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Gamma-ray response properties of Pr:$Lu_3Al_5O_{12}$ (LuAG) scintillating crystal with avalanche photodiode

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Pr:LuAG single crystal has interesting properties of a higher density host (6.7g/cm^3), high light yield (three times higher than $Bi_4Ge_3O_{12}$(BGO)) , a very fast 5d-4f emission decay time (~22ns) and good temperature stability around room temperature. Recently we have developed single crystal growth of 2-inch-diameter Pr:LuAG with high uniformity of the light output and decay time on the whole crystal. In this work, we report the results of gamma-ray spectroscopy measurements performed using Pr:LuAG crystal by APD (Hamamatsu S8864-55). Pr:LuAG crystals, which were cut in a rectangular shape (2x2x15mm^3) and mechanically polished, were used for all experiments. These samples were optically coupled to APD. Gamma-ray response have been evaluated in the range from 122 keV (152Eu) to 1.4 MeV (^{241}Am).

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Introduction

Single crystal scintillator materials are widely used for detection of high-energy particles. In past decades, scintillators based on 5d-4f luminescence of Ce^{3+} were intensively investigated because of their desirable properties of high light yield and a fast decay time. On the other hand, Pr^{3+} ion also shows the 5d-4f emission with the fast decay time in several host materials and such systems can be another candidate for high figure-of-merit scintillator. Recently we have studied about scintillation materials based on 5d-4f luminescence of Pr^{3+} ions[1,2]. Among those studies, We found out $Pr:Lu_3Al_5O_{12}$ (LuAG) has higher scintillation efficiency and better temperature stability around room temperature[3-5].

Recently we have developed single crystal growth of 2-inch-diameter Pr:LuAG with high uniformity of the light output and decay time on the whole crystal. In this work, we report and compare the results of gamma-ray spectroscopy measurements performed using Pr:LuAG crystal by APD (Hamamatsu S8864-55). Pr:LuAG crystals, which were cut in a rectangular shape (2mm x2mm x15mm) and mechanically polished, were used for all experiments. These samples were optically coupled to APD. Gamma-ray response have been evaluated in the range from 122 keV (^{152}Eu) to 1.4 MeV (^{241}Am). These samples are shown in figure 1.

Experiment

Several pieces with 2x2x15 mm^3 size were cut along the growth axis. Every surface were mechanically polished. The pieces were wrapped with PTFE tape as a reflector and mounted on a light sensitive window of APD (S8664-55, Hamamatsu) with silicone grease.

High voltages are supplied to them by CP6621, and radio isotopes are irradiated. An avalanche gain is controlled at ~20 times, because we have already investigated that the best energy resolution is achieved around this gain. The signal fed into preamplifier (CP580H), and multiplied at shaping amplifier (CP4417). Finally, we obtain a gamma-ray spectrum by accumulating at MCA (Amptec 8000A) in the range from 122 keV (^{152}Eu) to 1.4 MeV (^{241}Am) at room temperature.

Results

Figure 2 shows energy spectra of Pr:LuAG under 662 keV gamma-ray excitation (^{137}Cs source) measured by APD. Energy resolution was around 9%. Figure 3 shows gamma-ray response in the range from 122 keV (^{152}Eu) to 1.4 MeV (^{241}Am) detected by APD at room temperature. Pr:LuAG shows good linearity between energy and pulse height within around 2% of the standard deviation. Figure 4 shows Energy resolution relation in the range from 122 keV (^{152}Eu) to 1.4 MeV (^{241}Am) detected by APD at room temperature. The line was given by the equation: $\delta \propto 1/E^{1/2}$, where δ is energy resolution and E is energy of gamma-ray. Pr:LuAG shows good linearity energy of gamma-ray and energy resolution.

Conclusion

In this work, we report the results of gamma-ray spectroscopy measurements performed using Pr:LuAG crystal by APD (Hamamatsu S8864-55). Pr:LuAG shows good linearity between energy and pulse height within around 2% of the standard deviation in the range from 122 keV (^{152}Eu) to 1.4 MeV (^{241}Am).

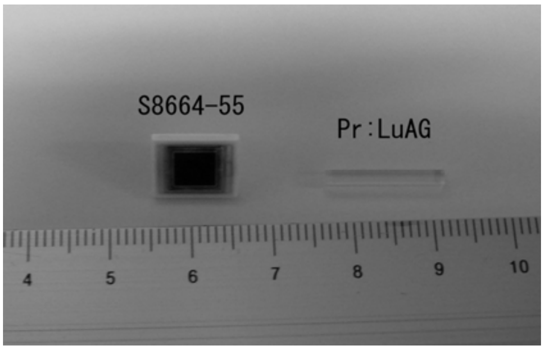

Figure 1. Photo of APD S8664-55 and Pr:LuAG

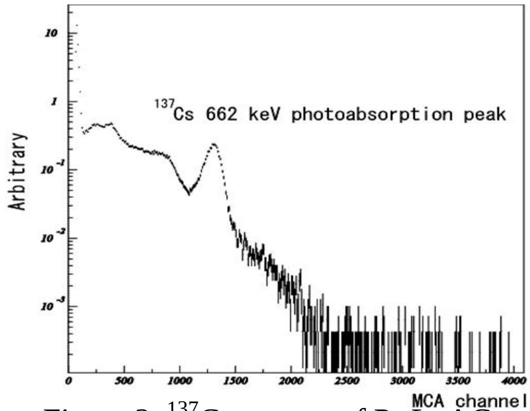

Figure 2. ^{137}Cs spectra of Pr:LuAG

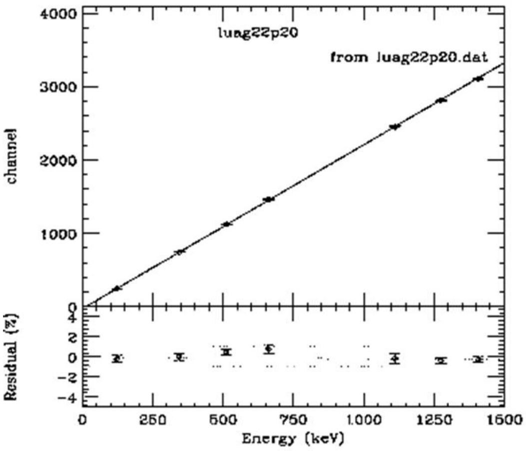

Figure 3. Gamma-ray response in the range from 122 keV (^{152}Eu) to 1.4 MeV (^{241}Am) detected by APD at r.t..

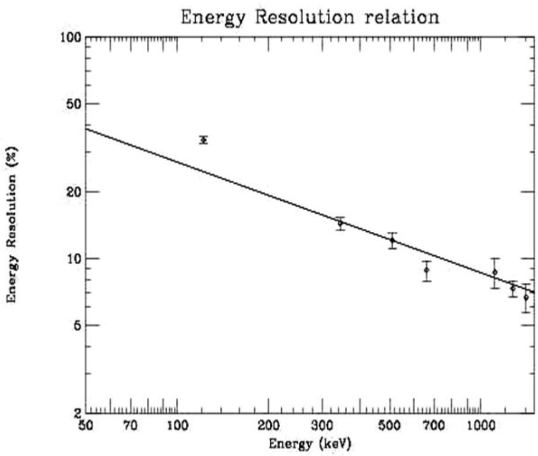

Figure 4. Energy resolution relation in the range from 122keV (^{152}Eu) to 1.4 MeV (^{241}Am) detected by APD at r.t..

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