

PACS: 07.85.Fv; 29.40.Mc; 85.60.Dw;

GAMMA SCINTILLATION DETECTOR BASED ON SILICON MAPD MATRIX

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Abstract: The article presents a scintillation detector based on a 2x2 matrix of micropixel avalanche photodiodes (MAPD) with a total active area of (7.5×7.5) mm². New samples of silicon avalanche photodiodes of the MAPD-3NK type with a sensitive area of (3.7×3.7) mm² have been used in this work. The yield of each MAPD in a 2x2 matrix was unified by the gain factor using a voltage divider consisting of a set of resistors. It has been used as a rectangular LYSO scintillator with a size of $(6 \times 6 \times 2)$ mm³ to study the linearity and energy resolution of the detector. The experiments were carried out at room temperature using gamma radiation sources in the energy range of 27–1332 keV.

Keywords: micropixel avalanche photodiodes MAPD; scintillation detector; gain factor; gamma radiation source; scintillator LYSO;

1. Introduction

In the process of improving detectors, much attention was paid to amplifying weak signals caused by ionizing radiation. From this point of view, traditional vacuum photoelectronic multipliers (PEM) have been used for a long time [1-2]. However, the development of technology required the development of new types of photodetectors with high registration efficiency, low operating voltage, and high resistance to magnetic fields [3-4]. For scintillation detectors, the efficiency of scintillation photon collection increases with the increase in the area of the photodetector. Besides, a higher detector volume has a higher sensitivity for detecting radioactive radiation [5]. Due to the small active area of micropixel avalanche photodiodes (MAPD), it becomes necessary to use several photodiodes to increase the efficiency of photon collection with a larger scintillator. This work is devoted to the study of the spectral characteristics of a scintillation detector based on a 2x2 matrix of MAPD [6] and inorganic scintillator LYSO [7].

2. Experimental part

In the experiments, micropixel avalanche photodiodes of the MAPD-3NK type were used, which have a sensitive area of (3.7×3.7) mm². A matrix of four micropixel photodiodes with a total sensitive area of (7.5×7.5) mm² was made to collect a sufficiently large number of photons. As a scintillator, a LYSO crystal with a size of $6 \times 6 \times 2$ mm³ was chosen. To supply voltage to each photodiode, a circuit of potentiometers was assembled. The voltage divider and a block diagram of the experiment are shown in Figure 1 (a, b).

