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МЕТОДИКА ФИЗИЧЕСКОГО ЭКСПЕРИМЕНТА

ALPHA PARTICLE DETECTOR BASED ON MICROPIXEL AVALANCHE PHOTODIODE

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The main goal of this work is to study the possibility of detecting alpha particles with a micropixel avalanche photodiode (MAPD) in combination with Lutetium Fine Silicate (LFS) scintillators (500 μm thick). The results show that alpha detectors based on the MAPD are expected to be useful in many applications: public security (associated particle imaging for explosives and drugs detection), radioactive contamination monitoring in various environments, and detection of charged particles from nuclear reactions.

Главная цель этой работы — изучение возможности регистрации альфа-частиц с помощью микропиксельного лавинного фотодиода (МЛФД) в комбинации со сцинтиллятором из ортосиликата лютеция (LFS) толщиной 500 мкм. Полученные результаты показывают, что основанные на МЛФД альфа-детекторы могут быть применены в следующих областях: общественная безопасность (обнаружение взрывчатых и наркотических веществ), мониторинг радиоактивного загрязнения окружающей среды и обнаружение заряженных частиц от ядерных реакций.

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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 deep 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 the deuterium beam interaction with a tritium target. The interaction is accompanied by emission of alpha particles flying in the direction opposite to that of neutrons. Capture of neutrons

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within a given nucleus produces a gamma spectrum specific for the resulting isotope. 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 the direction of the neutron and generate a trigger signal. This helps to detect the necessary signal even in the presence of a high background. Therefore, development of fast alpha particle detectors arouses growing interest.

It is well known that the micropixel avalanche photodiodes (MAPD) have good timing characteristics and radiation hardness. Therefore, the most challenging task in this work was registration of alpha particles with MAPD devices. A MAPD device designated MAPD-3N had Geiger mode performance.

1. EXPERIMENT PROCEDURES

The MAPD-3N used here contains a silicon plate of n-type conductivity on which two silicon epitaxial layers of p-type conductivity were grown. The device also contains a matrix of independent n^+-type pixels buried deep in the epitaxial layers mentioned above. This design of the device provides superwide linearity of photoresponse due to high pixel density on the sensitive area. The design and operation of this device were described in [3, 4]. The tested MAPD-3N device had a 3×3 mm active area and pixel density 15000 mm^{-2}. Full thickness of the depletion layer in the MAPD-3N was about 8 μm. The gain of the MAPD-3N diode was $5.5 \cdot 10^4$ at the operating voltage 94 V. The capacitance of the MAPD-3N was about 120 pF. The maximum photon detection efficiency of the MAPD-3N was about 30% around 450–525 nm light wavelengths. The dark current was 77 nA at the operating voltage.

The LFS (Lutetium Fine Silicate crystal) type scintillator sample LFS-8 [5] was used as a target for alpha particles. The size of the LFS-8 was $3 \times 3 \times 0.5$ mm. Its decay time was 19 ns. The LFS-8 scintillator was coupled to the MAPD-3N with silicone optical grease. Both the MAPD-3N diode and the LFS-8 scintillator were developed in collaboration with the Zecotek Photonics Singapore Pte. Ltd.

The ^{241}Am radionuclide was used as a source of alpha particles with energy 5.486 MeV. The distance between the MAPD diode and the alpha particle source was 1 cm; therefore, the alpha particle energy loss in the air was about 1 MeV and the remaining energy was about 4.5 MeV.

Figure 1 shows the block diagram of the setup. A high-voltage power supply Keithley 6487 was used for MAPD biasing. The spectrum measurements were performed using a preamplifier with the gain of 30, CAEN N-48 shaping discriminator, and LeCroy 2249W ADC. The amplified and delayed signal was fed into the ADC. The CAEN N-48 shaping

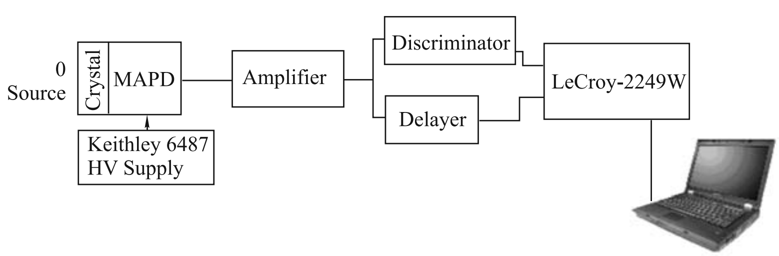

Fig. 1. Block diagram of the experimental setup

discriminator was used to form a gate signal for the ADC. All measurements were carried out at room temperature.

2. RESULTS AND DISCUSSION

In order to measure alpha particle spectra, the LFS-8 scintillator was placed on top of the MAPD-3N with a thin layer of optical grease between them. The alpha spectrum from the LFS-8 scintillator was taken at the MAPD-3N bias voltage 94 V (Fig. 2). When an alpha particle penetrates into the scintillator, it deposits its entire energy. The deposited energy converts into scintillation light which is emitted from the alpha particle track. The scintillation light was detected by the MAPD-3N. Edges of the scintillator were covered with 5 μm thick aluminum foil.

Two peaks are well seen in Fig. 2. It is known that the ^{241}Am source emits 59.6 keV gamma rays as well. To confirm that the first peak was due to the gamma ray, a thick aluminum layer was placed between the ^{241}Am source and the scintillator. Alpha particles were absorbed in aluminum and a single gamma ray peak was observed in the spectrum. The energy resolution for the 4.5 MeV alpha particles was 8.6%.

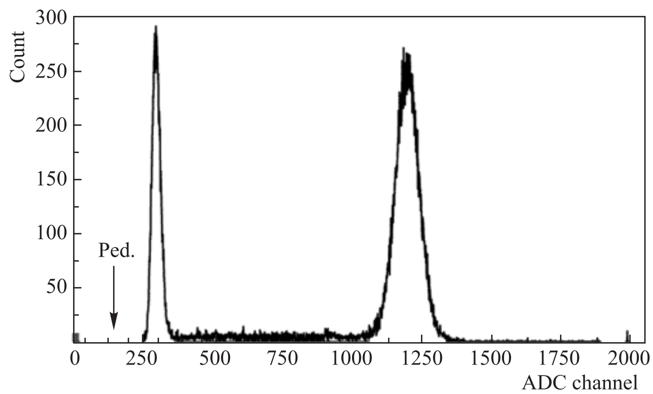

Fig. 2. Amplitude spectrum of the ^{241}Am source obtained with the MAPD-3N1P coupled with the LFS-8 scintillator (preamplifier gain 30)

The results show that the MAPD-3N-type devices in combination with a thin LFS-8-type scintillator can be used as fast alpha particle detectors for public security (associated particle imaging for explosives and drugs detection). In addition, these kinds of detectors can be used for monitoring radioactive contamination in various environments and for detecting charged particles from nuclear reactions.

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