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Revealing ^{226}Ra Alpha Peak by a Multi-Pixel Photon Counter

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Abstract: ^{226}Ra alpha peak was revealed by a Multi-Pixel Photon Counter (MPPC) through a developed spectrometer. MPPC is consisted of silicon photomultipliers (Si-PM) which can be used for photon detection and measurement. It is one of the new generation counter types. It has been used in many research areas such as radiation detection and optics. So, this type detector was chosen so that this study is up-to-date. Main goal of the study is to obtain pure alpha energy spectrum because no study was found in the literature about the neat alpha spectrum by the MPPC. For this reason, coincidence gate method was used in the presented study to acquire the spectrum. In the first section, alpha spectrum was recorded directly via MPPC module. This spectrum had too much electronic noise. The spectrum was secondly obtained through the developed spectrometer. This second spectrum had not almost all noise components. Then, the obtained spectra were compared with each other at the final section. The asserted spectrometer was highly successful in obtaining neat alpha spectrum by reducing the most noise components. It has been realized that the neat source spectra of other radioactive sources can be achieved by using this spectrometer with MPPC. Additionally, students who work about radiation detection can use the suggested spectrometer in their experiments.

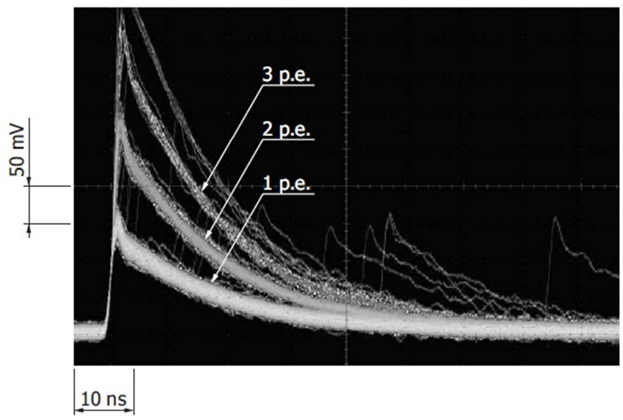
Keywords: Multi-Pixel Photon Counter, Alpha Spectrum, ^{226}Ra

1. Introduction

A Multi-Pixel Photon Counter (MPPC) is a kind of semiconductor device called Si-PM (silicon photomultiplier). It is a new type photon-counting device. It has high photon-counting capability and can be used in various applications to detect weak light at the photon counting level. Since it is immune to magnetic fields, highly resistant to mechanical shocks, and will not suffer from "burn-in" by incident light saturation, which are advantages unique to solid-state devices, it has a potential to replace conventional detectors used in photon counting up to now [1].

MPPC modules have been used in different application areas in recent years and it is expected to open up new applications in the photon counting region, such as fluorescence measurement, DNA analysis, environmental chemical analysis, high energy physics experiments, and many other fields [2-5].

A MPPC has too many pixels that electrically connected with each other. Each pixel in the MPPC outputs a pulse at the same amplitude when it detects a photon. Pulses generated by multiple pixels are output while superimposed onto each other (Figure 1).



(pe: photon equivalent, equivalent to detecting photon(s)).

***Figure 1.** MPPC pulse waveforms [1].*

Scintillators are the materials (solids, liquids, gases) that produce sparks or scintillation lights when ionizing radiation which passes through them [6].

Song et al. [7] have used the MPPC to build a PET detector module. The performance of the MPPC was studied in PET applications by Nassalski et al. [8]. Bonanno et al. [3] have shown characterization results of the MPPC module. ^{226}Ra spectrum was achieved through scintillation detector by Hosseini and Fathivand [9]. Romanko [10] has acquired the experimental ^{226}Ra energy spectrum. Tests of the different types of MPPCs were carried out by Tsujikawa et al. [4]. Kataoka et al. [5] have used the MPPC module in medical imaging. Pulse width measurement was made via MPPC module by Taira et al. [11]. Grodzicka-Kobylka et al. [12] have studied the n-γ discrimination by means of MPPC.

As it is known, light has a property in both a particle and a wave. When the light level becomes extremely low, light behaves as particles (photons) allowing us to count the number of them. The MPPC is suitable for photon counting since it offers high time resolution and gain with low noise. Compared to ordinary light measurement techniques that measure the output current as analog signals, photon counting delivers a higher stability even in measurements at very low light levels [1]. From this point of view, the study planned to count the photons generated by alpha particles in a light emitting medium.

In this study, experimental ^{226}Ra alpha spectrum was achieved by means of the introduced MPPC. In addition, pure alpha spectrum was obtained using coincidence gate method in the present study, reducing the noise components.

