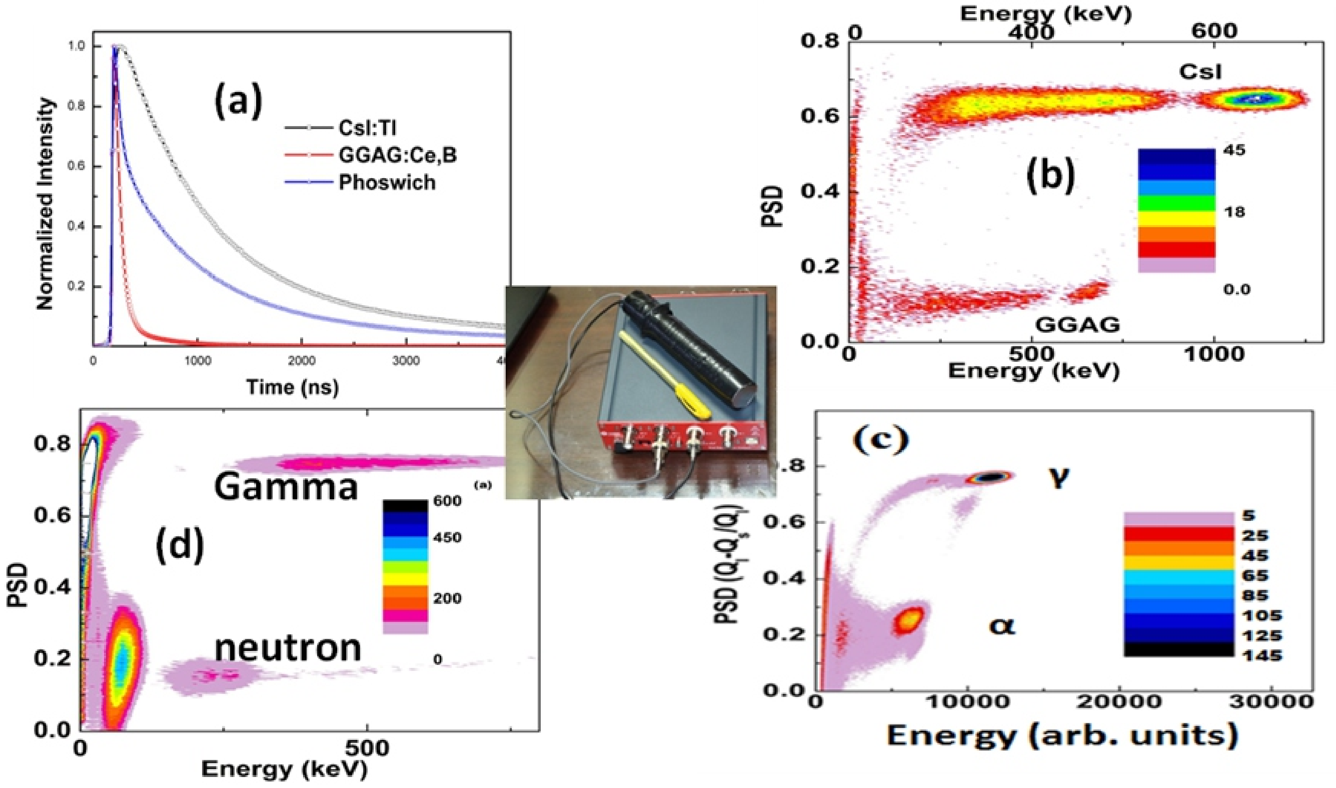

The actual photograph of the developed detector along with the measured (a) Scintillation decay times and discrimination of (b) Gamma-Gamma (c) Alpha-Gamma and (d) Neutron-Gamma radiations.

A Novel Versatile Phoswich Detector Consisting of Two Single Crystals to Discriminate Various Kinds of Radiations

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This invention was directed to develop a novel phoswich detector consisting of two single crystal scintillators to discriminate various types of radiation elements with high figure of merit and having versatile applications in academic, nuclear, security and medical fields.

Single crystal scintillators emit visible light when exposed to high energy nuclear radiations. The scintillator single crystals have various advantages like high density, high light yield, energy proportionality, high mechanical and radiation hardness etc. when compared to other detectors. For different kinds of radiations like α, β, γ, heavy charged particles, neutrons, etc., different scintillating materials are usually deployed based on the type of interaction, stopping efficiency and conversion into a measurable signal. In a mixed field, different kinds of radiations are usually discriminated by two methods; pulse-height discrimination (PHD) or pulse-shape discrimination (PSD) based on the variations in light-yield or decay kinetics, respectively. The phoswich detectors are sandwich/combination of two or more dissimilar materials with different pulse-shape characteristics and coupled to a common photo-sensor.

Limitations of existing phoswich detectors

The phoswich detectors, reported in the prior inventions and employing gas detectors, organic plastic scintillators, thin films, polycrystalline materials, etc. mainly suffer with the problem of poor efficiencies especially at higher gamma energies. The combination of single crystals has advantage of better efficiency but the difference in refractive indices limits the choice of crystals that could be optically coupled together. Additionally the emission of the first crystal should effectively pass through the transmission region of the second crystal without significant absorption/excitation. Hygroscopic crystals have to be encapsulated and therefore cannot be used for the charged particles. Moreover the detection of thermal neutron requires the presence of atoms having a high thermal neutron capture cross-section that further limits the choice of using single crystals phoswich detectors to discriminate neutrons in addition to charged particles and gamma radiations.

Development of a novel phoswich detector

Single crystals of B co-doped $Gd_{2.98}Ce_{0.02}Ga_3Al_2O_{12}$(GGAG) and Tl doped CsI were grown by the Czochralski and Bridgman technique respectively. The dopant and co-dopant concentrations were optimized for the best scintillation and discrimination properties. Both crystals have refractive index around 1.9; emit light around 550 nm and have light yield higher about 55000 ph/MeV. The average scintillation decay times are ~ 180 ns and 1900 ns respectively. Very high capture cross-section of the ^{157}Gd and ^{155}Gd isotopes and atomic density in the front Gd based garnet crystal stops almost 100% thermal neutrons in a very thin disk of the front crystal while background gamma deposits most of the energies in back halide crystals. The front garnet crystal has ability to discriminate alpha and gamma (X-ray) radiations falling on that. The photo sensor is connected with a desktop based digitizer for generating digital data equivalent to the photo sensor output and discriminating different radiation elements based on pulse-shape discrimination parameter (PSD) corresponds to charges integrated in different time windows corresponding to different radiations.

Novelty of the reported phoswich detector

This novel phoswich combination has the most versatile ability with an enhanced “figure-of-merit” to discriminate different radiations by more than 100% in comparison to that when crystals are used individually. Present phoswich detector also makes it possible to discriminate thermal neutrons due to involvement of the Gd based garnet crystal as the front crystal and the alkali halide single crystal as the back crystal exposed under various kinds of the radiations in a mixed field of neutrons, gamma and the charged particles including alpha particle. It has ability to discriminate incident EM radiation (Gamma, X-rays) radiations that interacted in the front and the back crystals due to the dissimilar pulse-shapes generated through the interactions in one or both the crystals. This is very useful for measuring low energy EM radiation in presence of high energies. Also the gamma interaction with both the front and the back crystals make it possible to measure depth of interaction.

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