INVESTIGATION OF DISADVANTAGES OF LFS SCINTILLATOR

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In this paper two main disadvantages of LFS scintillator. There are intrinsic background, which limited their using for low background applications, and trapped time of metastable state that makes worse energy resolution of detector.

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INTRODUCTION

Last years scintillators with high light output are widely used in different areas of science and industry [1-7]. Basic requirements to the scintillation materials are fast response, high light output, high density, and high atomic number (*Z*) [1]. Lutetium Fine Silicate (LFS) has extremely high density of 7.4 g /cm^3, as well as a high *Z* value (*Z*=64), making this crystal very attractive for manufacturing highly efficient detectors. Scintillation detector based on LFS scintillator was widely investigated and it was obtained that this scintillator was optimal one for PET scanners and electromagnetic calorimeter [3, 4]. At the same time, LFS scintillator has several disadvantages: LFS has a naturally occurring isotope $_{176}$Lu which emitted beta particle and gamma rays, LFS scintillator has trapping center (metastable state), where trapped electron stayed for a long time and these centers are main reason in delayed light emission [1]. These disadvantages decrease its usefulness for low background applications and decreases amplitude of detected gamma ray due to metastable state [7].

That is why this work is dedicated to investigate two main disadvantages of LFS scintillator: intrinsic background and trapped time of metastable states.

II. EXPERIMENT DETAILS AND RESULTS

Two different sized LFS (Lutetium Fine Silicate) scintillators is used (3×3×0.5 mm^3, 3×3×10 mm^3) in this work. Its decay time was 19 ns. The LFS-8 gives the light yield of 30000 photons/MeV deposited energy. The maximum wavelength of light emission is 422 nm. The sides of the LFS-8 crystals were wrapped into three layers of 0.1 mm thick white Teflon tape except one face open to join with the MAPD with silicone grease. The MAPD-1P was operated in Geiger mode. The used MAPD consisted of a silicon substrate of n-type conductivity (wafers with a specific resistivity in the range from 10 to 30 Ω×cm) on which two silicon epitaxial layers of *p*-type conductivity were grown (7 Ω×cm). The device also contains a matrix of independent *n*+-type pixels buried deep in the epitaxial layers mentioned above. The design and operation of the device were described in [6-8]. The used MAPD device had a 3×3 mm^2 active area and total pixel number was 1.35×10^5. The maximum photon detection efficiency of the MAPD was about 30% around 450-525 nm light wavelengths. In the gamma ray measurements, the MAPD signal was sent to preamplifiers (gain=30).

The signal from the preamplifiers was sent to CAEN DT5720 digitizer module with 12-bit resolution and 250 MS/s sampling rate. All measurements were carried out at room temperature and without shielding materials (or box).

The pulse-height spectra of the $_{113}$Sn source with different sizes of LFS scintillator is shown in fig.1. $_{113}$Sn activity was 70 Bq and measurement time was 1,800 seconds in the experiment. External and intrinsic background of LFS (due to $_{176}$Lu) strongly affected on the low energy tail of spectrum of $_{113}$Sn source due to low source activity. Photo peak of $_{113}$Sn is invisible at spectrum due to intrinsic radiation of LFS. Intrinsic radiation of LFS is reduced by decreasing thickness of LFS scintillator (3×3×0.5 mm^3) and in this way photo peak of $_{113}$Sn is separated perfectly from background. Energy resolution of 391.7keV gamma ray from $_{113}$Sn was 20%. The intrinsic radiation of LFS (3×3×10 mm^3) is investigated by high purity germanium (HpGe) detector. The measurement time was 2x10^4 seconds. Obtained activity and mass of Lu-176 were 23.5±3 Bq and 12.5 mg respectively. Four major gamma lines were observed in the spectrum: γ-54.4 keV (25.9%), γ-88.3 keV (13%), γ-201.6 keV (84%), γ-306.3 keV (93%) and a sum of the last two γ-507.9 keV (0.8%) [1].

Second main disadvantage of LFS-8 scintillators is sensitivity to light. When the scintillator LFS-8 stays under light for a long time the photon generates an excited electron which are captured by activator and trapping centers (also metastable states).

The trapped electrons in metastable states transited to the ground state by emitting delayed scintillation photons which will play a key role in background current.

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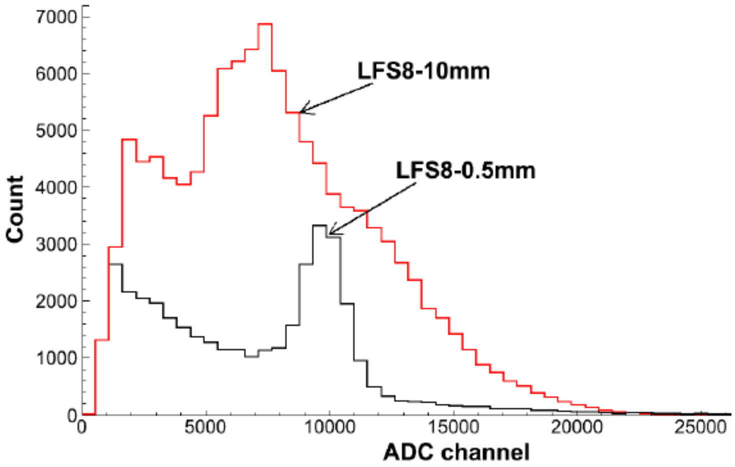

Fig. 1. The pulse-height spectra of the $_{113}$Sn source with different sizes of LFS scintillator.

