Temperature Response and Intrinsic Background Radiation Studies of a $LaBr_3$(Ce) Scintillation Detector for its use in Environmental Gamma Spectrometry

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Introduction

Scintillator based standalone γ-spectrometry systems suitable for continuous operation in open field environment are essential for online measurement of γ-spectra, facilitating in turn to regularly detect and quantify the radionuclides present in normal environment as well as in radiological/nuclear emergencies. Such systems, although not very common, are primarily built with NaI(Tl) as the detector. $LaBr_3$(Ce) detectors are commercially available nowadays, and have better energy resolution, higher light yield, higher density, faster scintillation decay without any significant slow component, and better linearity with respect to NaI(Tl) in case of laboratory based systems. Detailed study on their usage in open field environment is limited. This study reports some of their parameters which become important when the laboratory based systems are employed under open field environment. Results of the detector response studies against changes in temperature and the inherent detector background radiation studies are presented. Also described are the results of the application of a spectrum shifting methodology that restores the γ-spectra, shifted due to temperature variations.

Materials and Methods

The spectrometry system studied consisted of a 3″ × 3″ $LaBr_3$(Ce) detector (Make Saint-Gobain) coupled with a photomultiplier tube of 3″ diameter with built-in high voltage generator, preamplifier, and spectroscopic shaping amplifier, and a USB based 1k MCA.

For the temperature response studies, ^{137}Cs and ^{60}Co test sources were placed on top of the detector in an upright position inside an environmental chamber. Four light bulbs of different wattages provided the heat source to the chamber. This arrangement provided a temperature-range of 29^0C to 58^0C inside the chamber, measured by four thermometers, placed uniformly inside the chamber. Before recording each spectrum, it was ensured by reading all four thermometers that the temperature inside the chamber was stabilized to within $\pm1^0$C for at least 1 hour.

For the detector's inherent background radiation studies, background spectra were recorded by placing the detector inside the environmental chamber at room temperature (29^0C).

Results and Discussions

Temperature Response:

Fig.1 shows the peak position vs. temperature data.

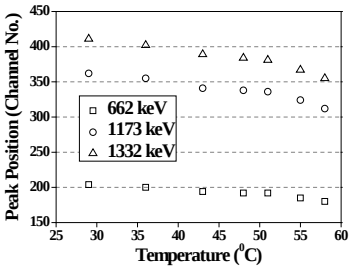

Fig. 1 Peak position as a function of temperature for a 3″ × 3″ $LaBr_3$(Ce) spectrometer

It is seen from Fig.1 that more the energy of the peak, the more is the shift in the peak position. This can be described by a model proposed elsewhere [1], in which the energy scale transformation is given by,

$$X(i) = a_0 + a_1 i \qquad (1)$$

where the i's are channel numbers of the reference spectrum (the one recorded at a reference temperature, i.e. 58^0C in Fig.2), and a_0

and a_1 are parameters given in terms of the moments of the reference and the shifted spectra. Since the overall gain change of the system (a_1) is constant for all energies, the shift in the peak position is more at higher energies.

Fig.2 shows the 300 s spectra recorded at 29^0C and 58^0C, and the former accurately restored to the (channel no.) scale of the later according to the methodology described in [1].

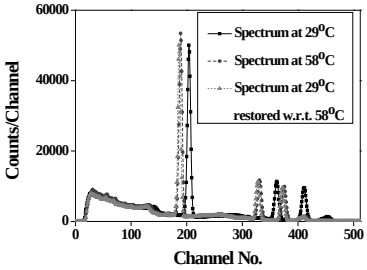

Fig. 2 Pulse height spectra of ^{137}Cs+^{60}Co test sources recorded at different temperatures using a 3″ × 3″ $LaBr_3$(Ce) spectrometer

It is to be noted from Fig.2 that the spectrum recorded at a higher temperature is shifted to the left relative to the one recorded at a lower temperature, indicating that the overall gain of the spectrometric system decreases with increasing temperature in this temperature regime.

Fig.3 shows the dependence of the energy resolution of the 662 keV peak on temperature. The energy resolution is seen to be nearly independent of temperature in the studied regime.

Intrinsic Detector Background:

Fig.4 shows the 5000 s background spectrum recorded with the detector. Also indicated in Fig.4 are the prominent spectral signatures below 1.5 MeV arising due to the decay of naturally occurring ^{138}La radioactive isotope, which is present in the detector crystal at trace levels [2]. On the other hand, the structure above 1.5 MeV, which arises from the decay chain of ^{227}Ac (a chemical analogue of La, also present in the crystal), is seen to be suppressed, a result that can be attributed to the high purity of the crystal. The 1436 keV peak is not very prominent in Fig. 4 because not many 32 keV X-rays can escape the 3″ × 3″ crystal without detection. Thus we see the 1468 keV sum peak as a whole [3]. This peak cannot be resolved from that of ^{40}K (1460 keV) which is a Naturally Occurring Radioactive Material (NORM) of great importance, thus limiting the usage of the detector for environmental γ-spectrometry.

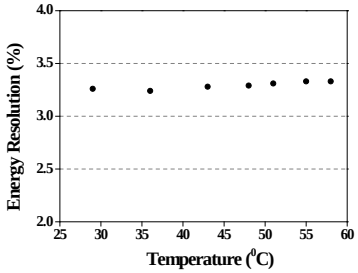

Fig. 3 Energy resolution of 662 keV peak measured with a 3″ × 3″ $LaBr_3$(Ce) spectrometer as a function of temperature

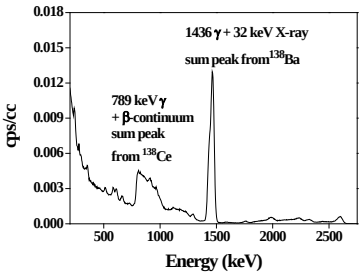

Fig. 4 5000 s background spectrum recorded with a 3” × 3” $LaBr_3$(Ce) spectrometer

Conclusion

Presence of internal contamination of ^{138}La poses the greatest limitation in the usage of $LaBr_3$(Ce) in environmental γ-spectrometry, wherein ^{40}K is a radionuclide of prime importance. For other commonly encountered radionuclides in the environment, the high resolution of the detector is its greatest advantage, and the spectrum shifting methodology ensures the correct identification of the radionuclides.

References

[1] Mitra P., *et al.*, Appl. Radiat. Isot., **107**, 133-137 (2016).

[2] Nicolini R., *et al.*, Nucl. Instrum. Meth. A, **582**, 554-561 (2007).

[3] Knoll G. F., Radiation Detection. and Measurement, **4th Ed.**, John Wiley & Sons, 251-253 (2010).