Development of a Scintillation Detector using a MPPC as an Alternative to an APD

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Abstract

The performance of multi-pixel photon counter (MPPC) was tested. MPPC is a novel type of semiconductor photodetector comprising multiple avalanche photodiode (APD) pixels operated in Geiger mode. Whereas MPPC has great advantage of signal multiplication which is comparable to that achieved with the photomultiplier tube (PMT), the detection of weak scintillation light signals is difficult due to the severe contamination of dark counts. In this study, we first compared the performances of a MPPC with those of an APD optically coupled with the crystals of BGO, CsI(Tl), LuAG(Pr), and YAG. Second, we applied the coincidence technique for scintillation detector to improve the detection efficiency for low energy gamma-rays. The detector consisted of a GSO crystals optically coupled with the 2x2 MPPC-array. It turned out that the APD has a great advantage for the energy resolution, while the MPPC is superior for the detection of the low energy gamma-rays with the coincidence technique.

1. Introduction

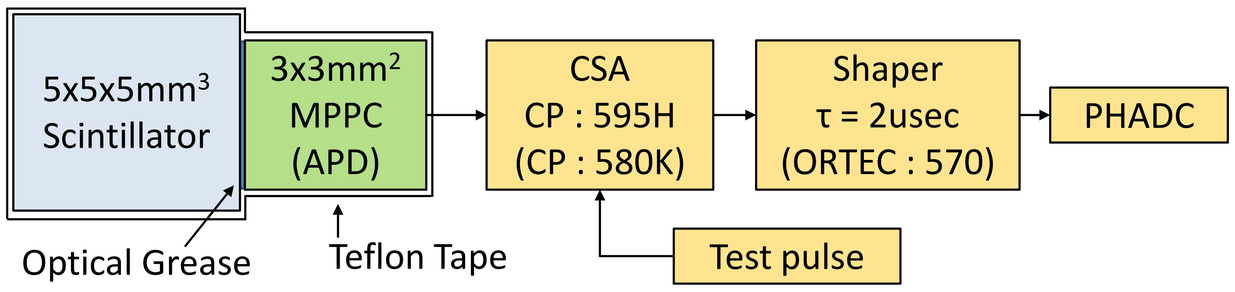
Performances of photodetectors

	PMT	PD	APD	MPPC
Gain	～$10^{5\text{-}6}$	1	50	～$10^{5\text{-}6}$
Q.E.(PDE)	≦25%	≧80%		≦25%
Size	× (Large)	○ (Compact)		
Operation in the magnetic fields	× (Unavailable)	○ (Available)		
Structure	× (Complex)	○(Simple)		
Power consumption	× (Huge)	○(little)		

MPPC offers great advantages such as compact and high gain!

2. Comparison of the performances

2.1. Setup



MPPC

- S10362-33-025C
- Gain : 2.75x10^5
- Dark counts : ～2.4 [Mcps] (0.5 p.e.)

APD

- S8664-33-8825(X)
- Gain : 50
- Dark current : 1.81 [nA]

