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A Method to Reveal ^{137}Cs Gamma Spectrum by a Multi-Pixel Photon Counter

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Abstract: An MPPC (multi-pixel photon counter) module which is composed of silicon photomultipliers (Si-PM) can be used for the photon detection and measurement. However, gamma energy spectrum could not be obtained when the module was only used. Therefore, the study was focused on finding out gamma energy spectrum of ^{137}Cs and developed a spectrometer which consisted of a MPPC module. The photopeak of 662 keV of the isotope could be revealed using the introduced method here. The used method was successful to enhance the energy resolution as well.

Keywords: Multi-Pixel Photon Counter, Silicon Photomultiplier, Gamma Spectrum

1. Introduction

Photon counting is a technique for measuring the number of individual photons. The MPPC is suitable for photon counting since it offers an excellent time resolution and a multiplication function having a high gain and low noise. Compared to ordinary light measurement techniques that measure the output current as analog signals, photon counting delivers a higher signal/noise and higher stability even in measurements at very low light levels [1].

The multi-pixel photon counter (MPPC) is a device called Si-PM (silicon photomultiplier). It is a new type of photon-counting device using multiple APD (avalanche photodiode) pixels operating in Geiger mode. Although the MPPC is essentially an opto-semiconductor device, it has an excellent photon-counting capability and can be used in various applications [1, 2] for detecting extremely weak light at the photon counting level. The MPPC operates on a low voltage and features a high multiplication ratio (gain), high photon detection efficiency, fast response, excellent time resolution, and wide spectral response range; thus it delivers the high-performance level needed for photon counting [3]. 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, including fluorescence measurement, DNA analysis, environmental chemical analysis, high energy physics experiments, and many other fields [4, 5-7]. The MPPC therefore has a potential for replacing conventional detectors used in photon counting [3].

Scintillators are the materials (solids, liquids, gases) that produce sparks or scintillation lights when ionizing radiation which passes through them [8]. The inorganic scintillators are mainly crystals of alkali halides containing a small activator impurity. The advantage of inorganic crystals lies in their greater stopping power due to their higher density and higher atomic number. Among all the scintillators, they also have some of the highest light outputs, which results in better energy resolution. This makes them extremely suitable for detection of gamma-rays [9].

Dividing the full width at half maximum (FWHM) of a peak to the peak centroid (E_0) in an energy spectrum identifies the energy resolution (R) of a detector [$R(\%)=(FWHM/E_0)x100$] [10].

MPPC modules consist of an MPPC, current-to-voltage converter, high-speed circuit, high-voltage power supply circuit, temperature-compensation circuit, counter circuit, and microcontroller. Operating an MPPC module is easy, since it runs on USB bus power and needs no external power supply (Figure 1) [11].

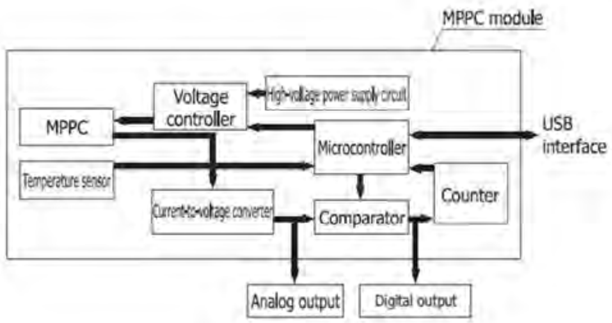

Figure 1. *Block diagram of the MPPC module [11].*

2. Experiment and Results

The MPPC module operates on USB bus power from the PC via the USB cable. MPPC module operation can be performed from the PC and the measurement data monitored on the PC [11]. As can be seen in Figure 1, the applied MPPC module has two outputs, namely analog and digital outputs. Analog output allows us to monitor the signal waveforms and to measure the signal characteristics for an application. Digital output gives a logic signal, and it is possible to obtain counting values via this output [11]. The signal shapes of the digital and analog outputs of the module are shown in Figures 2 and 3.

Since the energy spectrum obtained from the digital output did not matched with that of ^{137}Cs energy spectrum (Figure 4), an experimental method was developed, the details of which are given below. Finally, the photopeak counts were revealed in the spectrum, enhancing the energy resolution of the system.

