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NEW ALPHA PARTICLE COUNTER BASED ON MICRO-PIXEL AVALANCHE PHOTODIODE

F.Ahmadov[a,d], G.Ahmadov[a,b], N.Anfimov[a], A.Garibov[d],
E.Guliyev[e], Z.Krumshtein[a], R.Madatov[d], A.Olshevski[a],
A.Sadigov[a,d], Z.Sadygov[a,b], A.Titov[c]
[a] *Joint Institute for Nuclear Research, Dubna, Russia*
[b] *Institute of Physics-ANAS, Baku, Azerbaijan*
[c] *All-Russian Research Institute of Automatics named after N.L.Dukhov, Moscow, Russia*
[d] *Institute of Radiation Problems-ANAS, Baku, Azerbaijan*
[e] *LLR Ecole Polytechnique, Palaiseau, France*
farid-akhmedov@yandex.ru

Abstract: The main goal of this work is study of possibility to detect alpha particles with micro-pixel avalanche photodiode (MAPD) which has very thin active volume. The obtained results show that alpha detectors based on the MAPD can be used as alpha particle counter in many experiments: public security (Associated Particle Imaging for explosives and drugs detection), radioactive contamination monitoring in various environments and detection of charged particles from nuclear reactions.

Keywords: *micro-pixel avalanche photodiode, alpha counter, nuclear reaction, public security.*

1. Introduction

Challenges of the last decade have made detection of explosives and drugs in baggage and large cargoes an important task. Neutron based detection techniques have shown to be very promising in detection and identification of those (Associated particle imaging). Neutrons can penetrate deeply into luggage and cargo and interact with nuclei in the materials producing characteristic gamma spectra [1, 2].

The main idea of this method is creation of neutrons in the generator as a result of deuterium beam interaction with tritium target. The interaction is accompanied by emission of alpha particles flying in opposite to the neutrons direction. Capture of neutrons within a given nucleus produces a specific for the resulting isotope gamma spectrum. Analysis of the gamma spectrum allows one to determine atomic composition of the substance and identify it. Detection of the alpha particle allows one to determine direction of the neutron and generate a trigger signal. This helps to detect the necessary signal even in presence of a large background. Therefore development of fast alpha particle detectors has a growing interest.

It is well known that MAPD has good timing characteristics and radiation hardness. Therefore the most challenging task in this work is registration of alpha particle with the MAPD which has very thin (4 μm) active volume.

2. Experiment procedures

Design and operation principles of the MAPD were described in [3, 4]. Tested device MAPD (regular APD mode) had 3×3 mm^2 active area, the thickness of active layer 4 μm and pixel density 40000 pixels/mm^2. Gains of MAPD-3 diodes were 60 respectively at 126.5 V. Capacitance of the MAPD diodes reached up to 120 pF. Dark current of MAPD diode was 4 nA respectively at operating voltage. Recovery time of the MAPD was 40 nsec.

The tested MAPD samples were developed in collaboration with Zecotek Photonics Singapore Pte. Ltd. [5].

The ^{241}Am radionuclide was ***used*** as the ***source*** of alpha particles with energy 5.486 MeV. Activity of ^{241}Am point source was 50 kBk. Distance between the MAPD diode and alpha particle source was 1 cm, therefore, alpha particle ***energy*** loss in the air was about 1 MeV and remaining energy was about 4.5 MeV.

A block diagram of the experimental setup was described in Fig. 1. Experimental setup consists of the MAPD which is powered by Keithley 6487 high voltage source (H.V.), line amplifiers (K~ 80, 25), CAEN DT5720B Desktop Digitizer. The signal from MAPD is initially amplified by the line amplifier.

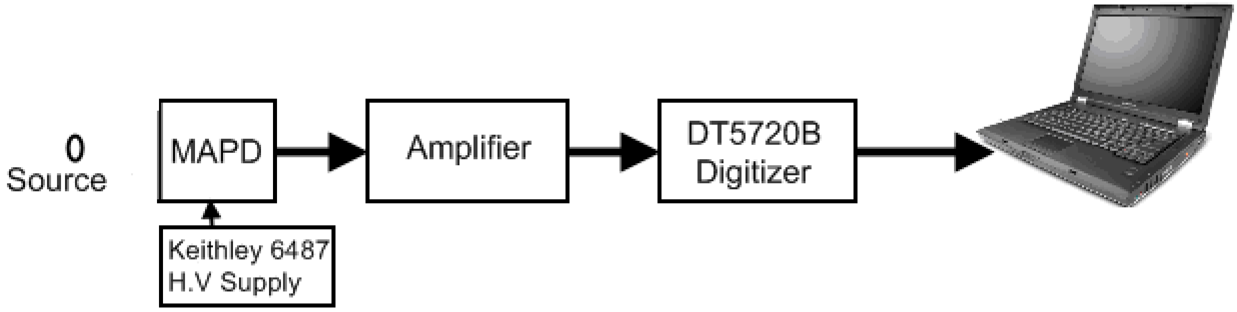

Figure 1: Block diagram of the experimental setup.

The output of the liner amplifier is connected directly to CAEN DT5720B Desktop Digitizer. Each of the pulses is digitized at 250 MS/s and 12 bit resolution. The sampled data are read out by the personal computer through USB connection. Peak positions and their full width at half maximum (FWHM) were obtained from Gaussian fit. All measurements were carried out at room temperature.

