INVESTIGATION OF THE PERFORMANCE OF ALPHA PARTICLE COUNTING AND ALPHA-GAMMA DISCRIMINATION BY PULSE SHAPE WITH MICRO-PIXEL AVALANCHE PHOTODIODE

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Being capable measuring small lights gives possibility to use micro-pixel avalanche photodiodes (MAPD) with scintillators. We show two prototypes to use MAPD with and without scintillators as alpha and gamma counters in this paper. First prototype is to use two MAPD. One for detecting alpha particles and closer to it second one with a thin plastic scintillator for detecting gamma rays. Second prototype is called two-layers configuration in which used only one MAPD but two scintillators with different decay times. One can distinguish alpha particle and gamma ray events by using pulse shape discrimination techniques in the two-layer configuration.

Keywords: micropixel avalanche photodiode; scintillator; counter, pulse shape discrimination.
PACS: 07.77.-n; 07.77.-Ka; 29.40 Wk; 85.30 De; 85.60 Dw.

INTRODUCTION

Micro-pixel avalanche photodiodes are powerful tools for an optical readout. Their gain is about $\sim 10^5$-10^6, photon detection efficiency 15–30%, up to15000 pixel/mm^2 high pixel density and low operation voltage (~90V). Detailed information about Micro-pixel Avalanche Photo Diodes and their parameters can be found [1, 2]. MAPD and its modifications are widely used in the fields such as astronomy, high energy particle physics, medicine, spectroscopy, environmental measurements et.c. [2-8].

COUNTER DESIGNS

a. Two MAPD and 3x3x1 mm plastic scintillator were used in the fist prototype. The MAPD without scintillator is for alpha particle detector. It is completely insensitive to gamma rays due to small active region (4mkm). Gamma photon detection is usually performed with scintillation detectors. Therefore the second MAPD with the plastic scintillator (p-terphenil) was placed very close to the first one to register gamma rays. The MAPD with scintillator is also sensitive alpha particles. Experimental setup is shown in Fig.1 (a) for testing the prototype.

b. Only a MAPD and two scintillators were used in the second prototype (the two-layer configuration). The scintillators were BGO (Bismuth germinate Bi4Ge3O12) and p-terphenil (C14H18) plastic which decay times are 300ns and 3.7 ns, consequently. Plastic scintillator thickness was very thin (1mm) but it is enough to stop alpha particles since the range of 6 MeV alpha particles in plastic is around 50 μm [9]. Therefore all of the energy of the alpha particles is absorbed in plastic scintillator (the first layer). Besides alpha particles low energy gamma photons are also absorbed in the first layer due to the thickness of the plastic scintillator. 3x3x10 mm BGO scintillator was used for detection penetrated gamma rays through the first layer. Experimental setup is shown in Fig.1 (b) for testing the prototype.

EXPERIMENTAL SETUP AND METHODS

Experimental setup is shown in Fig.1 for testing the prototypes. The MAPD was biased by Keithley high voltage supply via RC circuit (390kOm resistor and 30 nF capacitor) for noise suppression. Amplifier with a 25 voltage gain was used to amplify signal from the MAPD. The signals from the MAPD were digitized using a 5GS/s DRS-4 digitizer. The digitized signals were fed to personal computer (PC). The digitized data were processed offline using ROOT. It was used a subtraction method to find number of alpha and gamma events in the first prototype. If assumed that N_g is event number of gamma photons and N_a alpha particles then event numbers are N_a on the first detector, but N_a+N_g on the second. Event numbers corresponding to alpha particles and gamma rays were found from their difference. Because N_a is always known (the bare MAPD is insensitive gamma rays). Am^{241} alpha and Cs^{137} gamma ray radioactive sources were used for testing the both detectors. The registered alpha particle events by the both detectors were shown in Fig.2.

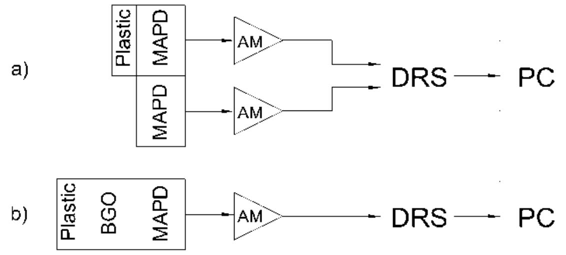

Fig.1. Experimental setup.

