Development of a detector setup based on BGO single crystals to measure high energy gamma spectra of neutron sources

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Introduction

Radiation detectors based on $Bi_4Ge_3O_{12}$ (BGO) single crystal scintillators have many applications, mainly in high- energy physics, and nuclear industry. The BGO possesses several advantages including high density, large effective atomic number Z_{eff}, small radiation length, high radiation hardness, stability of chemical properties, non-hygroscopic nature and much smaller afterglow which make these crystals indispensible in many applications. These crystals are the best choices for the spectroscopy of high energies gamma rays which are usually produced from (α, n) reactions in various neutron sources.

The major applications of these crystals in high energy physics and to detect high energy gammas require large size crystals. It has been well known that the signal output from BGO crystals is strongly governed by the purity and crystal defects. To grow high quality single crystals with large size and minimum number of defects has always been a daunting task for crystal growers.

In this communication, we describe the growth and characterization BGO single crystals. Fabrication of a setup based on BGO scintillator useful to measure gamma-rays from an Am-Be neutron source is discussed.

Experiment

Single crystals of BGO were successfully grown using the Czochralski technique. The constituent oxides were mixed in their stoichiometric ratio and sintered at 700°C, to prepare the initial charge for crystal growth. Single crystals having diameter up to ~ 55 mm were grown from melts with a pulling rate of ~ 2 mm/h. The single phase formation of the grown crystal was confirmed by recording the X-ray diffraction pattern using Rigaku X-ray diffractometer. A small sample, having thickness of 2 mm, was cut from the grown crystal to measure the transmission spectrum which confirmed the purity and overall quality of the crystal. A grown crystal was cut in a hexagonal shape having dimension of about 60 mm height and 48 mm width. The crystal was wrapped with several round of reflecting Teflon tapes and then coupled to ADIT 2 inch PMT using optical grease to optimize the light collection. The whole assembly was sealed in a custom made aluminum casing. The PMT output was given to a pulse processing assembly consisting of pre-Amp, shaping amp, and a 1k MCA. The power to all the components including HV to PMT was provided from a USB port by employing required DC-DC converters. It made the whole setup portable and convenient to use with a laptop. The data processing was carried out by the Spectrum Analysis and Acquisition Software (SAAS).

Results and Discussion

Fig.1 shows photographs of an as-grown BGO crystal and a hexagonal shaped scintillator detector.

Fig. 1 As-grown single crystal and hexagonal shaped scintillator cut from the ingot.

Fig.2 shows a photograph of the setup developed using hexagonal BGO scintillator. The setup was connected to the USB port of a laptop to acquire the data and simultaneously to provide necessary power to the components including HV to the PMT and bias to Pre-amp.

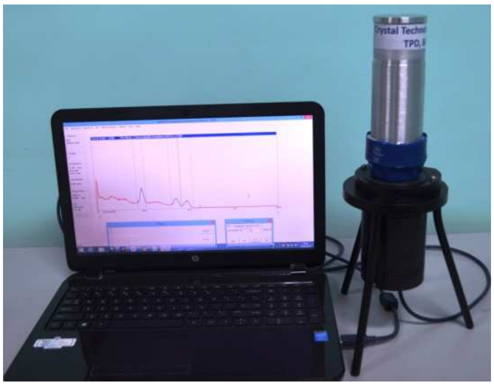

Fig. 2 A photograph of the setup employing BGO crystal to measure gamma spectra.

Fig. 3 shows the pulse height spectrum measured with ^{137}Cs and ^{60}Co sources. The energy resolution was measured to be about 10 % at 662 keV. The higher stopping power of BGO crystals ensured a lesser contribution from Compton scattering and well defined photo-peaks.

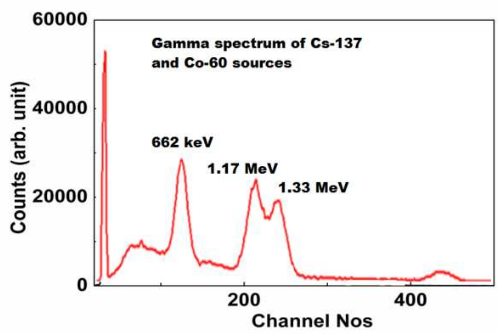

Fig. 3 Pulse height spectra from ^{137}Cs and ^{60}Co sources measured using the BGO crystal coupled to a PMT.

These photo-peaks obtained from ^{137}Cs (662keV) and ^{60}Co sources (1.17MeV & 1.33 MeV) were used to calibrate the system.

After that, the system was employed to measure high energy gammas from an Am-Be neutron source. When Be is placed in intimate contact with an alpha-emitting Am, neutrons are produced along with high energy gammas. When the $^{9}Be(\alpha,n)^{12}C$ reaction occurs, the carbon residue is frequently left in its first excited state that gives gamma emission at 4.44 MeV during the de-excitation. The well distinguished photo-peak corresponding to the high energy gamma was observed from the detector as shown in Fig. 4.

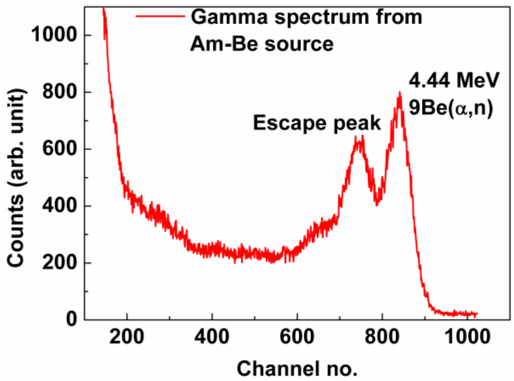

Fig. 4 Pulse height spectrum of gamma-rays from an Am-Be source measured with the BGO crystal coupled to a PMT.

The poor resolution of photo-peaks resulting from such a high energy is mainly due to Doppler broadening rather than the detector as ^{12}C nucleus de-excites very rapidly. Single-escape peaks are also prominent at these energies and therefore observed at lower channel numbers.

Conclusion

A setup has been developed using a BGO single crystal coupled to a PMT. The setup showed satisfactorily performance as high energy gamma radiation from neutron sources was effectively detected. It can be deployed to measure other high energy gamma radiations from the background of various neutron sources.

References

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