Single Crystal Scintillation Detectorfor Spectroscopy of Gamma Rays

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Introduction

The crystal is useful as a scintillation detector responsive to gamma ray or similar energy radiation. The crystal as scintillation detector has wide application for the use in the fields of physics, chemistry, medicine, geology and cosmology because of its enhanced scintillation response to gamma rays, x-rays, cosmic rays and similar high energy particle radiation.

A scintillator is a material that emits low-energy photons (usually in the visible range) when they are struck by a high-energy charged particle. When used as a gamma-ray detector, the scintillator does not directly detect the gamma-rays. Instead, the gamma-rays produce charged particles in the scintillator crystals, which interact with the crystal and emit photons. These lower-energy photons are subsequently collected by photomultiplier tubes (PMTs).

When gamma-rays pass through matter, they can cause three basic processes: Compton scattering, photoabsorption, or pair production. Each of these processes can create high-energy electrons or anti-electrons (positrons) that interact in the scintillator as charged particles. By adding up the energy collected in the surrounding photomultiplier tubes, the energy of the detected gamma-ray can be determined.

Scintillators can be made of a variety of materials, depending on the intended applications. The most common scintillators used in gamma-ray detectors are made of inorganic materials, and are usually an alkali halide salt, such as sodium iodide (NaI) or cesium iodide (CsI). To help these materials do their job, an impurity, called an "activator," is often added. Thallium and sodium are often used for this purpose, so detectors are usually described as NaI(Tl), which means it is a sodium iodide crystal with a thallium activator, or as CsI(Na), which is a cesium iodide crystal with a sodium activator.

For a long time the choice of a scintillator has been limited to only a few which were used in a large range of applications. NaI(Tl) is the best example of a material, which, because of its exceptionally high light yield, has been considered as an acceptable compromise for the majority of applications in spite of its low density. However, through important progress in the understanding of fundamental mechanisms underlying scintillation properties as well as in the production technology, the large amount of materials available now and the possibility to tune some important properties give a larger flexibility and allow tailoring, to some extent, the performance of a scintillator to the specific requirements of different end users. Recently were obtained new scintillation crystals GSO and LYSO.

GSO single crystal is used as a scintillator in nuclear physics and in medical imaging equipment like PET (Positron Emission Tomography) scanners and other radiation detection equipment. Its superior energy resolution, fast decay time, large light output support quick and high precision radiation detection.

LYSO crystal is an ideal generation scintillator crystal. LYSO (Cerium-doped Lutetium Yttrium Orthosilicate.) LYSO crystal has the advantages of high light output and density, quick decay time, excellent energy resolution. These properties make LYSO an ideal candidate for a range of ray detection applications in nuclear physics and nuclear medicine, which require higher, improved timing resolution and superior energy resolution.

The setup for investigation

The basic elements of the setup are scintillator (crystal), two photodetectors, precision mechanical system, digitizer, cosmic veto detector, collimator and radiation sources. The setup general view is shown in Fig. 1. The mechanical system can measure the position of source with an accuracy of 1 micron (Fig.2). Two photomultipliers (both sides) determine the correlated timing and amplituding signals. Digitizer with a frequency of 5 GHz and 14 bits ADC allows receiving time and amplitude characteristics of studied radiation (Fig.3). The collimator with radiation source is shows in Fig. 4. The setup is fully automated.

The signal from the photodetector which proportional to energy allocated in scintillator is digitized by using the digitizer. After this the signal processes by using of special programs to receive spectra and to study properties of scintillation detector.

