Neutron Tagging Experimentation for Explosive Detection

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Introduction

The non-intrusive devices for the detection of explosives and illicit materials hidden in cargo containers are playing a major role in national security. At present controls are based on X- or gamma-ray scanners. It provides only projection images with information on shape and as per density of the transported goods but fails to analyze chemical elements present inside the container. Customs control can be further improved at next level with the use of fast neutrons which provides information on the elemental composition of a suspect region in the container identified by analyzing the X-ray or gamma ray image. As prompt gamma rays following fast-neutron-induced interactions [2] are nuclei specific, it can be used to identify chemical elements. Consequently, the yield of specific gamma rays in the recorded energy spectrum can be related to the amount of the corresponding element. In particular, explosive materials can be in principle identified by means of fast neutron interrogation and discriminated against benign goods, due to their specific carbon-to-oxygen (C/O), carbon-to-nitrogen (C/N) and nitrogen-to-oxygen ratios [4]

We are developing an explosive detection system based on associated particle technique (APT) using 14MeV neutrons from DT neutron generator [3] in association with a bank of gamma detectors and associated electronics.

$$_1H^2 +_1H^3 —_2He^4 +_0n^1 \text{---------- (1)}$$

In the associated particle technique the alpha particle following the fusion reaction (1) is detected. This allows defining the direction in which the neutron has been emitted as they are emitted almost in back to back geometry. The gamma detector signal in combination with time of flight (ToF) analysis and the direction of neutrons from the alpha detector signal helps in locating the corresponding element spatially. In this manner interrogation of a specific volume element with tagged neutrons yields information's about the chemical composition of the material (Fig1).

First level experimental evaluation of APT for tagging of DT and DD neutron using front end NIM based electronics has been already carried out successfully [1]. On the basis of its performance a high-end system with better spatial resolution for field applications has been developed. Successful installation, testing and initial experimental results using this system are reported here.

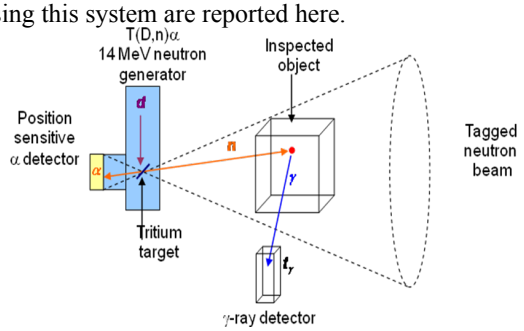

Fig1. Associated particle technique

Electronic set-up and alpha detector

Various components of the developed system are as follows: DT neutron generator, front–end electronics, multi-pixel alpha detectors, gamma detectors (BGO) and data acquisition software with GUI. Front-end VME based electronics along with high density (multi-channel) modules with FPGE based firmware were used. An array of 8x8 YAP:Ce segmented detector (64-pixel) coupled to a multi-anode photomultiplier has been installed with the neutron generator for alpha particle detection (Fig.2) and BGO detectors were used as gamma detectors.

Fig2. 8x8 array of Multi-pixel alpha detector

Experiments and results discussion:

Experimental set-up as shown in figure3, the sample was placed opposite to the alpha detector and is irradiated with fast neutrons. The signal from the segmented YAP:Ce detector determines the direction of the respective outgoing neutron (named as tagged

neutron) and as per the size of the alpha detector a volume of interaction of the bulk sample with tagged beam, at a certain distance is defined. Common samples such as water for oxygen and graphite for carbon detection were taken for experiments. Gamma rays produced on interaction of tagged neutrons with the materials are detected using BGO scintillation detector in coincidence with the respective alpha particle, as decided by the cone of interaction.

Fig3. Experimental Set Up at NXPD with Neutron Generator

In this manner, the construction of neutron time-of-flight (TOF) for determination of neutron interaction position and gamma-ray spectrum for building an elemental composition map has been achieved. Energy spectrum for oxygen (from water) and carbon (from graphite) is shown in Fig.4 and the ToF for the same is shown in Fig.5. Spectrum acquisition time was ~ 10 minutes. Lots of experimentations related to tuning of electronics and their interdependence with detectors has been carried out to obtain these coincidence results.

We have clearly observed the elemental signature of carbon element (4.43MeV as well as oxygen (6.13MeV)) and position of sample at 15ns in the path of tagged neutron beam from energy and TOF spectra respectively as shown in fig4-5. In this fashion various bulk samples simulating compositional ratios similar to the explosive or narcotics can be investigated to generate database related to individual elements of interest. The next step would be to find out their amount and their compositional quantities to term them as narcotics, explosives or benign material.

Conclusion:

Tagged neutron based explosive detection system has been designed and coupled with DT neutron generator. Front–end electronics was tuned for BGO gamma detector and YAP:Ce alpha detector. Experimentally energy and ToF spectra of water and graphite were acquired with a single BGO detector. Analysis of energy and TOF spectra depicts the presence of carbon and oxygen elements in the inspected object and position of the sample. Further the use of multiple gamma detectors with shielding are under progress to increase counting statistics and to improve signal/background ratio . GUI for data acquisition is also under development. Quantitative analysis of data and decision making algorithms will be implemented for identification of hazardous materials from benign at a later stage.

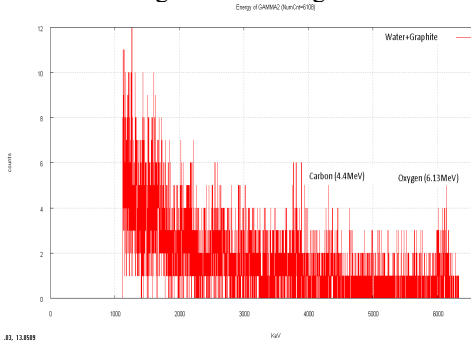

Fig.4 Total energy spectrum including sample environment. Inelastic gamma signature of carbon (4.43MeV) from graphite and 6.13MeV of oxygen from water has been observed

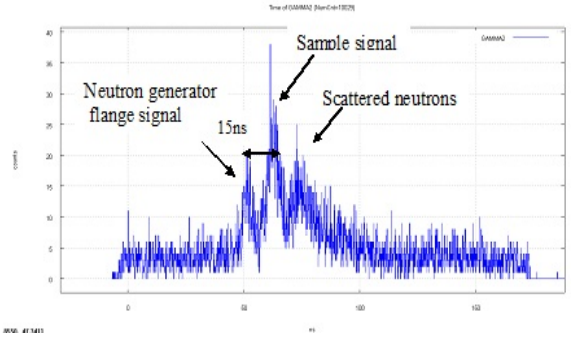

Fig.5 Time of flight of water and graphite sample designating their respective position with respect to the neutron generation target

References:

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