# A versatile phoswich detector for radioactive waste assay using simultaneous detection of neutron and gamma

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## Introduction

The detection of special nuclear materials is necessary for precise accountability and nuclear safeguard applications. There are various methods to determine the radio-isotopes in mixed alpha waste having Am, Pu etc. including alpha spectroscopy, mass spectrometry, chemical chromatography etc. However these techniques have the limitation of source phase, strength, age and mixing quantity etc. The measurements of characteristic gamma energies can also carried out using HPGe detectors [1]. Although HPGe detectors have the best resolution for isotopic ratio measurements through gamma detection, they have the limitation of lower efficiency, slower decay time and low temperature requirement.

Detection of neutrons from spontaneous fission of Pu isotope or fission neutrons using active neutron techniques are also measured in addition to gamma radiations for assaying particular isotopes. He-3 thermal neutron detectors have good n-gamma discrimination but have a very dwindling supply and also very costly.

Single crystal scintillators, possessing higher atomic density, have very high thermal neutron stopping efficiency in a very compact size. The recently patented novel phoswich detector by DAE has shown a capability of measuring neutron and gamma radiations simultaneously. In this communication, the performance of this phoswich detector, having combination of single crystals of $Gd_3Ga_3Al_2O_{12}$:Ce,B (GGAG) and CsI:Tl (CsI), has been investigated in details to detect thermal neutrons and gammas from standard Pu and Am-241 mixed sources using same detector setup.

## Experimental Details

The single crystals of GGAG and CsI were grown by using Czochralski and Bridgman technique respectively. The diameter of both crystals was 50 mm while the thickness was 1 mm and 50 mm for the GGAG and CsI crystals respectively. Only one surface of GGAG crystal was optically polished, that was coupled to CsI crystal having both surface polished. The phoswich detector was wrapped with Teflon tape except the surface to be coupled with a Hamamatsu PMT. An aluminum casing was used to encapsulate the detector assembly of crystal and PMT to avoid any ambient light leakage. The anode output of PMT was fed to a desktop digitizer which processed the combined pulse for pulse shape discrimination (PSD) and pulse height analysis (PHA). Only the shielding of detector was changed for gamma or neutron measurements.

Figure 1 shows the shielding arrangement for the thermal neutron measurements. HDPE tiles and thicker lead sheets were used to cover all faces for the measurement of thermal neutrons, while the moderator and extra lead front was removed for gamma measurements. The detector was calibrated using standard Cs-137, Na-22 and Eu-152 radioactive sources.

Six Pu standard sources were taken for investigating the performance of the detector. The strengths of these sources were 5.6, 22.7, 50.0, 120.0, 240.0, 581.0 mg respectively. All the double sealed sources were kept inside a separate PVC bag except the highest one which was placed inside a wooden box. The presence of Am-241 was due to the aging of these sources.

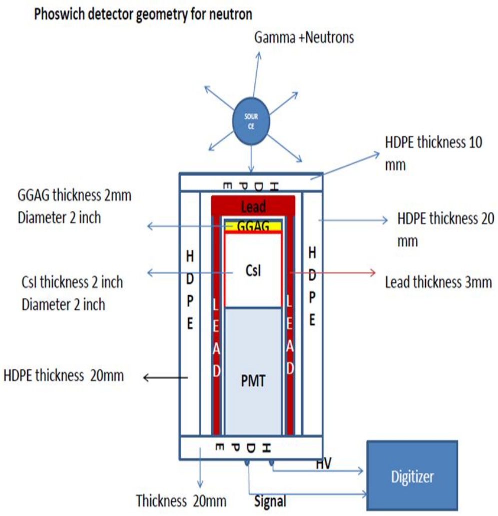


**Fig. 1** The detector setup for measuring spontaneous fission neutrons after thermalization. The same setup was used for gamma measurements after removing moderator and front lead.

## Results and Discussion

Figure 2 shows a typical pulse shape discrimination spectrum measured for the phoswich detector.

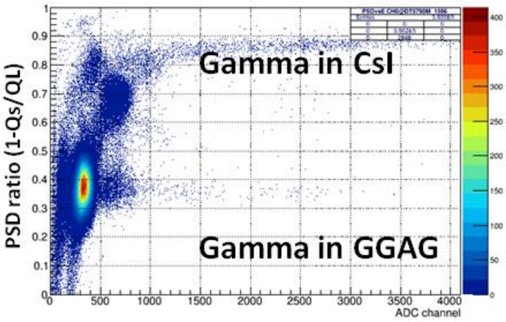


**Fig.2** 2-D spectra obtained from phoswich by irradiation of source without moderator.

The Y -axis in Fig. 2 represents the PSD ratio calculated as $[1 - (Q_S/Q_L)]$, where $Q_S$ and $Q_L$ are the charges collectedin short and long gates, respectively. The X-axis representstheenergy of the deposited gamma. Gamma rays depositing energy in the front GGAG and in the back CsI crystals could be well separated. Therefore 59 keV from Am-241, having very high branching ratio of activity, was almost stopped completely in front crystal and does not introduce any dead time of detector in measurement of higher energies like hump, from 290 keV to 440 keV, consists of various gamma energies to measure the quantity of Pu isotopes. The integrated counts in region of interested (ROI) around various specific gamma energies from Pu and Am isotopes were observed in the linear response with the known concentration of Pu as shown in figure 3.

When the setup was used for thermal neutron measurements, the ROI was selected around 75 keV. The thick shielding in this case ensures the absence of any contribution from low energies of gamma from source. In addition to a continuum gamma up to 8 MeV, the interaction of thermal neutrons with Gd isotopes produces low-energy conversion electrons and X-rays also which represents about 35% events in the form of well discriminated peak at 74 keV [2]. The linear response of integrated peak with Pu concentration and matching slope with Pu gamma counts confirms the neutron detection.

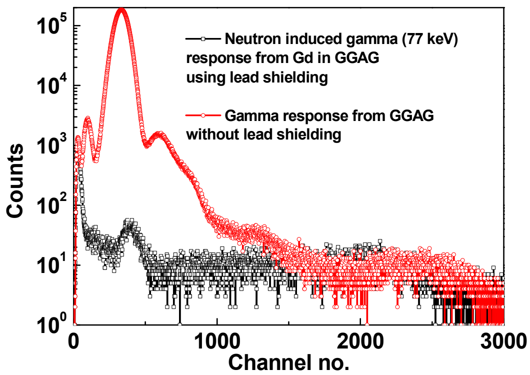


**Fig. 3** Pulse height spectra obtained from phoswich by irradiation ofsource with different shielding for gamma and neutron induced gamma response.

## References

[1] Francis X. Haas et al. IEEE Trans. Nucl. Sci. NS-22, 734 (1975).

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