In-House Development of D-D Neutron Generator

B. K. Das[1*], A. Shyam[1], R. Das[1] and A. D. P. Rao[2]
[1]Energetics and Electromagnetics Division, Bhabha Atomic Research Centre, Autonagar, Visakhapatnam, India
[2]Department of Nuclear Physics, Andhra University, Visakhapatnam, India
[*]E-Mail: dasbabu31@gmail.com

Introduction

In recent years, the threat from terrorist groups for the humanity has increased many folds in almost all corners of this earth. Thus, restriction of the illegal movements of the explosive and illicit materials, drug trafficking in air, sea and road routes become very important. Imaging of the cargo container, luggage bags is not enough but it becomes essential to do elemental analysis of all the containers. The development of a non-destructive technology that can detect illicit materials within very short period of time has become an important issue in the area of cargo and luggage inspection. Prompt Gamma activation Analysis (PGAA) in the form of Thermal Neutron Analysis (TNA) and Fast Neutron Analysis (FNA) [1,2] is promising techniques in which the detection of the nature of the element as well as the quantity present inside the container is possible. For this purpose, production of neutrons plays an important role. Compact neutron generator has several advantages over other type of neutron sources like nuclear reactors and radioisotope sources. Though the radioactive neutron sources are used in industry for various applications, ideal for fixed installations and for continuous operation, they are not well suited for pulse operation, they creates safety issues and logistic complications. Neutron generator is more environmentally friendly, safer for operators, more sensitive for an elemental analysis. It is easier to control the neutron characteristics like the neutron yield, pulse repetition rate and the duration in neutron generator. This can be made as compact as ~600mm length and ~100 mm diameter. The main feature of this type of accelerator is ion source, gas source, acceleration electrode system and a target. We are developing one compact neutron generator in our laboratory. The reactions for the neutron production are as follows

$$^{2}H_{1} + {}^{2}H_{1} = {}^{3}He_{2} + n \qquad Q=3.270\ MeV$$

$$^{2}H_{1} + {}^{3}H_{1} = {}^{4}He_{2} + n \qquad Q=17.590\ MeV$$

Energetic deuterium ions are required for both the reactions. The schematic diagram of a typical electrostatic compact neutron generator is shown in fig. 1. The different components of this generator are described in next sections.

Neutron Generator Assembly

As shown in fig. 1, a compact electrostatic neutron generator consists of ion source, accelerating electrode and the target. For steady operation the cooling of the target is required. The ion source is one of the important components for the generator. In this generator, we have used one penning ion source that was developed in our laboratory. The detail design and performance of the ion source is described elsewhere [3]. Because of compactness, maintenance free, roughed and easy instrumentation, the penning ion source is suitable for this instrument rather than other type ion sources. Plasma is created in between two cathode plates and one anode placed in-between them. Deuterium plasma was created in pressure range of 1 x 10^{-4} to 5 x 10^{-5} Torr, a potential difference of 1 KV between the cathodes and the anode and a magnetic field of 600 gauss along the axis. This ion source acts as self-extracted ion source. The ions produced in the plasma region come out through one aperture made in one of the cathode plate known as the plasma electrode. The high voltage breakdown between various metal parts with electric potential plays an important role for the acceleration of ions to higher energy. The high voltage breakdown in vacuum gap depends upon various factors like, the gap distance, the area, geometry, material and surface condition of the electrode, gas pressure and the nature of the gas. The detail vacuum break down study has been discussed in our earlier report [4]. The assembly was tested up to –ve 80 KV for high voltage breakdown and will be tested for higher potential in future experiments. The assembly is housed in a standard 100 CF nipple. One Delryn flange with high voltage electrode was used for the high voltage connection to the target and the accelerating electrode. The enclosure was pumped by one turbo molecular pump for base pressure up to 5E-7 Torr.

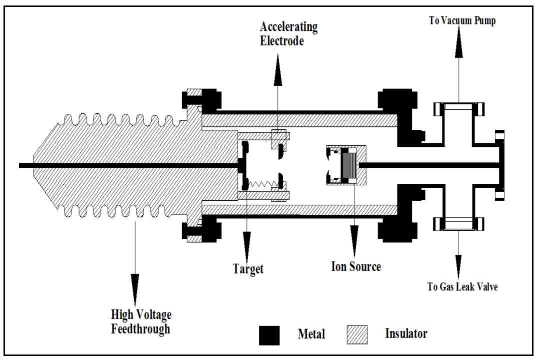

Fig. 1 Schematic diagram of the neutron generator

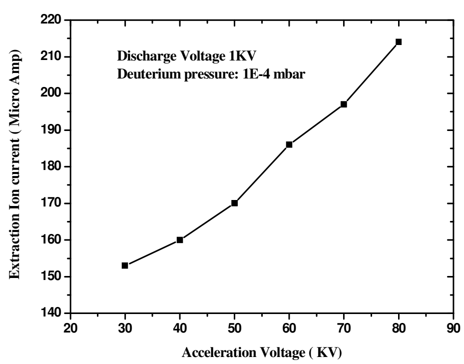

Fig. 2 Extracted deuteron current at the target

Neutron Production

The first experiment for the neutron production from this generator has been carried out. Ion source was operated with 1KV potential difference between the electrodes and a deuterium filled pressure of 1E-4 Torr. The extraction deuteron current for different acceleration potential is shown in the fig. 2. In this experiment one pure titanium target of 30mm diameter and 1mm thickness was used. As the titanium has a characteristic for the retention of hydrogenous isotopes, the first batch of deuteron ions are getting implanted into the target while the subsequent deuteron ions collide with them and produce neutrons of 2.5 MeV energy from the D-D reaction. The generator was operated for one minute with acceleration potential of 80 KV.

Neutrons being electrically neutral, it is difficult to measure by direct methods. The detection of neutrons is possible only through nuclear reactions. In our case, one LiI(Eu)[5] detector was used for the detection of neutrons. The detector was placed close to the target position in a radial direction. During the operation of the generator the detector reading was 300 cps. From the detector efficiency and the size, a neutron flux of 3 x 10^5 n/sec was estimated for 4pi direction. The neutrons from the target spread in isotropic direction with very little variation of energy.

Conclusion

In this study, the production of neutron from D-D reactions in an electrostatic accelerator based neutron generator was examined. The neutrons were produced at deuteron energy of 81KeV bombarded into a titanium drive in target. A flux of 3.5 x 10^5 n/sec was measured by one LiI(Eu) detector. In future, detail energy and flux measurement experiments will be carried out with higher deuteron energy and different targets likes deuteriated titanium targets and pure zirconium and vanadium targets. We will endeavour for production of 14MeV neutrons from D-T reactions in future experiments.

References

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