Implementation of Tagged Neutron Method with in-house developed D-T Neutron Generator for Explosive detection

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Introduction

Neutron based interrogation techniques have been actively pursued over the years for the non-intrusive inspection of concealed explosives in various environments such as large shipping containers, airline bags, trucks, car etc. This is due to high penetrating power of neutrons and their ability to identify the elemental composition of materials. The methodology rest on the principle that explosives can be distinguished from each other and from benign materials by analyzing the quantities and ratios of carbon (C), nitrogen (N) and oxygen (O) in the material [1]. Neutron-interrogation methods in general exploit mainly two types of neutron interactions with nuclei, (a) inelastic scattering or (b) neutron captures and then detects the neutron induced element- specific high-energy prompt gamma rays. One such techniques is the Associated Particle Technique (APT or also known as tagged neutron method (TNM)), which has been actively pursued in recent years as most suitable method for the non-intrusive inspection of hidden/concealed explosives in objects ranging from small airline bags to large shipping containers.

Tagged Neutron Method

Tagged Neutron Method is based on using mono-energetic neutrons produced by accelerating deuterium ions into the tritium target of a neutron generator. This reaction produces neutrons (14.1MeV) and alpha (3.5 MeV) particles, which are generated nearly back-to-back relative to the production site in the tritium target. This correlation is used to tag a specific fraction of the emitted neutrons. The tagged neutrons interact with the nuclei of the interrogated object, producing element-specific prompt gamma-rays that are detected by suitable gamma detectors. Measuring the time delay between the detection of the alpha particle and the gamma-ray determines where the neutron interaction has taken place (14.1 MeV neutrons travel at 5 cm ns^{-1}, while gamma rays cover 30 cm ns^{-1}). The main advantage of the technique is its ability to simultaneously provide 2D and 3D imaging of objects and their elemental composition.

Towards the aim of illicit material detection, a neutron interrogation system based on Tagged Neutron Method is being developed at Purnima Labs, NXPS, TPD. This paper discuss the D-T Neutron Generator (NG) which is one of the major component of the system and the tagged neutron beam profile measurement important for the characterization of the system as well as for successful implementation of the TNM.

D-T Neutron Generator

D-T Neutron Generator with tagging detector is the key component of the TNM system. TNM system utilizes a laboratory based in housed developed D-T NG [2]. The photograph of D-T NG developed at BARC is shown in Figure1. It is a 150 kV deuteron (D) accelerator and incorporates a RF ion source. The deuterium ions (d^+) produced in RF ion source (13.5 MHz) are extracted, focused, accelerated and bombarded on the tritium target (TiT), which is maintained at ground potential. The main parameters of the neutron generator are stated in Table1. The deuteron ions impinge on titanium-tritium target (with copper backing), provides neutrons (14.1 MeV) via T (d, n) ^{4}He fusion reactions. Tagging of the D-T neutrons was realized using a 8x8 matrix of 64 YAP:Ce crystals for registering respective associated alpha particles .

Figure1: Neutron Generator

Table1: Important parameter of the Neutron Generator

Neutron Energy	14.1 MeV
Nneutron Yield (in 4π)	10^8 ns^{-1}
Tagging Detector	YAP (Ce)
Number of pixels	64 (8x8 matrix)
Maximum Beam current	200 μA
Maximum high voltage	150kV

Tagged Beam Profile Measurement

In order to map the tagged neutron beam geometry, a beam profile measurement was performed using a neutron detector (plastic scintillator of size 2 inch × 2 inch) in coincidence with alpha-particle detector (alpha detected in any of the 64 pixels). The neutron detector placed at about 107 cm from the tritium target as shown in Figure 2.

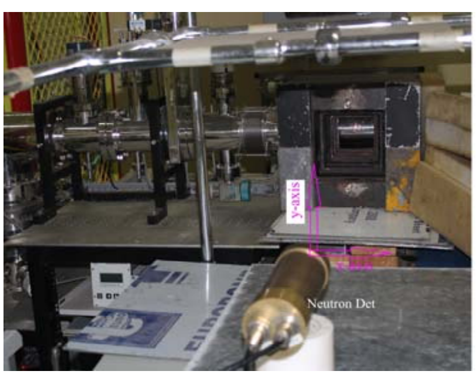

Figure 2: Experimental arrangement for beam profile measurement.

A scan along the x and y axes (horizontal and vertical directions) was performed in step of 5 cm. At different position of the neutron detector, alpha - neutron coincidence event rate was recorded keeping total alpha count rate constant during the experiment. The measured α-neutron coincidences rate as a function of positions of the neutron detector is plotted as shown in Figure3 for vertical scan (y-direction scan). The Full Width at Half Maximum (FWHM) of the tagged beam profile found to be of the order of Δx = 45± 2 cm and Δy =46± 2 cm at about 107 cm from the neutron source.

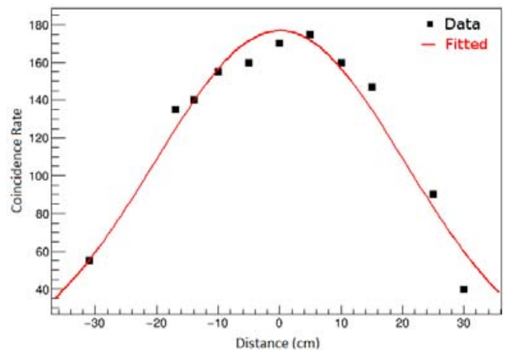

Figure3: alpha-neutron coincidences rate as a function of the position of neutron detector (y-scan).

Result and Conclusion

Tagged Neutron Method has been implemented successfully with the laboratory based D-T Neutorn Generator. The Tagged neutron beam profile measured was around Δx = 45± 2 cm and Δy =46± 2 cm at a distance of 107 cm from the neutron source. The various other experimental results such as system time resolution, pure elemental and complex sample spectra including benign as well as explosive simulants acquired with the system will also be presented in the conference.

References

[1] A. Buffler, Radiation Physics and Chemistry, **71**, 853 (2004).
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