Detection of Fissile Material using Active Neutron Interrogation

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Introduction

Trafficking of fissile material/ special nuclear materials remains a realistic threat. With the increase in global terrorist activities, it is imperative to develop systems to detect fissile materials at entry checkpoints. A possible route of trafficking is through air cargo where it is difficult to detect fissile material using prevalent X-ray based techniques employed at airports. For such applications, neutrons prove to be one of the best probes to detect fissile materials even if they are shielded.

In this paper, we describe the development of a system for the detection of fissile materials in air baggage using an active neutron interrogation technique. The system is still under development and we present results of some preliminary investigations.

Active Neutron Interrogation

Although most fissile materials naturally emit neutrons and/or γ-rays, the intensity of the spontaneous radiation is low, and the energies of the γ -rays are fairly low in most cases. The active neutron interrogation approach involves bombarding the sample with external neutron source and thereby inducing additional fission in the sample and counting the emitted neutrons due to fission. The advantage of active neutron interrogation technique is that it can detect very small quantities of fissile materials directly even in the presence of neutron and gamma background and is much more sensitive compared to passive techniques. Active neutron interrogation determines the total fissile content of the waste to be measured (comprising the fissile nuclides ^{235}U, ^{239}Pu and ^{241}Pu). Differential Die-Away (DDA) is an active neutron interrogation technique [1-3]. In this technique, an external fast neutron detector measures the time-dependent decay of neutrons from the matrix. When fissile material is present, the die-away time significantly differs from the die-away time of the system without any fissile material. The DDA technique works by separating time zone of decay of primary signal of fast neutrons, signal region of prompt neutrons emitted by interaction of die away thermal neutron with fissile material in the system and signal region of delayed neutrons (Fig.1). These regions are well separated in time domain by an order of magnitude.

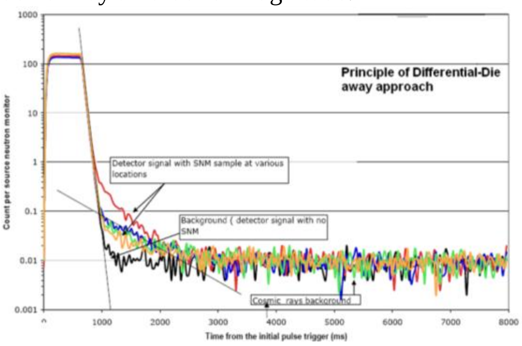

Fig. 1 Principle of Differential Die-away

Experimental set-up

The experimental set-up is shown in Fig.2. The inspected baggage is surrounded by a bank of epithermal neutron detectors (^{3}He detector enclosed in HDPe covered with cadmium) from three sides. An indigenously developed D-T neutron generator with 14.1 MeV neutrons of source strength 5 X 10^{8}n/s has been used as an external neutron source for inducing fission. The neutron pulses are generated at a frequency of 400 Hz with pulse width of 80 ms. The pre-amplifier signal from ^{3}He detectors is processed through amplifier and discriminator and summed TTL signal is fed to MCS for collecting the data. The total acquisition time for each data set is 300 second.

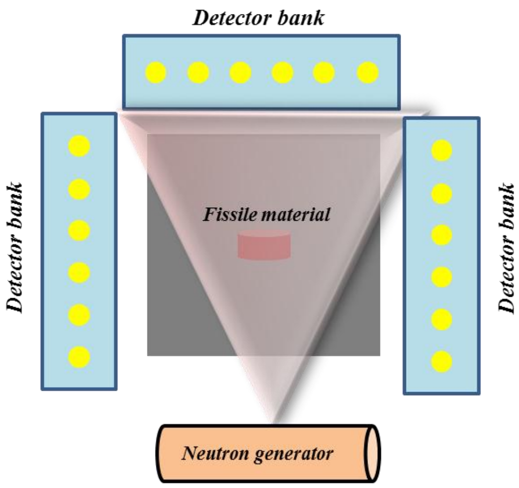

Fig. 2 Schematic of experimental set-up

Results and Discussion

Experiments have been carried out by varying amount of fissile mass of ^{235}U kept within the hull matrix. The neutron counts detected are plotted as a function of time (Fig.3).

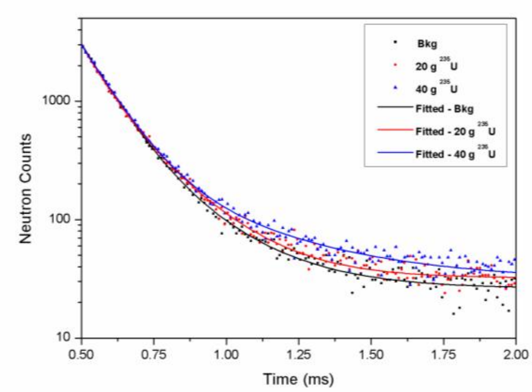

Fig. 3 Plot of neutron counts as a function of time

The start time must be so chosen as to minimize the effect of source neutrons. The experiments conducted with different samples for the present system show that the separation of decay curves in the presence and absence of fissile materials is approximately at 0.5 ms. The time range selected for quantitative analysis (0.5–2.0 ms) corresponds pre-dominantly to prompt neutrons from thermal fissions. The source neutrons as well as neutrons from fast fission mostly decay within a few hundred micro-second. A calibration curve is obtained for the total neutron counts (background corrected) as a function of ^{235}U mass which can be used for quantifying unknown fissile mass. A minimum mass of 20g of ^{235}U in a volume of 500 mm X 500 mm X 500 mm of baggage filled with cotton material has been presently detected with the system

The sensitivity can be further improved by increasing number of detectors, adding reflector and using a compact geometry. Further studies to improve the sensitivity of the system are underway.

References

[1] Yogesh Kashyap Ashish Agrawal, Tushar Roy, P.S.Sarkar, Mayank Shukla, Tarun Patel, Amar Sinha, Nucl. Instr. & Meth - A 806 (2016)

[2] H.O.Menlove, T.W. Crane, Nucl. Instr. & Meth. 152, 549 (1978).

[3] Kelly A. Jordan, Tsahi Gozani,, Nucl. Instr. & Meth - B 261, 365 (2007).

[4] K.A. Jordan, T.Gozani, J.Vujic, Nucl. Instr. & Meth - A 589 (2008) 436.

[5] K.A.Jordan, J.Vujic, T.Gozani, Nucl. Instr. & Meth - A 579 (2007) 407.