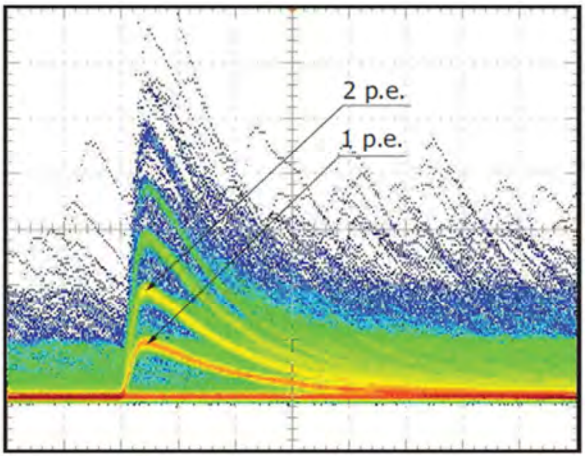

Figure 2. *The analog output of the MPPC module (p.e.: photon equivalent) [11].*

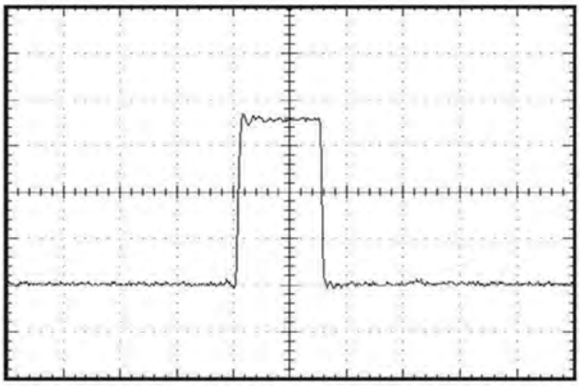

Figure 3. *The digital output of the MPPC module [11].*

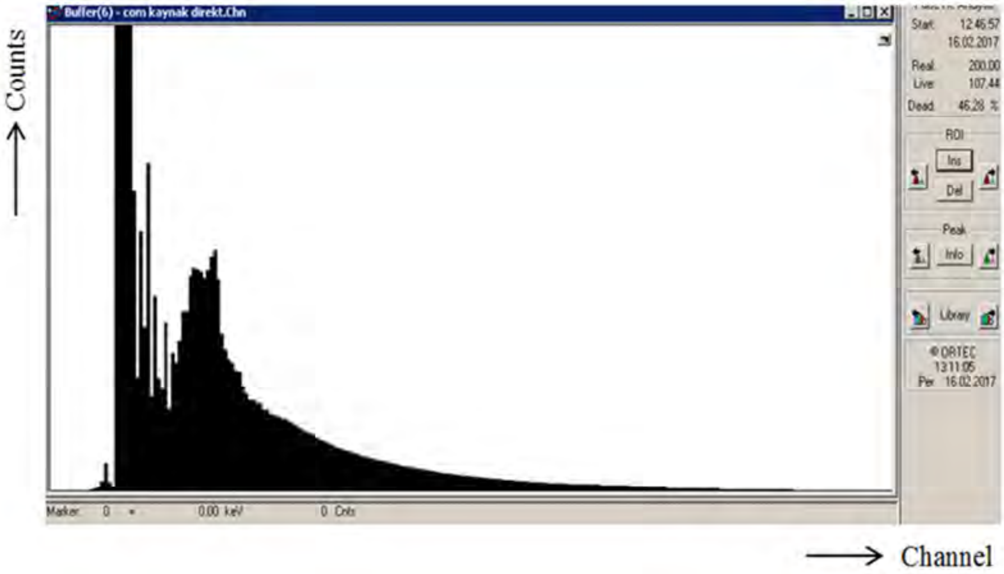

Figure 4. *Digital output of the module in the MCA.*

A HAMAMATSU MPPC standard module (C10507-11-100U) was used in the experimental setup. The temperature of the system was 15°C during data acquisition. CsI(Tl) inorganic scintillator (Epic-Crystal) coated with teflon tape in the dimensions of 10 x 10 x 30 mm^3 was used. Especially big crystal size was used despite its negative effect to the spectral performance in order to test the proposed method here. The scintillator was attached to the Si-PM window by optically clear silicone gel (Silicone Technology, LS-3252). A solid and point type ^{137}Cs gamma radiation source with the activity of 5 µCi (Spectrum Techniques) was used in the experiment. The module, the scintillator and the source were put into a light-tight dark box to prevent electronic noise due to the ambient light. The box was moved into a cooler to keep the temperature of the module constant. Data acquisition time was chosen as 200 s during measurements. A photo of the used module is shown in Figure 5.

Figure 5. *Photo of the used MPPC module.*

The block diagram of the used experimental setup is depicted in Figure 6.

