D-D/D-T neutron generator facilities for basic and applied research

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Introduction

Development of accelerator based neutron generators has greatly expanded worldwide compared to reactors and isotopic neutron sources for various applications in research, medical, industrial and security due to their on/off operation, inherent safety during switch off condition, controllable neutron yield and application specific customized design. Among various accelerators based neutron sources, D-D & D-T neutron generators have advantages of mono-energetic fast neutrons, high neutron yield at low accelerating energy and compact size.

In particular, D-D/D-T reaction based multipurpose neutron generator facilities have been indigenously developed in NXPS, TPD at Purnima, BARC to carry out various experiments. Fast neutrons are produced using following D-D/D-T fusion reactions: En is the neutron energy.

$D + D \rightarrow {}^{3}He + n + 3.3$ MeV, En = 2.45 MeV…(1)

$D + T \rightarrow {}^{4}He + n + 17.6$ MeV, En = 14.1 MeV..(2)

Neutron generator facilities

1. Purnima Neutron Generator Facility

Purnima neutron generator facility (PNGF) is a 300 kV electrostatic DC deuteron accelerator installed in Purnima hall, BARC. This can produce neutrons strength upto 5 x 10^{10} n/s neutron yield which can be operated in both continuous and pulse mode. Figure 1 shows the photograph of Purnima neutron generator [1][2].

Inductively coupled radiofrequency ion source is used to produce deuteron beam upto 1 mA. Deuteron beam is extracted from ion source, focused using Einzel lens and accelerated onto the Deuterium or Tritium target to produce neutrons. Neutron generator has water cooled replaceable target assembly to accommodate 25-47 mm diameter target.

Fig. 1 Purnima neutron generator

The neutron generator has been upgraded with a new beam chopper to produce pulse beam with repetition rate 0.1 Hz to 10 kHz and variable duty cycle for pulse neutron applications. A specially designed current transformer (DCCT/ACCT) has also been incorporated for online beam current measurement (fig. 2) in continuous and pulse mode operation.

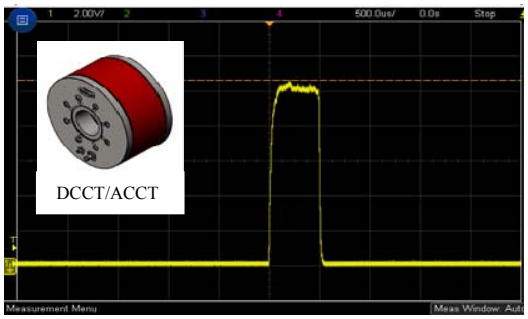

Fig. 2 pulsed beam measured by ACCT

A silicone surface barrier detector with 5 mm diameter (fig. 3) has been installed at 80 cm distance from target inside the vacuum chamber to measure online neutron yield using neutron

associated alpha measurement. Two He-3 detectors with HDPe moderator kept at 1.3 meter and 2.5 meter distance from the target have also been incorporated for neutron yield measurement and redundancy in safety interlock system.

Fig. 3 SSB based α-detector

2. Trolley mounted Neutron Generator Facility

Trolley mounted neutron generator is specifically designed for Neutron Activation Analysis (NAA) / Prompt Gamma Neutron Activation Analysis (PGNAA) experiments using Associated Particle Imaging (API) technology. It is a 150 kV DC accelerator capable of producing neuron yield upto 10^9 n/s. Figure 4 shows photograph of neutron generator mounted on a trolley at Purnima labs, BARC.

Fig. 4 Trolley mounted neutron generator

The target assembly consists a water cooled Tritium target placed at 45 degree angle with respect to deuteron beam and a multipixel (64 pixels) YAP:Ce α-detector (fig. 5). This α-detector is used for neutron tagging and neutron time of flight measurement [3]. This neutron generator can be operated in both continuous as well as in pulse mode. In pulse mode, the neutron generator can be operated from 1 Hz to 10 kHz frequency and variable duty cycle. Presently, the neutron generator is being used for development of illicit material detection system using API technique.

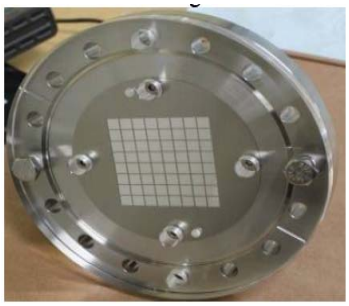

Fig. 5 64 pixels α-detector

Conclusion

Neutron generator facilities at Purnima laboratories, BARC are being extensively used for various experiments such as neutron radiography, ADS experiments, quenching factor determination of crystals for dark matter research, irradiation studies, cross-section measurements, neutron damage, neutron detector performance testing and shielding evaluation. These facilities can be used as test beds for various validation experiments.

References

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