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Conference Paper

Scintillation light detection with MAPD-3NK and MPPC-S12572-010P readout

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Abstract

The linearity and energy resolution of two different solid-state photomultipliers (SiPMs) has been studied with reading out the LFS-8 scintillator (3x3x10 mm^3). First SiPM (MAPD-3NK) from Zecotek Photonics consists of deeply burned pixels (cells) and has an active area of 3.7x3.7 mm^2. The second one (MPPC-S12572-010P) from Hamamatsu has a surface cell structure and an active area of 3x3 mm^2. Both SiPMs have the same pixel density of 10000 mm^{-2}. Energy resolution and linearity of the SiPMs has been studied in the energy range of 59.6-1275 keV. It is found that both SiPMs demonstrate good linearity of signal amplitude as a function of the gamma ray energy in the studied energy range. The detector based on the MAPD-3NK provides significantly good energy resolution in comparison to the detector based on the MPPC-S12572-010P.

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1. Introduction

Capabilities of application of silicon photodiodes (SiPM) have advantages over the analogues. These advantages refer to a number of additional characteristics such as low operating voltage, high quantum efficiency, insensitivity to magnetic fields, small size and etc [1-4]. Despite advantages, there are a number of drawbacks related to SiPM performance for scintillation light readout. These drawbacks include dynamic range limitation, photon detection efficiency (PDE) and a possible effect on energy resolution. The dynamic range of SiPM is a measure of its ability to give a signal relative to the energy of incident radiation. SiPM with a wide dynamic range is able to register both low and high incident photon fluxes. The main way to increase the dynamic range of SiPM is increasing the number of pixels. This, however, leads to a decrease in PDE that, in turn, allows accurate light measurement [4-7].

There are a limited number of SiPMs with the high dynamic range. Hamamatsu Photonics produces new SiPMs (MPPC H-015 and MPPC-S12572-010P) with high pixel

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density (up to 10000 mm^{-2}) using a standard surface-pixel technology [8-9]. This decreases significantly the geometric fill factor (GFF) and the PDE due to a high fraction of dead spaces between the individual pixels. Zecotek Photonics Inc. uses deeply buried pixel design to manufacture their SiPMs (also named as Multi-Pixel Avalanche Photo Diode – MAPD) with high pixel density (up to 10000-40000 mm^{-2}). Therefore, the dynamic range of MAPDs has been significantly improved with maintaining the PDE [10-11].

This work is dedicated to studying gamma-ray detection performance of two types of SiPMs with high pixel density (10000 mm^{-2}) produced using a standard surface and deeply burned pixel technology.

2. Parameters of the SiPMs and the scintillator

Two types of SiPMs with a very high pixel density have been used in the experiment. The first one is Hamamatsu's MPPC of S12572-010P type device produced using a standard surface-pixel technology. The S12572-010P has an active area of 3x3 mm^2 and pixel density of 10000 mm^{-2}. Its PDE is 12 % at the operation voltage (70.42 V) [8, 9]. The second is MAPD-3NK produced by Zecotek Photonics Inc with an active area of 3.7x3.7 mm^2. The MAPD-3NK has high PDE ($\approx$ 40 %) at a pixel density of 10000 mm^{-2} due to deeply buried micro pixel design [10, 11]. The same gain (8x10^4) is chosen for both devices in our experiments. Therefore, the bias voltage is 91.3 V for the MAPD-3NK and 69.4 V for the MPPC. The energy linearity of the photodiodes has been studied using the LFS-8 scintillator (3x3x10 mm^3). The LFS-8 is an inorganic scintillator manufactured by Zecotek Photonics Inc [10]. The scintillator is characterized by its fast decay constant (< 35 ns), high density (7.4 g/cm^3) and high light yield (80-85 %). The wavelength of maximum light emission is 422 nm.

3. Experimental

The diagram of the experimental setup is depicted in Figure 1. During the measurements, the LFS-8 crystal, the photodiodes, the preamplifier are placed in a shielded light-tight black box. The LFS-8 scintillator is coupled to the MAPD and the MPPC. The LFS-8 crystal is wrapped with multiple layers of white Teflon tape on all sides except one side, which attached to the photodiode with special optical grease. The signal is amplified by a preamplifier (with a signal gain of 5 and bandwidth ~54 MHz) and is recorded by CAEN DT5720B Desktop Waveform Digitizer (4 Channel 12- bit 250 MS/s). The data are taken in the self-triggering mode of the digitizer and saved for offline analysis in a computer. All the data analysis has been performed using ROOT data analysis framework. The measurements are carried out at room temperature.