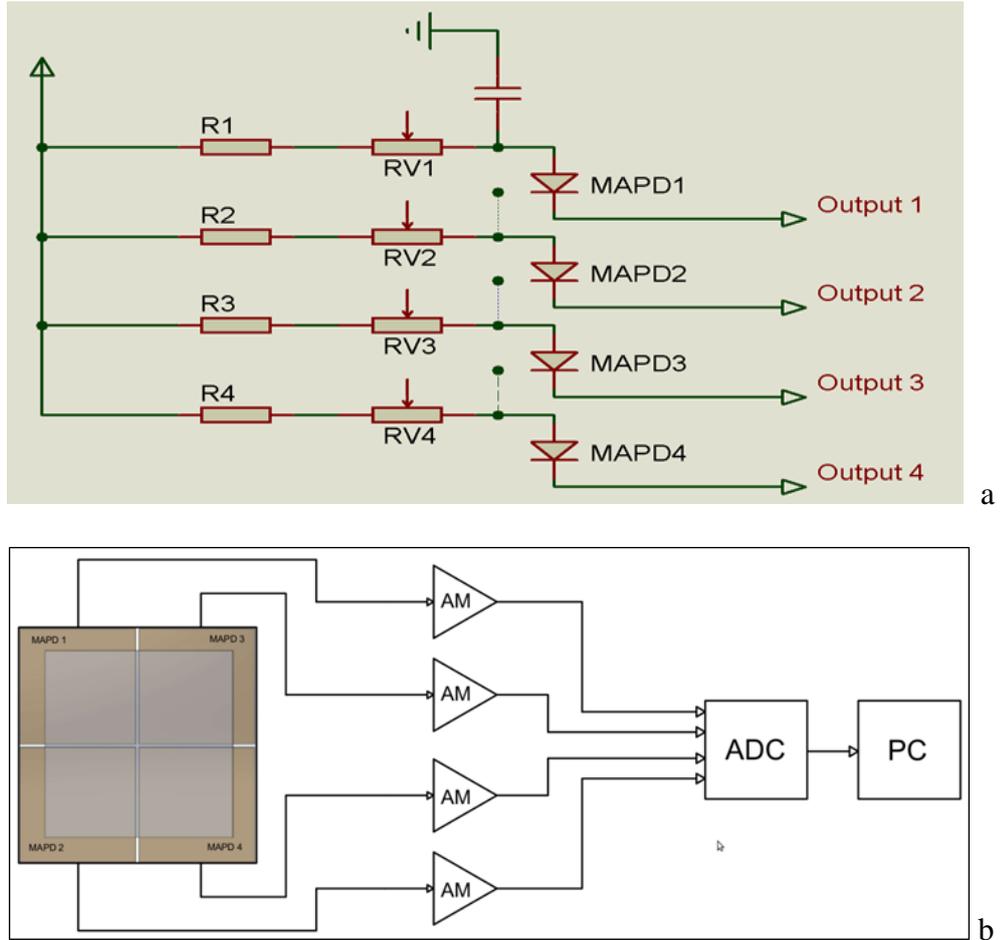


Fig. 1. Voltage distributor circuit (a) and experiment block diagram (b).

A voltage of 93V was applied to the distribution block. For each diode, the optimal operating voltage was selected using RV potentiometers. RC filters were used in each channel of the MAPD to eliminate electrical noise.

To amplify the signal, an AM preamplifier with a gain factor of 40 was installed in each MAPD channel. The signals received from the preamplifiers were recorded and analyzed by a four channel analog-to-digital converter (ADC) CAEN 5720 with a conversion frequency of 250 MS/s and a signal reception speed of 2000 signals/sec.

3. Results and discussions

An inorganic cerium-doped lutetium orthosilicate crystal (LYSO) with a wavelength of 420 nm was used as a scintillator. The specific light yield of this scintillator is ~32000 photons/MeV, which is 65~75% of the specific light yield for the sodium iodine crystal - NaI (Tl).

The presence of the Lu-176 isotope in the LYSO scintillator created its radioactive detector background. This background in the energy spectrum was below 300 keV. The LYSO background spectrum for each MAPD after equalization of their amplification is shown in Figure 2.

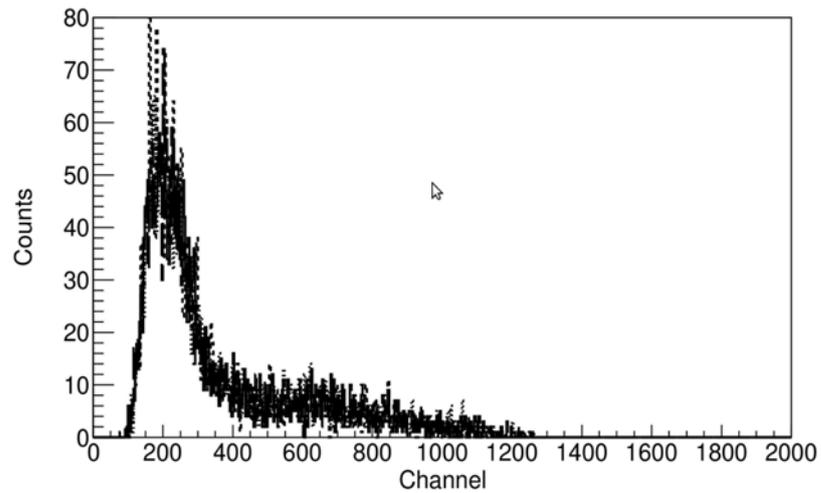


Fig. 2. Background LYSO spectrum from each MAPD.

To analyze the signal received by the CAEN 5720 digital converter, an algorithm was written for the ROOT software environment. The program analyzed the number of events for each photodiode in the case of a signal. This approach excluded extraneous signals arising in the MAPD circuit.

