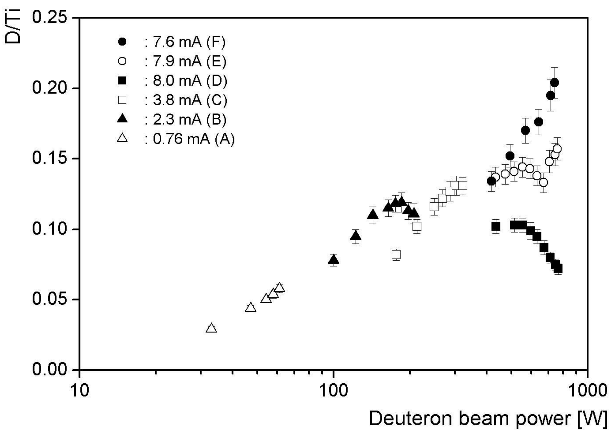

Figure 5. D/Ti ratios at various experimental conditions plotted according to deuteron beam power.

4. Conclusion

The D-D neutron generator was re-assembled with a new large current helicon plasma ion source. Current and energy of the deuteron beam was extended to 8.0 mA, 97.5 keV, respectively. As the beam power was increased, it was required to improve cooling performance for the target. Finally, the target cooling problem was solved and a stable yield of 2×10^8 n/s was achieved successfully with 7.6 mA, 97.5 keV deuteron beam.

ACKNOWLEDGEMENTS

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