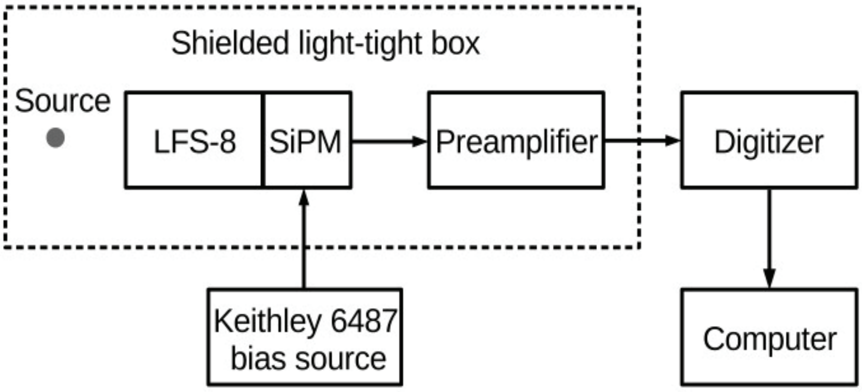

Figure 1: The block diagram of the experimental setup.

The energy linearity has been evaluated by measuring the energy spectrum of different radioactive sources: ^{241}Am (59.6 keV), ^{137}Cs (662 keV) and ^{22}Na (511 keV and 1275 keV). The spectra have been measured at a fixed distance of 10 mm from the source to the photodiodes. Gamma-ray spectra for used sources have been drawn. The characteristic pulse height spectra for ^{241}Am (59.6 keV) and ^{137}Cs (662 keV) gamma sources are shown in Figure 2.

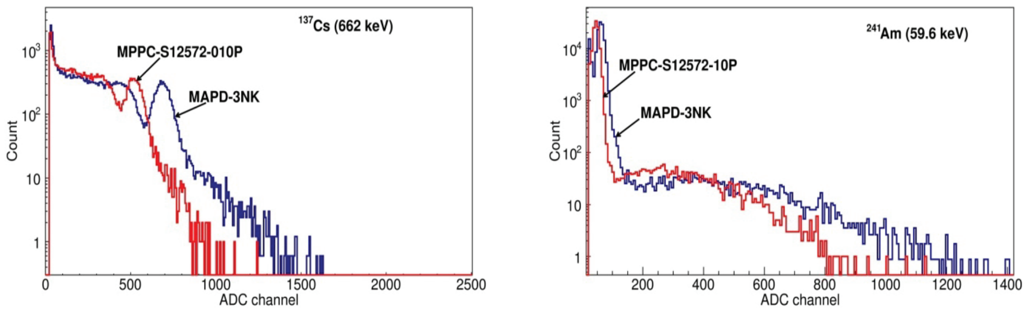

Figure 2: The pulse height spectra of gamma rays from ^{241}Am (left) and ^{137}Cs (right) sources measured with LFS scintillator coupled to the MAPD-3NK and the MPPC-S12572-010P.

The pulse heights and energy resolutions have been found fitting the peaks with the Gaussian function. As shown in Figure 2 the peak positions for the MAPD-3NK have been shifted to a higher channel number. This shift is related to the high GFF (or PDE) of the MAPD-3NK. The GFF is about 33 % for the MPPC-S12572-010P and 100 % for the MAPD-3NK [9]. The SiPM with the higher GFF, being able to collect more light, offers a better energy resolution. The energy resolution for the MAPD-3NK and the MPPC has been found to be 26 % and 37 % for 59.6 keV, respectively. For ^{137}Cs source (662 keV) the energy resolution has been found to equal to 13 % (the MAPD-3NK) and 20.5% (the MPPC-S12572-010P). The obtained results show that MAPD-3NK provides the better response than the MPPC-S12572-010P. The energy resolution of scintillation detector based on the MAPD-3NK is 55 % better than that on the MPPC-S12572-010P.

