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Technological applications of LiI scintillators (Eu), coupled to light guides for studies of moisture and densification of soil layers, wood density and quality control of asphalt layers and the petroleum industry

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1. Introduction

The detection of radiation and quantization is a necessity of nuclear technology and its applications in different areas of knowledge: reactor operation, in industry, in the medical field, etc. Radiation detectors, with their associated electronics, are systems that allow identification of the type of radiation and quantization. Depending on the type of radiation beam, the energy and the environment where the interaction takes place, the choice of the appropriate detector is made. For these applications we have gas detectors, scintillators and semiconductor detectors.

The scintillation method is still one of the most used for detecting ionizing radiation. It can be used to record almost any type of radiation over a wide energy range from eV to tens of GeV [1].

Among the crystals used in scintillators are LiI (Eu) crystals. Due to its high sensitivity, the 6 Lithium Iodide crystal doped by Europium can be used for detection of gamma radiation and neutrons. These scintillators are extremely robust, being resistant to all organic and inorganic chemicals with the exception of hydrofluoric acid. Densimeters built with detection systems for remote monitoring of gamma and neutron radiation present technological advances in relation to conventional densimeters.

This work has as its main objective the construction of a system for neutron and gamma ray detection and its associated electronics, with high sensitivity and efficiency, good reproducibility and data recording directly in a portable real-time computing system, using a a europium-doped lithium iodide scintillator that allows, depending on the pulse height generated, to determine the spectrum of neutrons and gamma rays [2].

2. Methodology

The proposed systems will be developed using optical fiber-coupled scintillators. Equipment that uses optical fibers have advantages such as simplicity, versatility and safety. Due to the fact that they are insulating materials, the fibers are also not subject to electromagnetic noise. Optical fibers are also less sensitive to vibrations and can be used even in moving objects and in industrial environments. In addition, fiber-optic-coupled sensors (SFO) have small dimensions and enable remote monitoring, as the fibers can carry light pulses over long distances without loss.

The gamma and neutron radiation detection system will consist of a first module with a scintillator (LiI (Eu)); the second module with a light guide coupled to Hamamatsu's H9319-01 module; the third module with a PMT9319-01 light pulse digitizer from Hamamatsu; and, finally, a data acquisition system using a notebook and software. In the gamma detection system, the source to be used will be americium-241, with an energy of 59.7 keV. The neutron detection system will have a variation in the structure of the first module, inside and near the scintillator, where a ^{241}Am-Be source will be used, with an average energy of 3.5 MeV, which emits both photons and neutrons. The principle is based on neutron moderation in hydrogenated material (elastic collisions), since LiI (Eu) has a high efficiency in the detection of thermal neutrons (0.025 eV), since ^{6}Li has a very high absorption cross section. Neutrons are detected through the nuclear reaction $^{6}Li + n1 \rightarrow {}^{4}He + {}^{3}H + 4.78$ MeV.

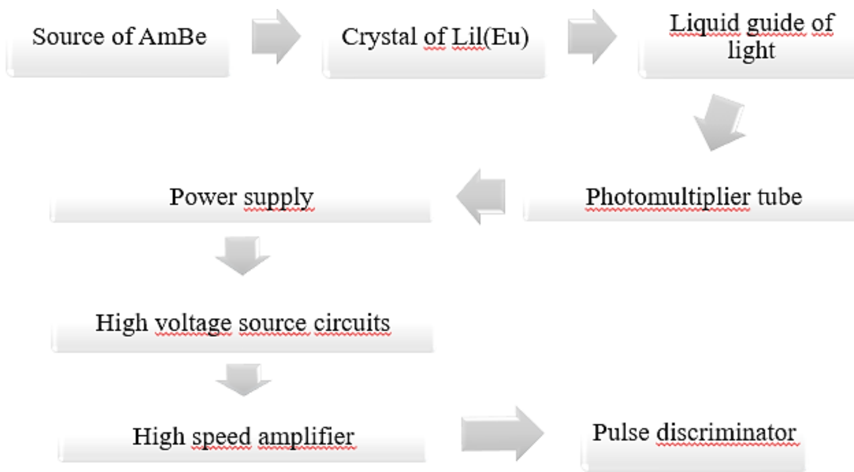

Figure 1: Diagram of the data acquisition system.

3. Results and Discussion

In similar studies, crystals of cesium iodide (CsI), doped with lithium (Li) and bromine (Br), were used using the Bridgman technique. Which consists of keeping the charge at high temperature (350º C) for 10 hours. Therefore, a small thermal neutron detector based on natural CsI:Li and CsI:Br scintillator was used. As a result, the spectrum of background radiation from natural radioactive sources was obtained in the measurement of the environment. The addition of Li and Br to the CsI matrix resulted in crystals with good performance when excited with a neutron beam [3].

In another work, intrinsic thallium-zirconium chloride (Tl_2ZrCl_6) and hafnium (Tl_2HfCl_6) scintillators were used to detect gamma rays and their spectroscopy. The absorption spectrum at room temperature showed a spectrum band of 3.45 eV. Evidencing the high electronegativity of Tl compared to Cs. [4].

4. Conclusions

It is expected to obtain a data acquisition system, via the operation of counters that work for intervals of 10 ms. During this time, pulses are collected and, after integrated, they are stored in the microcontroller's internal memory. A new 10 ms cycle is started, and the same operation is repeated until the user-defined time is completed or until a computer interrupt arrives. Further studies are necessary, in order to obtain better pulse detection.

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References

[1] M. J. Weber, "Inorganic scintillators: Today and tomorrow," *J. Luminescence*, vol. 100, pp. 35–45 (2002).

[2] T. Matsumoto, H. Harano, A. Masuda, J. Nishiyama, Y. Sakurai, and A. Uritani, "New idea of a small-sized neutron detector with a plastic fibre," *Radiat. Protection Dosimetry*, pp. 1–4 (2011).

[3] M. Conceição, T. Madi, J. Patrício, "Inorganic Scintillation Crystals for Neutron Detection", *IEEE Transactions On Nuclear Science*, Vol. 63, No. 3 (2016).

[4] P. Bhattacharya, C. Brown, C. Sosa, M. Wart, S. Miller, C. Brecher, V. Nagarkar, "Tl_2ZrCl_6 and Tl_2HfCl_6 Intrinsic Scintillators for Gamma Rays and Fast Neutron Detection", *IEEE Transactions On Nuclear Science*, Vol. 67, No. 6 (2020).