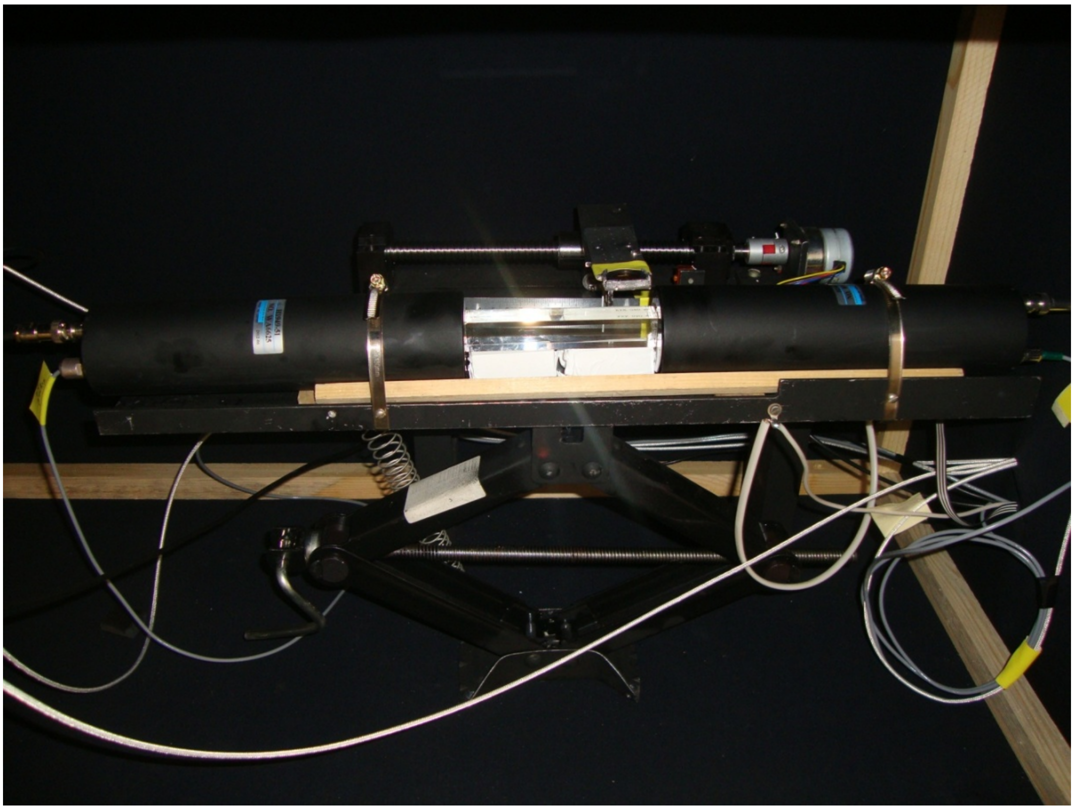

Fig.1. The single crystal scintillation detector

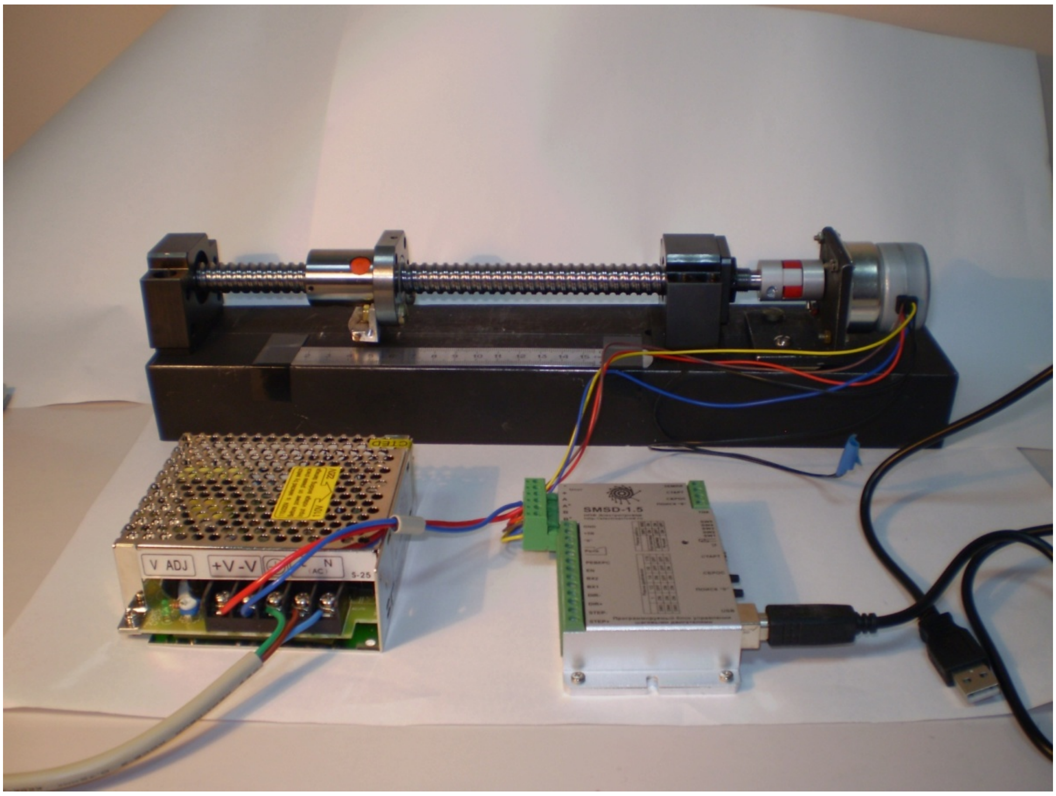

Fig. 2. The precision mechanical systems

Fig. 3. The digitizer

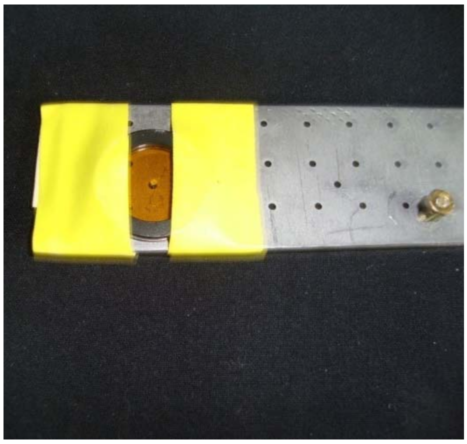

Fig. 4. The collimator

The project aim

Student have to investigate properties inorganic single crystal scintillation detectors on the basis of new crystals GSO and LYSO.

Practical task for student

1. Students need to simulate detectors on GSO and LYSO crystals in GEANT4.
2. They have to receive experimental spectra of scintillation detectors on the basis of crystals GSO and LYSO for different sources of radiation.
3. They have to define the energy resolution and efficiency of scintillation detectors on the basis of crystals GSO and LYSO.

Experience

Required courses: Atomic and Nuclear Physics, Optics, Programming on C^{++}. Experience in using Origin, Excel, ROOT software.

References

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Number of participants

The number of participants is limited to two.

Dates

Working time in the project it is from September, 8th till September, 23rd.

Project supervisor

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