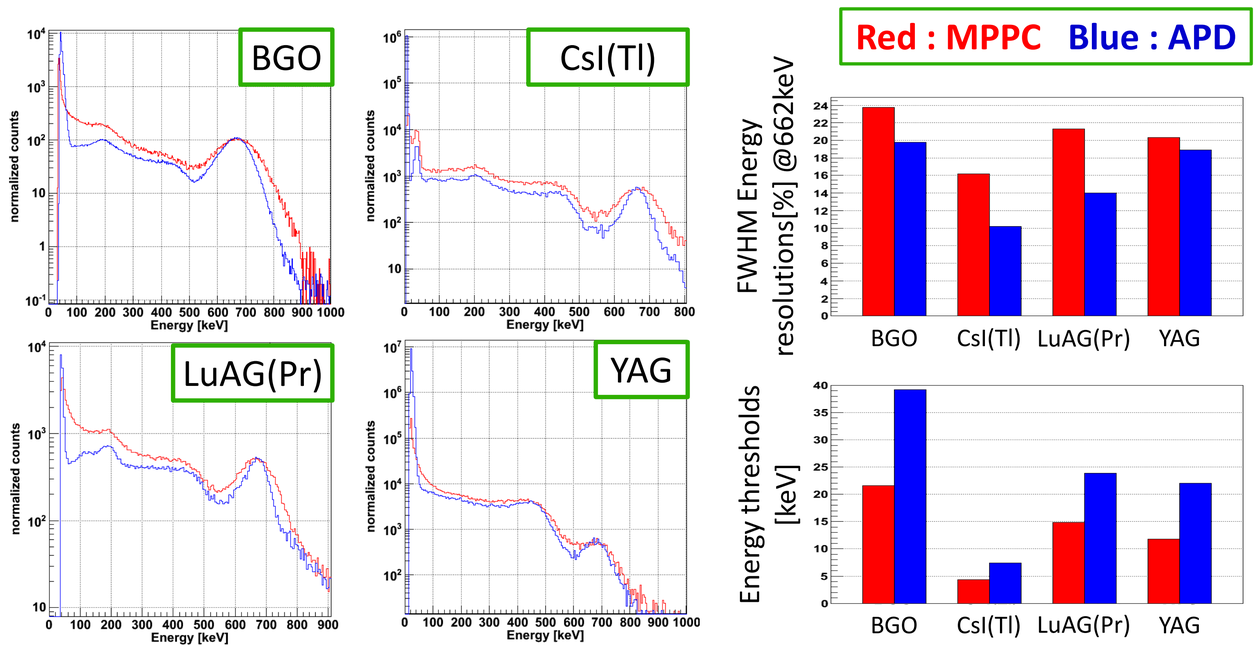
Common conditions

- + 20 degree
- 662 and 32keV gamma-rays from ^{137}Cs.

Energy thresholds were defined using Test pulse

$$thr.[keV] = \frac{662\,[keV]}{peak\,[ch]} \cdot 2.35\sigma_{TP}\,[ch]$$

2.2. Energy thresholds and Energy resolutions



Red : MPPC Blue : APD

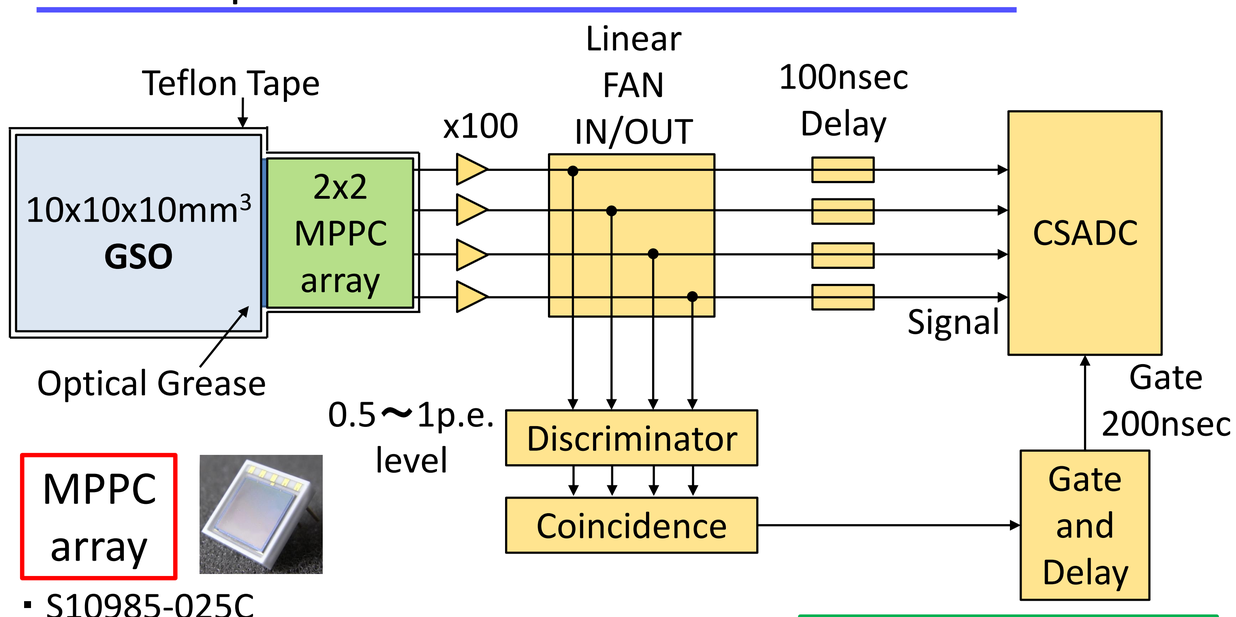
Measured results...

