Investigation of gamma ray detection performance of thin LFS scintillator with MAPD readout

E.Guliyev\textsuperscript{a}, F.Ahmadov\textsuperscript{b}, G.Ahmadov\textsuperscript{b}, A. Sadigov\textsuperscript{b}, Z.Sadygov\textsuperscript{b}, N. Anfimov\textsuperscript{b}, Z. Krumshtein\textsuperscript{b}, A. Olshevski\textsuperscript{b}, V. Shvetsov\textsuperscript{b}, V. Zhezher\textsuperscript{b}, R. Madatov\textsuperscript{c}

\textsuperscript{a}LLR-Ecole Polytechnique, CNRS/In2p3, 91128 Palaiseau, France CEDEX
\textsuperscript{b}Joint Institute for Nuclear Research, 141980 Dubna, Russia
\textsuperscript{c}Institute of Radiation Problems, AZ-1143 Baku, Azerbaijan

E-mail: elmaddin@llr.in2p3.fr

ABSTRACT: Prototype of gamma ray detector based on Micro Pixel Avalanche Photodiodes (MAPD) with high pixel density 15000 pixel/mm\textsuperscript{2}, optically coupled to Lutetium Fine Silicate (LFS) scintillator has been developed. The detection performance investigated in the range of energy 59.6 - 662 keV at room temperature. The results of measurements are presented in this work.

KEYWORDS: gamma ray, photo-diode, scintillator, detector, pixel, spectroscopy, low energy.
1. Introduction

Gamma ray detectors play an important role in detection and spectroscopy of the emitted photons of unstable nucleus, nuclear reactions and high energy physics experiments. The performance of gamma ray detectors puts a series of requirements on detector active material and readout electronics. For instance, the main requirements of detector material to have a high light yield and fast decay time, radiation hard and high photon detection efficiency, small size, high sensitivity for single photons in wide spectral energy range, insensitivity to magnetic field, low noise, dynamic range for detector readout electronics together with photo-sensor. The scintillation crystal Lutetium Fine Silicate (LFS-8) fits very well those requirements in small size with the combination of MicroPixel Avalanche Photodiode (MAPD). The performance of gamma ray detector based on LFS-8 scintillator with MAPD photo-sensor investigated in the energy range from 59.6 keV to 662 keV. MAPD and scintillator LFS-8 manufactured by Zecotek Company were used [1].

2. Experimental setup and results

In this study, LFS-8 scintillating crystal with dimensions 3 x 3 x 0.5 mm³ produced by Zecotek Company, was tested. The surface of crystal polished and was shielded with 5 µm thin aluminium film [2]. The light luminescence yield compared to NaI(Tl) is very high, about 80% (main properties of LFS-8 crystal are presented in Table 1).

| Parameter          | LFS     |
|--------------------|---------|
| Density            | 7.13 g/cm³ |
| Light yield        | 30000 ph/MeV |
| Decay time         | 12-25 ns |
| Attenuation length | 2.6 cm  |

The LFS-8 scintillation crystals assembly with the MAPD to measure the energy response of radioactive sources. These photo-sensors have several advantages: insensitivity of magnetic field and a high pixel density, 15000 pixels/mm² [4], high gain 5.5 × 10⁴ and photon detection efficiency
25-30% at room temperature in a wide wavelength range at operation voltage [5]. The number of pixels in per \( \text{mm}^2 \) is almost 10 time higher and less dark count compare to Hamamatsu silicon based MPPC (Multi Pixel Photon Counter) [6]. Dark current is around of 70 nA at operation voltage 94 V. Capacitance of MAPD reaches up to 120 pF [7]. The block-diagram of experimental setup is depicted in Figure 1 and contains photo-detector, charge sensitive preamplifier, the digitizer module. The surface of LFS-8 scintillator was placed at a distance of 1 cm from the gamma ray source. The preamplifier output signals were directly digitized by the 12-bit resolution and 250 MS/s sampling rate of CAEN DT5720B digitizer module ([8]) and the digitized traces were stored on disk for further analysis.

![Figure 1](image.png)

**Figure 1.** The scheme of the experimental setup to study the performance of the gamma ray detector base on thin LFS scintillator with MAPD readout [2].

The data acquisition (DAQ) was triggered when the gamma ray of the point source hits the detector. For the events, we took the amplitude of the obtained pulse to obtain about the energy. The baseline is estimated from the left side of preamplifier waveform (Figure 2).

The details of used sources is shown in Table 2. The corresponding spectrum of that sources presented in Figure 3. As shown in Figure 3, the combination of LFS-8 with MAPD gives possibility to detect the low rate gamma rays (Sn-113 70Bq).

| Radionuclide | Activity, kBq | Energy, keV |
|--------------|--------------|-------------|
| Am-241       | 101          | 59.6        |
| Cd-109       | 241          | 88          |
| Co-57        | 4.7          | 122         |
| Ce-139       | 0.22         | 165.9       |
| Sn-113       | 0.07         | 391.7       |
| Cs-137       | 104          | 662         |

The calibration curve between measured ADC channels and known gamma ray energy was given in Figure 4. The uncertainties for measured peak positions are very small.

There is one measurement we confirmed to see that, the separation of the gamma rays, where
energies to closed each other. For this measurement Am-241 and Cd-109 sources placed together in front of the LFS-8 scintillator. From the Figure 5 we can see separated gamma rays from different sources, that measured at same time.

3. Conclusion

The series of study was shown that LFS-8 scintillator with MAPD photo-sensor readout are suitable for compact gamma ray spectroscopy. Due to high efficiency of MAPD photo-sensor and enough luminescence light yield of LFS-8 scintillator gives possibility to utilize such combination low-level radioactivity measurement in environmental radiation pollution.

References

[1] www.zecotek.com
[2] F.Ahmadov, E.Guliyev, Development of scintillation detectors based on Micro Pixel Avalanche Photodiode (MAPD), International workshop on new photon-detectors 2012.LAL, Orsay, France
[3] Nucl. Instr. and Meth. in Phys. Res. A 617 (2010)78
[4] Z. Sadygov, Russian Patent â˝U 2316848, priority from 01.06.2006
[5] Nucl. Instr. and Meth. in Phys. Res. A 610 (2009)381
[6] www.hamamatsu.com
[7] Nucl. Instr. and Meth. in Phys. Res. A 628 (2011)369
[8] www.caen.it
[9] www.keithley.com
Figure 2. The recorded trace from the preamplifier output.
Figure 3. The energy spectrum for different gamma ray source in the LFS-8 scintillator coupled to MAPD readout.

Figure 4. The calibration curve between measured ADC channels and known gamma ray energy. The uncertainties for measured peak positions to smaller.
Figure 5. The energy spectra measured at the same time with Am-241 and Cd-109 gamma ray sources. It is clear that the 3 x 3 x 0.5 mm$^3$ size of scintillator with 3 x 3 mm$^2$ MAPD can distinguish low energy 59.6 keV and 88 keV gammas.