3. Results and discussion

The MAPD operating in regime of convenient APD was used for direct detection of alpha particles from ^{241}Am source. When ***alpha particle*** penetrates the diode it generates electron-hole pairs. Alpha particle loses about 700 keV (for 0^{o} incident angle) in the 4 μm thick depletion region of the MAPD. Alpha particle generates about 200000 electron and hole pairs in depletion region.

In Figure 2 the typical output of digitized preamplifier signal presented. The signal is obtained using of Am-241 source. The rise and fall time of output signal is 3 nsec and 28 nsec. The amplitude of output signal is 133 mV.

The alpha spectra were taken at MAPD bias voltages in the range from 50V to 126.5 V. The spectra obtained at all bias voltages differed substantially from the spectrum obtained with a conventional semiconductor detector. The first major difference was observation of two peaks (50-115 V, diode gain reaches 2) corresponding to the same particle energy (Fig. 3 (a)).

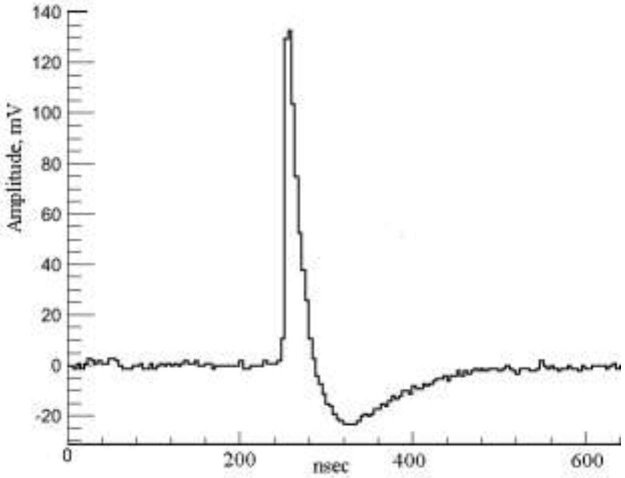

Figure 2: The recorded trace from the amplifier output.

Positions of the primary (left) peak depended strongly on the bias voltage (or gain) while dependence on the voltage of the secondary peak was much weaker. With further increasing voltage and gain the secondary peak became wider and proportion between peak areas had changed (Fig. 3(b)). The possible explanation of this is following. In the case of small incident angles, most of the electrons (several hundred thousands) produced by alpha particle hit the same pixel or area between two or four adjacent pixels within very short time (several ns). Due to gain saturation in the first case the pixel does not work in normal mode (or does not multiply electrons in normal mode) while in the second case (hitting area between two or four adjacent pixels) charge is spread between the pixels and that does not cause such saturation. It is well known these difference dependences on the incident angles too.

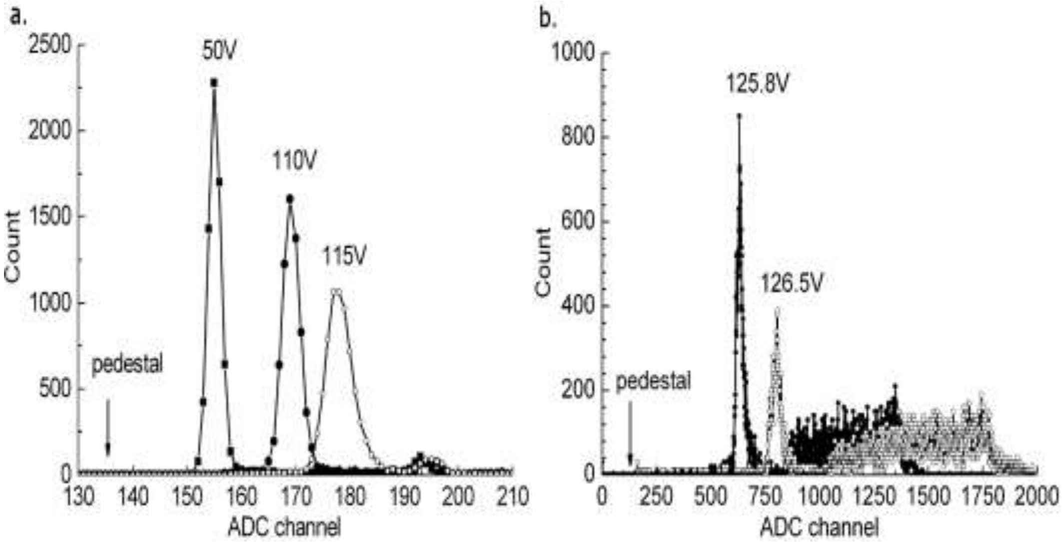

Fig. 3. A set of alpha spectra recorded with an MAPD avalanche photodiode: a- bias voltage 50–115 V (amplifier- 80); b- bias voltage 125.8–126.5 V (amplifier- 25).

Obtained results of experiment shows the MAPD can also be used as alpha detector only in the energy range from 100keV to 700keV and as alpha particle counter in the energy range from 800keV to several MeV in different experiments (associated particle imaging, detection of fission fragments and dosimetry [6-8].

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