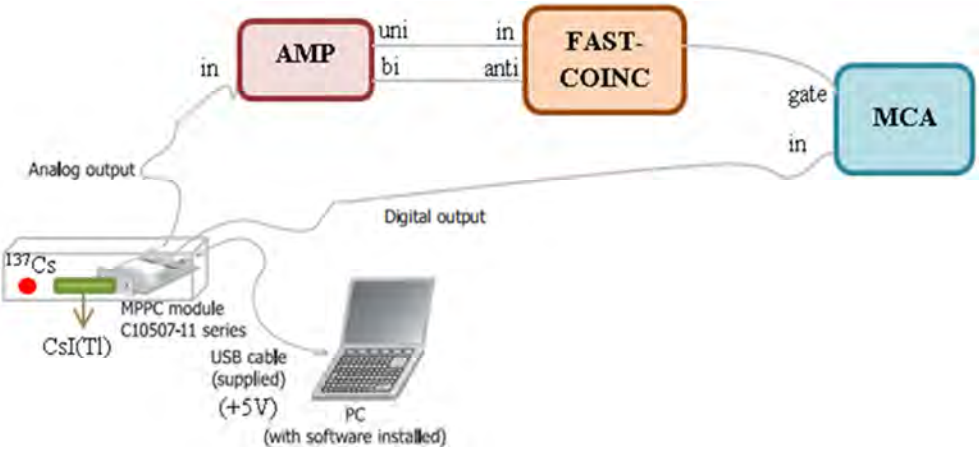

Figure 6. *Block diagram of the used experimental setuph*

The amplitudes of analog and digital outputs of the MPPC module were measured averagely as 600 mV and 3.5 V respectively during the experiments. The comparator unit in the module (Figure 1) operates as an operational amplifier (op-amp), generating an amplified logic output.

In the setup, digital output of the MPPC was first directly connected to the main input of a multichannel analyzer (MCA, Ortec Trump 8K). Secondly, the analog output of the MPPC was sent to the input of an amplifier [AMP, Ortec 671 (fine gain: 0.5, coarse gain: 50)] since its output has low amplitude. The AMP input was terminated with 50 Ω to prevent reflection. Then, its unipolar and bipolar outputs were forwarded to a coincidence module [FAST-COINC, Ortec 414A (Resolving time: 110 ns)]. Unipolar signal was used as input to 414A since unipolar signal has better signal to noise characteristics at low counting rates and excepts a small possible undershoot [9, 10]. In a coincidence unit, moreover, if one normal input is selected, an output pulse will appear for the input pulse that is not accompanied by an anticoincidence pulse within the resolving time [10]. To eliminate undesirable events, for this reason, the bipolar output of the AMP was connected to anti-coinc. knob of 414A. Its logic output was combined with the gate input of the MCA. Connecting the digital and logic outputs from the MPPC and 414A respectively to the MCA produced another coincidence combination in this device, leading to a logic-logic parallel input. Thus, coincident neat energy spectrum was achieved (Figure 7).

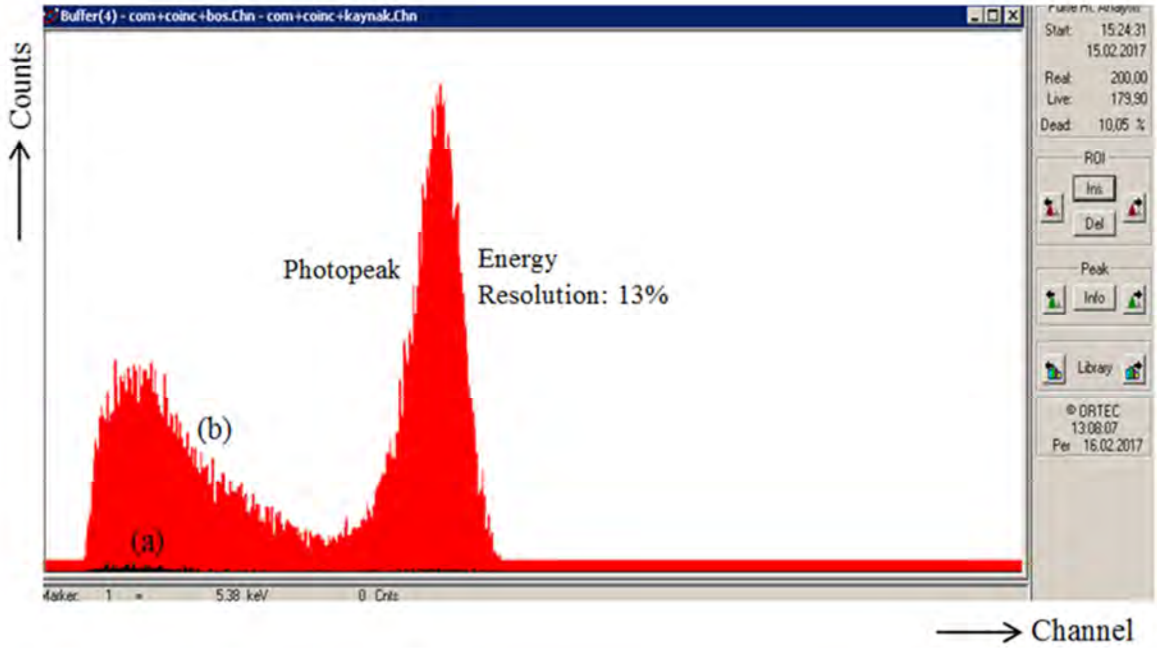

Figure 7. *Obtained coincident spectra in the MCA(a) without, (b) with ^{137}Cs source.*

3. Conclusion

It was observed that the gross counts at the photopeak, which is depended on the medium temperature i.e. the photopeak counts, have increased as the medium temperature decreased owing to noise decrement. This improvement led to a good energy resolution result of 13% for the photopeak.

