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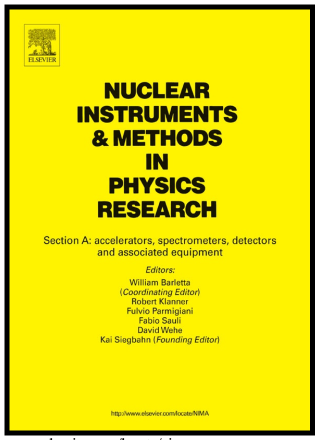

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Luminescence and scintillation timing characteristics of $(Lu_xGd_{2-x})SiO_5$:Ce single crystals

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Abstract

The luminescence and scintillation characteristics of cerium-doped lutetium-gadolinium orthosilicate ($Lu_xGd_{2-x}SiO_5$:Ce; x = 0, 0.8, 1.8) single crystals were investigated. At 662 keV γ-rays, the light yield of 29,800 ± 3000 ph MeV^{-1} obtained for $Lu_{1.8}Gd_{0.2}SiO_5$:Ce is higher than that of 20,200 ± 2000 and 11,800 ± 1200 ph MeV^{-1} obtained for $Lu_{0.8}Gd_{1.2}SiO_5$:Ce and Gd_2SiO_5:Ce, respectively. The fast component decay time of 32, 18 and 17 ns was measured in the scintillation decay of Gd_2SiO_5:Ce, $Lu_{0.8}Gd_{1.2}SiO_5$:Ce and $Lu_{1.8}Gd_{0.2}SiO_5$:Ce, respectively. The coincidence time spectra for 511 keV annihilation quanta were measured in reference to a fast BaF_2 detector and time resolution was discussed in terms of a number of photoelectrons and decay time of the fast component. The mass attenuation coefficient for studied crystals at 60 and 662 keV γ-rays was also evaluated and discussed.
Keywords: Coincidence time resolution; Light yield; Gd_2SiO_5:Ce; $Lu_xGd_{2-x}SiO_5$:Ce; Scintillation decays

1. Introduction

Cerium -doped ortho- and pyrosilicate single crystals have been intensively studied and optimized to specific scintillator applications in the last two decades, see review in [1]. Lu_2SiO_5:Ce (LSO:Ce) [2] and $(Lu,Y)_2SiO_5$:Ce (LYSO:Ce) [3] have been developed as promising scintillators for positron emission tomography (PET) scanners due to their excellent scintillation properties such as high density, high light yield (LY) and short decay time. Gd_2SiO_5:Ce (GSO:Ce) was described by Takagi and Fukazawa [4] in 1983 and technology of large crystal growth was developed [5, 6]. GSO:Ce found its application in geological explorations due to stability of its scintillation characteristics up to high temperatures [7]. Low LY value about 10,000 ph MeV^{-1} [8] for GSO:Ce can be explained by the luminescence quenching of Ce^{3+} at Gd(2) site at room temperature [3, 9]. The $(Lu,Gd)_2SiO_5$:Ce (LGSO:Ce) crystal has been developed by Hitachi Chemical Co. as an alternative to GSO:Ce and LSO:Ce in an application to PET detectors [10-12]. LY value of 17,000 ph MeV^{-1} and good energy resolution of 6.5% at 662 keV γ-rays was reported for $Lu_{0.4}Gd_{1.6}SiO_5$:Ce crystal [8]. The scintillation characteristics of $Lu_{2x}Gd_{2-2x}SiO_5$:Ce (0 < x < 1) were also investigated [13, 14]. It was determined that the LY increases in the range 0.3 < x < 0.8 and reaches 29,000 ph MeV^{-1} at 60% of Lu in the host and energy resolution improves up to 6.7% at 662 keV γ-rays [14]. The optimization of LGSO:Ce by heat treatment was reported in [15], showing an energy-resolution improvement but no significant effect on LY. A systematic study of the luminescence properties and emission mechanisms of the highly efficient cerium-doped scintillators LSO, LGSO ($Lu_{1.1}Gd_{0.9}SiO_5$) and GSO was recently carried out [9]. It was determined that an advantage of LGSO:Ce with respect to both LSO:Ce and GSO:Ce comprises