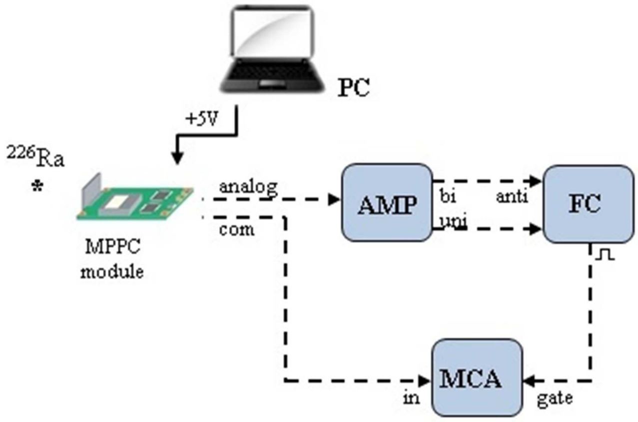
2. Experiments and Results

In this experimental study, A HAMAMATSU MPPC standard module (C10507-11-100U) which composed of Si-PM semiconductor sensor was used. The module has analog and comparator (digital) outputs. A photo of the used module is shown in Figure 2.

Figure 2. Photograph of the used MPPC and the radiosource.

The ambient temperature was 25°C during the measurement. EJ-428-00 Fast Neutron Scintillator (FNS) (same as EJ-26-00, much ZnS:Ag but less ^{6}LiF with no backing) which has 100μm thickness was placed in front of the Si-PM window. When alpha particles are hit the FNS, photons at 450 nm wavelength are released [13], and the Si-PM sensor detects these photons since it is sensitive to photons in the wavelength range of 320-900 nm [14]. Thus, the MPPC device can be used as an alpha detector.

226Ra radiation source with the activity of 9 µCi for alpha particles was used in this study. In order to prevent electronic noise generated by the ambient light, all system was put into a dark box. And also, the box was placed in a cooler to keep the system in constant temperature. Data acquisition time was set 100 s. The block diagram of the used experimental setup is also depicted in Figure 3.



(AMP: amplifier, FC: fast coincidence, MCA: multichannel analyzer).

Figure 3. *Circuit scheme of the used spectrometer.*

Firstly, the comparator (com) output of the MPPC was directly forwarded to input of a multichannel analyzer (MCA, ORTEC Trump 8K) in the experimental setup (Figure 3). The comparator output signal shape of the MPPC module was shown in Figure 4. The recorded system noise can be seen in the figure.

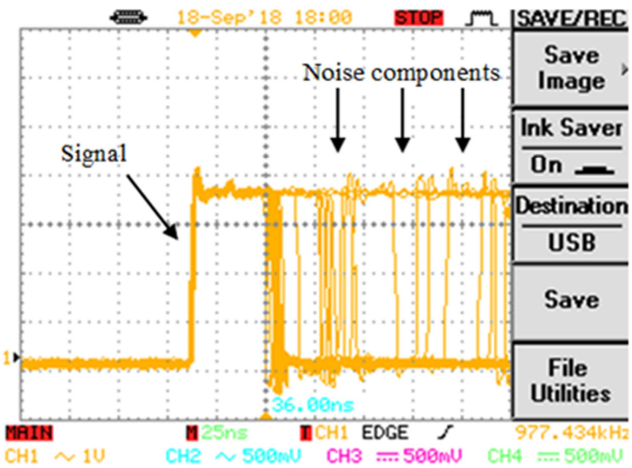


Figure 4. *Comparator output signal shape of the used MPPC module.*

Secondly, analog output of the MPPC was connected to the amplifier (AMP, ORTEC 671). In Figure 5, analog output signals of the used MPPC module were shown. Noise signals, which are also called as afterpulses, can be noticed in this figure.

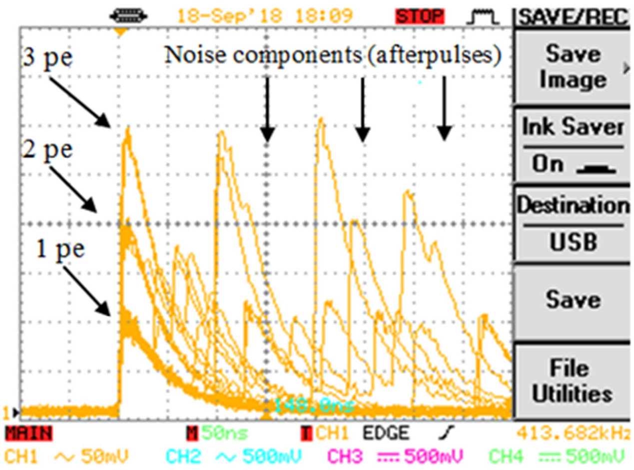


Figure 5. Analog output of the used MPPC module.

Then, the bipolar and unipolar outputs of AMP were connected to the anti-coincidence and the coincidence inputs of a coincidence module (FC, ORTEC 414A), respectively. The output signal shape of the FC was given in Figure 6.