- The **APD** has a better performance for the energy resolution.
- The energy thresholds of the **MPPC** is lower than those of the **APD**; nevertheless, the detection of low energy gamma-rays is difficult for the **MPPC** due to the severe contamination of dark counts.

3. Coincidence technique

Coincidence technique was applied to reduce the contamination of dark counts.

3.1. Setup



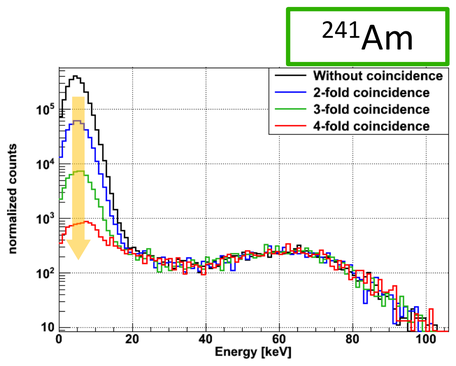
MPPC array

- S10985-025C
- Gain : 2.75x10^5
- Dark counts : ～900 [kcps] (0.5 p.e.)

Measurements were operated at + 20 degree.

3.2. Spectra using coincidence technique

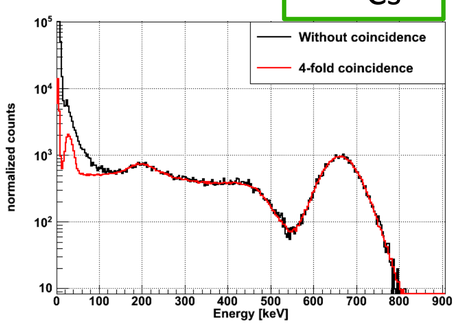
^{241}Am



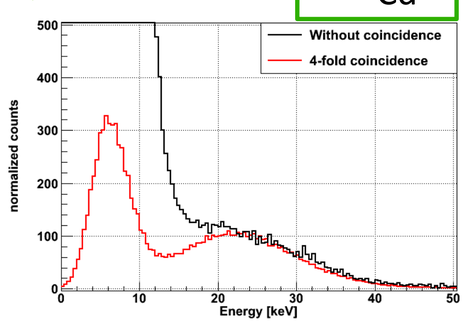
Background trigger rate decreases from 9.0x10^{2}kcps (without the coincidence) to 1.7kcps (with 4-fold coincidence) !

32keV and 22keV peaks were clearly detected with 4-fold coincidence !

^{137}Cs



^{109}Cd



FWHM
Energy resolutions
- 15% @ 662keV
- 60% @ 59.5keV
- 63% @ 22.2keV

4. Conclusion

Energy resolution

The **APD** has a great advantage for the energy resolution.
This is probably because quantum efficiency is the dominant factor.

Energy threshold

Although the measured results using the test pulse suggest that the **MPPC** has lower energy thresholds than those of the **APD**, low energy gamma-rays peak was diluted by the dark count and inevitably smoothed out.

Coincidence technique with the 2x2 monolithic **MPPC array** rejected dark noise by more than 99.8% and 22.2keV gamma-rays were successfully detected.

A few 10 keV energy thresholds were achieved using **MPPC array** with coincidence techniques as scintillation detectors !