In the experiment, point sources of gamma radiation with different energies were used. The energy range of gamma rays emitted by these sources was 27–1332 keV. Figure 3 shows the amplitude distribution spectrum of Co^{60} (1327, 1332 keV), Am^{241} (60 keV), Ba^{133} (81, 303, 356 keV) and Bi^{207} (570, 1064, 1770 keV) sources recorded by a scintillation detector.

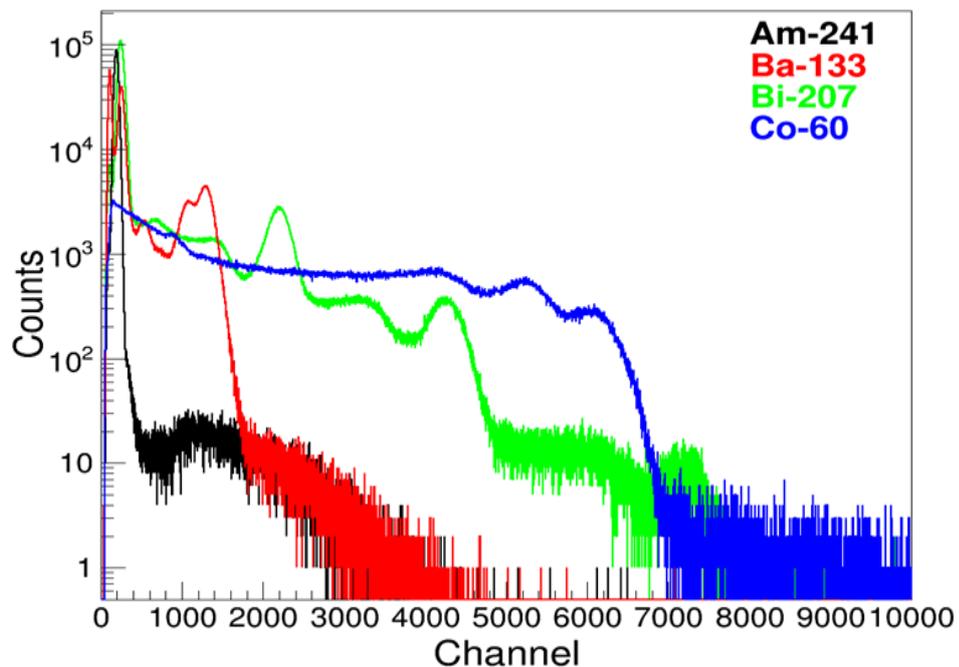


Fig. 3. The amplitude distribution spectrum of Co^{60} (1327, 1332 keV), Am^{241} (60 keV), Ba^{133} (81, 303, 356 keV) and Bi^{207} (570, 1064, 1770 keV) sources

For gamma radiation with the an energy of 662 keV, the resolution was 13%. The dependence of the channels of the analog-to-digital converter (ADC) on the energy of the detected gamma quanta is shown in Figure 4. As can be seen from the graph, this dependence is linear. This result shows that a matrix based on micropixel avalanche photodiodes with an LYSO scintillator can be used as a detector of various ionizing radiation.