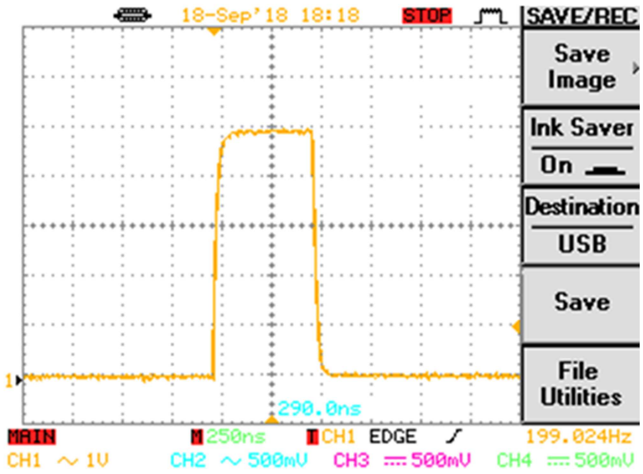
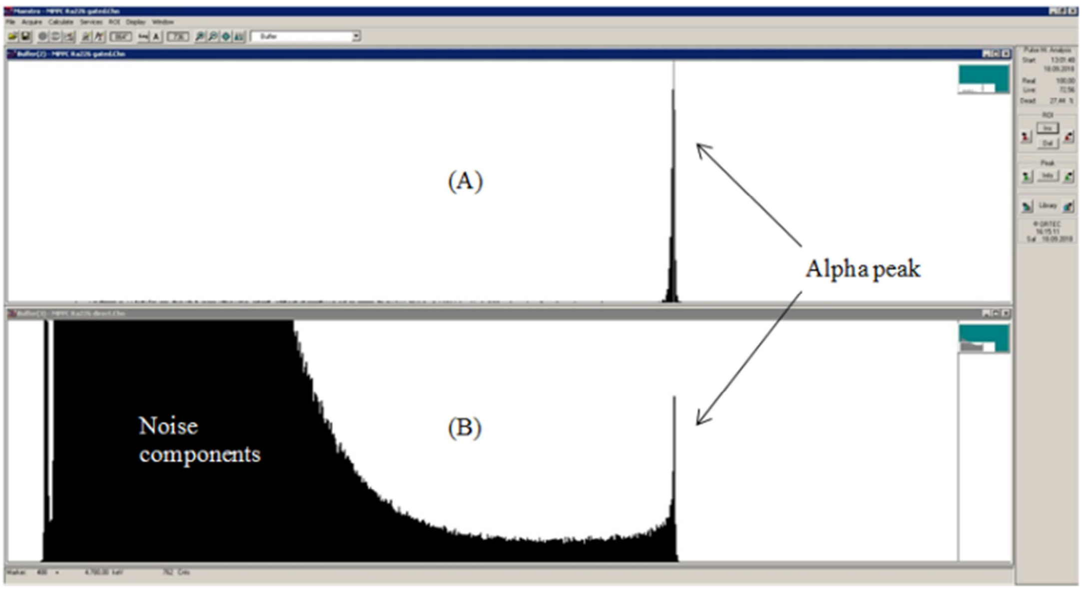


Figure 6. Output shape of the used fast coincidence unit.



(A) through the developed spectrometer, (B) MPPC output.

Figure 7. *Images of the alpha spectra from the MCA (x: channel numbers, y: counts).*

The logic output of the FC was finally forwarded to gate input of the MCA. Coincidence signal acquisition of the outputs from the FC and the comparator output of the module in the MCA has generated the noise free energy spectrum of the used radioisotope. Coincident energy spectrum from the presented spectrometer and the energy spectrum directly from the MPPC output were shown in Figure 7, respectively in (A) and (B).

3. Discussion

It was concluded from the literature browse that the used MPPC module was initially utilized as an alpha detection system by the presented study.

^{226}Ra alpha spectrum via the MPPC can be obtained without any noise component by the suggested spectrometer using coincidence method. Additionally, suggested spectrometer can be used to acquire neat source spectra of other radioactive sources, rejecting the other unwanted effects. Thus, pure energy spectrum of an alpha particle emitting radioisotope can also be obtained theoretically through the experimental neat source spectrum from the suggested spectrometer here.

4. Conclusion

It was observed that the neat alpha spectrum was obtained by the used MPPC and through the developed spectrometer (Figure 7). As can be seen in Figure 7, noise components were reduced after the suggested coincidence technique.

It was concluded that the introduced coincidence measurement method was quite efficient to achieve alpha spectrum of ^{226}Ra by using a spectrometer consisted of MPPC. In addition, the suggested spectrometer can be used in the nuclear physics student experiments.

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