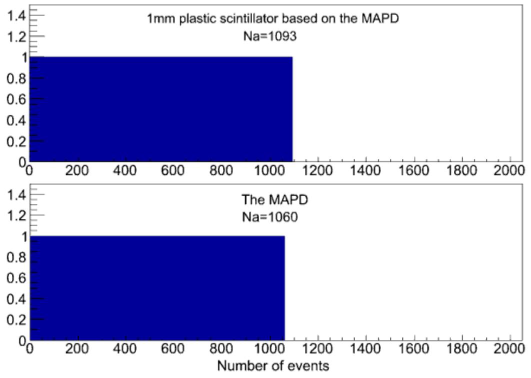

Fig 2. Alpha particle events from the plastic scintillator based on MAPD (up) and from the MAPD (bottom).

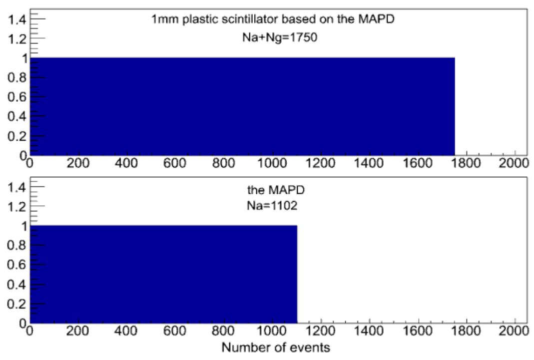

Fig 3. Alpha-gamma events from the plastic scintillator based on MAPD (up) and alpha particle events from the MAPD (bottom).

It is shown that from Fig.2 the both detectors register about same events. The experiment was repeated for several times and every time the registered events were close to each other with 5% uncertainty. Number of events from Cs^{137} and Am^{241} sources was shown in Fig. 3. Counted events by the MAPD for two cases were about same as shown from Fig.2 and Fig.3. One can calculate number of gamma events from difference of the both detectors' responses. Gamma ray events were 650 in the experiment. This result was also tested with just Cs^{137} gamma ray source and the registered events were close to each other with 5% uncertainty.

The pulse shape discrimination technique was used for the second prototype. Since the decay time of BGO is 300 ns and of plastic scintillator is 2.4 ns, and then one can easily discriminate long and short signals. Output signals from MAPD with BGO and plastic scintillators are shown in Fig. 4. Because of the limitation of the band width of the amplifier, the measured decay time is around 80 ns for plastic scintillator.

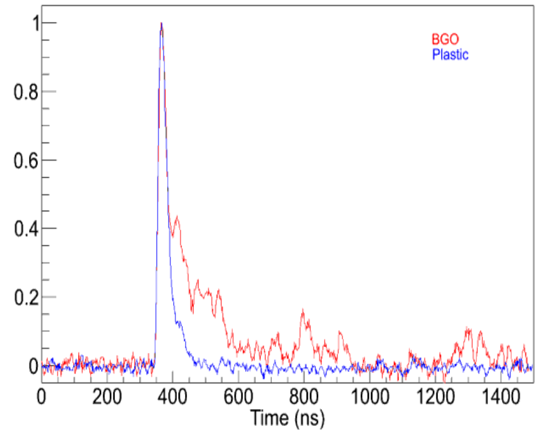

Fig. 4. Normalized output signals from MAPD with BGO and plastic scintillators.

Pulse height differences between the scintillators that complicate signal processing were solved using normalization. Signals from both detectors were normalized to 1 for exact discrimination. It makes discrimination easy and prevents to confuse alpha and gamma events. The integration windows were selected digitally by PC.

CONCLUSION

In this work a alpha particle and gamma ray counting performance of MAPD diode without scintillators and in combination of plastic and BGO+ plastic scintillators was investigated. Obtained results showed the detection performance of the MAPD diode in combination plastic scintillator was about same as conventional semiconductor detectors. The pulse shape discrimination technique was studied by MAPD diode in combination of BGO+plastic scintillators too. The large differences between scintillators decay times allowed making discrimination easy and preventing to confuse alpha and gamma events.

This research was supported by SOCAR grant.

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Recevied:16.01.2015