When digital output was connected directly to the MCA (Figure 4), quite high dead time of the system was recorded (46%). The coincidence method was applied to the system since this value is not acceptable for an energy spectrum. Applying the coincidence measurement, it decreased to 10%. This result showed that the coincidence measurement affected system dead time positively.

4. Discussion

It was concluded that the introduced coincidence measurement method was quite effective to reveal the gamma energy spectrum of ^{137}Cs, to decrease the dead time and to improve the energy resolution of the spectrometer consisted of C10507-11-100U model MPPC. In addition, the introduced experimental setup can be used in the student experiments of nuclear physics laboratories such as determination of the energy spectrum of different gamma-ray sources, calculation of the gamma-ray attenuation coefficient of absorbers.

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References

[1] D. Rigamonti, A. Muraro, M. Nocente, V. Perseo, G. Boltruczyk, A. Fernandes, J. Figueiredo, L. Giacomelli, G. Gorihi, M. Gosk, V. Kiptily, S. Korolczuk, S. Mianowski, R. C. Pereira, E. P. Cippo, I. Zychor, M. Tardocchi, and JET Contributors, "Performance of the prototype LaBr$_3$ spectrometer developed for the JET gamma-ray camera upgrade", Rev. Sci. Instrum., vol. 87, no. 111E217, pp. 1-4, 2016.

[2] M. Nocente, D. Rigamonti, V. Perseo, M. Tardocchi, G. Boltruczyk, A. Broslawski, A. Cremona, G. Croci, M. Gosk, V. Kiptily, S. Korolczuk, M. Mazzocca, A. Muraro, E. Strano, I. Zychor, G. Gorini, and JET Contributors, "Gamma-ray spectroscopy at MHz counting rates with a compact LaBr$_3$ detector and silicon photomultipliers for fusion plasma applications", Rev. Sci. Instrum., vol. 87, no. 111E714, pp. 1-4, 2016.

[3] Si APD, MPPC Modules, Hamamatsu Company, https://www.hamamatsu.com/resources/pdf/ssd/e03_handbook_si_apd_mppc.pdf Accessed 26 August 2017.

[4] MPPC Modules, C10507-11 series, C10751 series, Hamamatsu Company, http://www.hamamatsu.com.cn/UserFiles/DownFile/Product/20130913163411890.pdf Accessed 26 August 2017.

[5] G. Bonanno, D. Marano, G. Romeo, S. Garozzo, A. Grillo, M. C. Timpanaro, O. Catalano, S. Giarrusso, D. Impiombato, G. La Rosa, and G. Sottile, "Advances in multi-pixel photon counter technology: First characterization results," Nucl. Instrum. Meth. A, vol. 806, no. 2016, pp. 383-394, 2016.

[6] T. Tsujikawa, H. Funamoto, J. Kataoka, T. Fujita, T. Nishiyama, Y. Kurei, K. Sato, K. Yamamura, and S. Nakamura, "Performance of the latest MPPCs with reduced dark counts and improved photon detection efficiency," Nucl. Instrum. Meth. A, vol. 765, no. 2014, pp. 247-251, 2014.

[7] J. Kataoka, A. Kishimoto, T. Fujita, T. Nishiyama, Y. Kurei, T. Tsujikawa, T. Oshima, T. Taya, Y. Iwamoto, H. Ogata, H. Okochi, S. Ohsuka, H. Ikeda, and S. Yamamoto, ‘‘Recent progress of MPPC-based scintillation detectors in high precision X-ray and gamma-ray imaging,’’ Nucl. Instrum. Meth. A, vol.784, no. 2015, pp. 248-254, 2015.

[8] Tsoulfanidis N. (1995) Measurements and Detection Radiation USA: Taylor & Francis.

[9] Leo R. W. (1987) Techniques for Nuclear and Particle Physics Germany: Experiments Springer–Verlag Berlin Heidelberg.

[10] Knoll G. F. (2000) Radiation Detection and Measurements New York: John & Sons Inc.

[11] Module Products, Hamamatsu Company, http://web.sensor-ic.com:8000/ZLXIAZAI/Hamamatsu/chapter10_module%20products.pdf Accessed 26 August 2017.