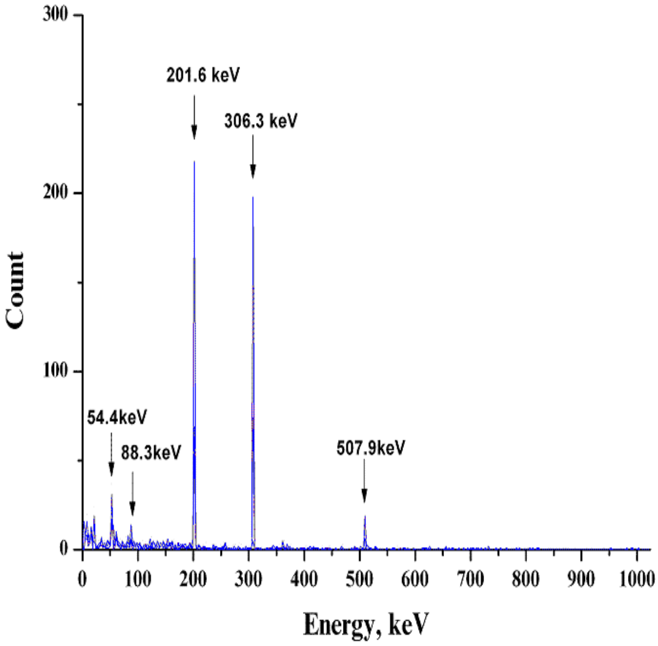

Fig. 2. Energy spectrum of gamma rays from the natural radioactivity in the LFS (Lu-176) measured using HPGe detector.

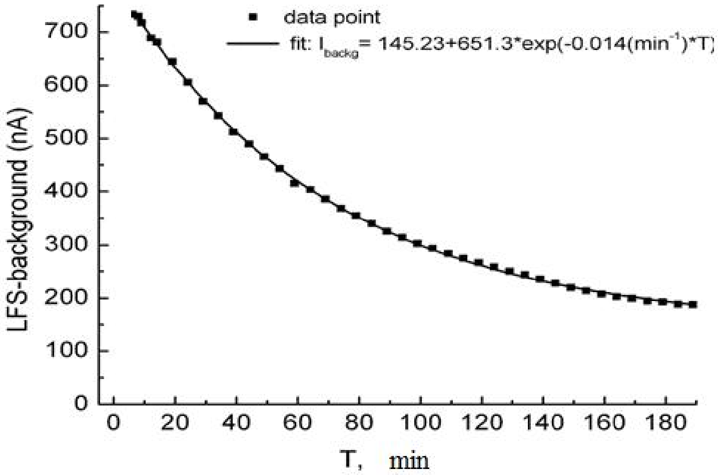

Fig 3. The internal excited background of LFS scintillator dependence of time.

In fig 3 showed dependence of change of background current of MAPD diode on time for the LFS-8 scintillator which stayed under light for long time. The scintillation photons which emitted from LFS scintillator detected by MAPD-3A photodiode. The sides of the LFS-8 crystals were wrapped into three layers with thickness of 0.1 mm of white of teflon tape except one face open to join with the MAPD with silicone grease and kept in the dark box for one day. The internal dark current of diode was 180nA at the operating voltage and all experiments was carried out at room temperature. LFS scintillator was irradiated with light (for 20 minute) and after that, background current was increased sharply to 730nA. The background decreased exponentially law with time: $I_{backg}(nA)=145.23+651.3\times\exp(-0.014(\text{min}^{-1})\times T)$ here T-time and I_{backg} –background current. It was defined that background current reached to previous internal dark current of diodes during 170 minute. For this reason LFS-8 scintillator have to be protected during measurements from external light source. During gamma ray detection, some of scintillation light delayed for long time due to the trapped electron by metastable state. The amplitude of gamma ray is reduced by amount of excited electron which trapped by metastable state and this makes worse energy resolution of detector.

CONCLUSION

Two disadvantages of LFS scintillator was investigated in this work. Intrinsic background of larger size LFS (due to $_{176}$Lu) is measured with HPGe detector. Obtained activity and mass of $_{176}$Lu were 23.5±3 Bq and 12.5 mg respectively. Intrinsic radiation of LFS was reduced by decreasing thickness of LFS scintillator ($3\times3\times0.5$ mm^3) in this way photo peak of $_{113}$Sn (low activity) is separated perfectly from background . Energy resolution of 391.7keV gamma ray from $_{113}$Sn was 20%.

It was obtained that the excited background current due to metastable center is decreased exponential law with time. The background current reached to initial value during 170 minute. This effect reduced the amplitude of gamma ray (due to electron which trapped by metastable state) and it makes worse energy resolution of detector.

Acknowledgments

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