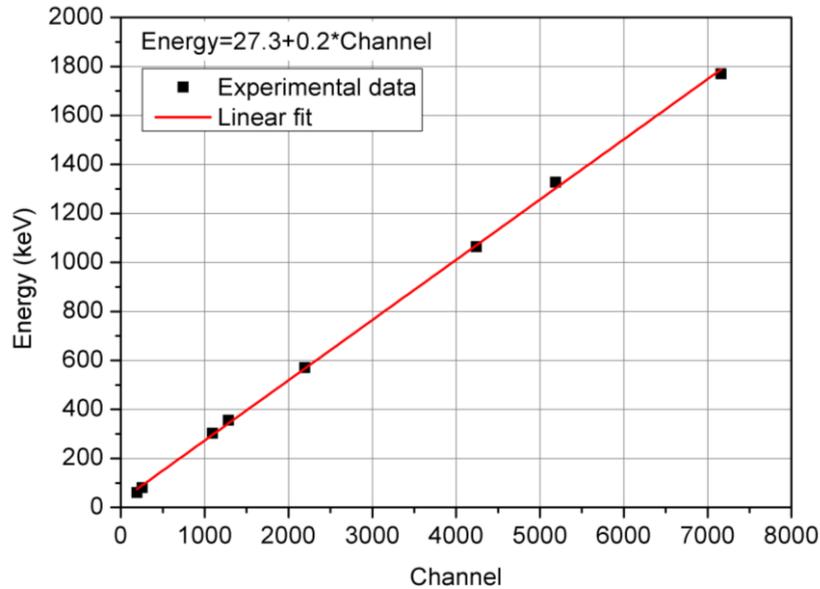


Fig. 4. The dependence of the energy on the channel for analog-to-digital converter CAEN

4. Conclusion

A 2×2 matrix was assembled based on MAPD-3NK photodiodes with an active area of $7.5 \times 7.5 \text{ mm}^2$ with a 0.1 mm gap between crystals. The matrix was tested with an LYSO type scintillator in the size of $6 \times 6 \times 2 \text{ mm}^3$. The energy resolution for gamma radiation of 662 keV (Cs^{137}) was 13%. It is worth noting that the matrix gives a very good linear dependence of the ADC channels on the energy of the detected gamma quanta in the energy range of 27–1332 keV. The results show that the assembled matrix can be used in spectroscopic scintillation detectors of radiation.

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ГАММА-СЦИНТИЛЛЯЦИОННЫЙ ДЕТЕКТОР НА ОСНОВЕ КРЕМНИЕВОЙ -МАТРИЦЫ

С.М. Нуруев

Резюме: В статье представлен сцинтилляционный детектор на основе 2x2 матрицы микропиксельных лавинных фотодиодов (МЛФД) с общей активной зоной (7,5×7,5) мм². В работе использованы новые образцы кремниевых лавинных фотодиодов типа MAPD-3NK с чувствительной площадью (3,7×3,7) мм². Выход каждого МЛФД в 2x2 матрице был унифицирован по коэффициенту усиления с помощью делителя напряжений, состоящего из набора резисторов. Для исследования линейности и энергетического разрешения детектора был применен прямоугольный сцинтиллятор LYSO размером (6×6×2) мм³. Эксперименты были проведены при комнатной температуре с использованием источников гамма излучения в энергетическом диапазоне 27-1332 кэВ.

Ключевые слова: микропиксельные лавинные фотодиоды МЛФД; сцинтилляционный детектор; коэффициент усиления; источник гамма излучения; сцинтиллятор LYSO;

SİLİKON MAPD MATRİSİNƏ ƏSASLANAN GAMMA SİNTİLASIYA DETEKTORU

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Xülasə: Məqalədə ümumi aktiv sahəsi (7,5×7,5) mm² olan, 2×2 şəklində kvadratik yerləşmiş dörd mikropikselli selvari fotodiodlar (MSFD) əsasında yığılmış sinsilyasion detektor təqdim edilmişdir. Sinsilyasion detektor ionlaşdırıcı qamma şüaların qeydedilməsi üçün nəzərdə tutulmuşdur. İşdə həssas sahəsi (3,7×3,7) mm² olan MAPD-3NK tipli silisium əsaslı selvari fotodiodların yeni nümunələrindən istifadə edilmişdir. Dörd MSFD elementindən təşkil edilmiş 2×2 matrisasında hər bir elementin gücləndirmə əmsalına görə çıxışı müqavimətlər sistemindən ibarən gərginlik bölüşdürücüsünün köməyi ilə idarə olunur. Detektorun xəttliliyini və enerjiyə görə ayırdetmə qabiliyyətini tədqiq etmək üçün ölçüləri (6×6×2) mm³ olan, düzbucaqlı LYSO sinsilyatorundan istifadə edilmişdir. Təcrübələr otaq temperaturunda, 27-1332 keV enerji diapazonunu əhatə edən qamma şüalanma mənbələrindən istifadə etməklə aparılmışdır.

Açar sözlər: mikropikselli selvari fotodiodlar MSFD; sinsilyasiya detektoru; güclənmə əmsalı; qamma şüalanma mənbəi; LYSO sinsilyatoru;