Figure 3 shows the pulse height spectra from both photodiodes in response to 511 keV and 1274 keV gamma photons from ^{22}Na source.

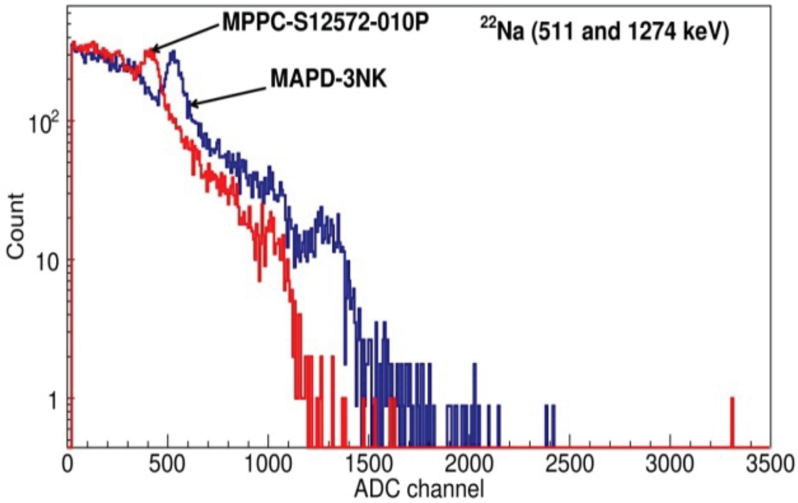

Figure 3: Pulse-height spectra of gamma rays from ^{22}Na source measured with LFS scintillator coupled to the MAPD-3NK and the MPPC-S12572-010P.

An energy calibration curve has been drawn for both photodiodes, taking two points obtained from ^{22}Na spectrum and one point obtained from ^{137}Cs and ^{241}Am spectrum. The linear dependence of the energies and the experimentally measured pulse heights has been observed. This dependence is shown in Figure 4.

The calibration curve has been fitted with a straight line. As shown in Figure 4 both photodiodes demonstrate linearity behavior in the studied energy range (59.6-1275 keV).

4. Conclusion

The gamma-ray detection performance of LFS+MAPD-3NK and LFS+MPPC-S12572-010P is studied in a wide energy range (59.6-1275 keV) at same gain. The energy resolution of 13 ± 2.3% and 20.5 ± 3.8% has been measured for the MAPD-3NK and the MPPC-S12572-010P devices, respectively, for the 662 keV energy gamma rays. The energy resolution was comparable or a little better comparing to the results obtained with the Hamamatsu MPPC. The energy resolution of the scintillation detector based on the MAPD-3NK is 55 % better than that on the MPPC-S12572-010P. Both avalanche photodiodes demonstrate good linearity in the studied energy range.

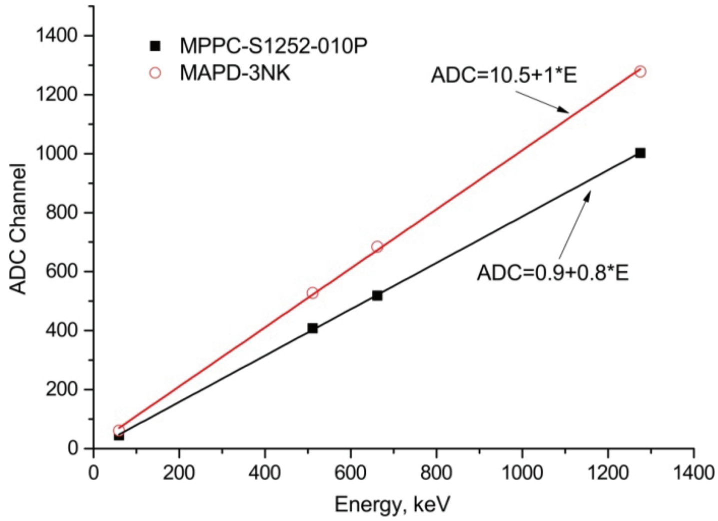

Figure 4: The pulse heights of gamma rays as a function of energy for the MAPD-3NK and the MPPC-S12572-010P.

The results show that these types of photodetectors can be used in high energy physics, public security, industry, and in the space experiments.

Acknowledgments

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