Characteristics Measurements of $CdWO_4$ Crystal and Photo PIN Diode for X-ray Scanner

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1. Introduction

For cargo inspection, we study X-ray scanner by using $CdWO_4$ (CWO) crystal and photo PIN diode (PD). CWO is commonly used in X-ray scanner due to its detection efficiency and low after glow [1].

We measured a decay time, emission wavelength, and light yield of CWO [2]. And we measure signal-to-noise ratio (SNR) and energy resolution of γ-ray with CsI(Tl) by using the PD. Measurements results determine quality of the CWO crystal and PD. After this study, we will study X-ray response by using combined CWO and PD.

2. Photo PIN Diode

2.1 Experimental Setup

The PD is fabricate in a 6-inch fabrication line at Electronics and Telecommunications Research Institute (ETRI). The wafer is 6-inch, n-type, and high resistivity (>5 kΩ·cm). We design 16 and 32 channels array type with 2.1 $\times$ 2.1 mm^2 pad size and 3 mm pitch. Backside of the array PD has light entrance window for photo sensitivity that shows quantum efficiency to be above 80% at visible light. Fig. 1 shows back side (left) and front side (right) with readout electrode. One channel of the array PD is connected for performance test and 100 V is applied to the PD as an operating voltage.

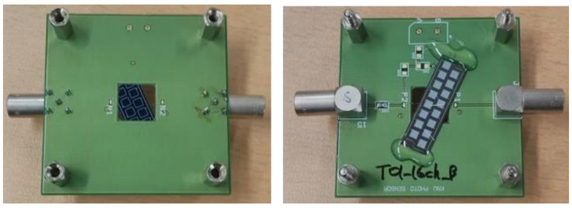

Fig. 1. Array PD is assembled with printed circuit board (PCB).

The SNR about minimum ionization particle (MIP) commonly indicates quality of detector. We use the ^{90}Sr radioactive source and PIN diode for trigger detector to measure SNR of the array PD. To select MIP signal from ^{90}Sr β-ray, we use collimator and trigger sensor. Fig. 2 shows experimental setup for SNR measurements.

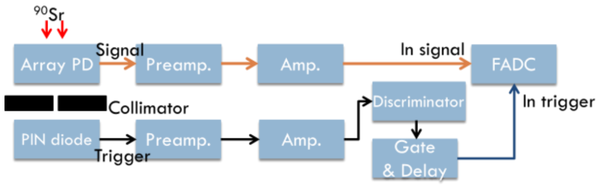

Fig. 2. Experimental setup for SNR measurements.

For energy resolution measurements, we use ^{137}Cs (662 keV γ-ray) radioactive source and CsI(Tl) crystal with dimensions 0.5 $\times$ 0.5 $\times$ 0.5 mm^3. The CsI(Tl) crystal is shielded by a Teflon tape for light guide and is attached to backside of the array PD by using optical grease. A pre-amplifier, amplifier, and flash ADC (FADC) are used for this measurements.

2.2 SNR and Energy Resolution

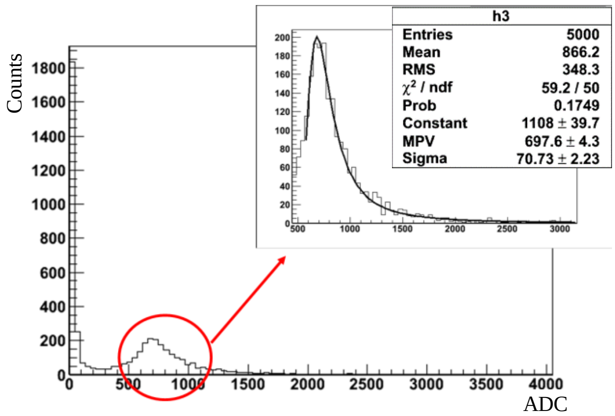

Fig. 3. Measurements result of signal-to-noise ratio with ^{90}Sr radioactive source.

The SNR about MIP signal is measured with commercial electronics. Fig. 3 shows ADC distribution. The SNR is measured to be 228, it is good enough to distinguish signals from pedestal.

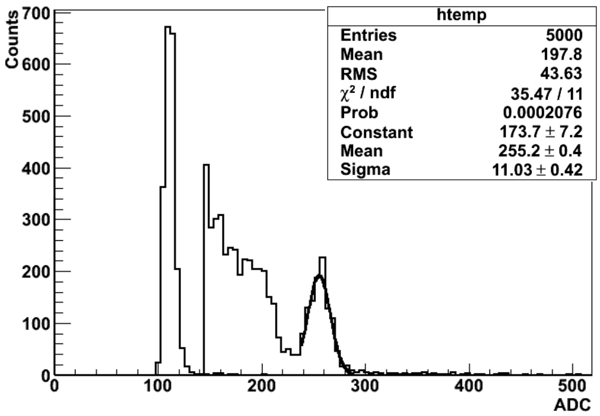

Fig. 4. Measurements of γ-ray with ^{137}Cs and CsI(Tl)

The energy resolution about γ-ray is measured with CsI(Tl) crystal and ^{137}Cs source, and 17.5% is obtained. This result is very helpful to measure the γ-ray with CWO crystal.

3. $CdWO_4$ Crystal

3.1 Experimental Setup

We measure three properties of the CWO crystals made by Ukraina. The average decay time and emission wavelength are generally 12 μs and 480 nm, respectively. The relativity light yield and its uniformity are important to check quality of crystal. We use reference CWO crystal made by Russia for comparison [2]. All CWO crystal samples have dimensions 4 × 4 × 30 mm^3 and are shielded except for front face.

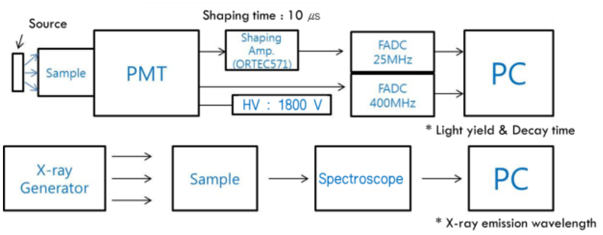

Fig. 5. Experimental setup for measurements of CWO properties

Fig. 5 shows experimental setup. For light yield and decay time measurements, we use ^{137}Cs radioactive source. And for X-ray emission wavelength measurement, we use 20 keV X-ray from X-ray generator.

3.2 Measurement Result of $CdWO_4$ Crystal Properties

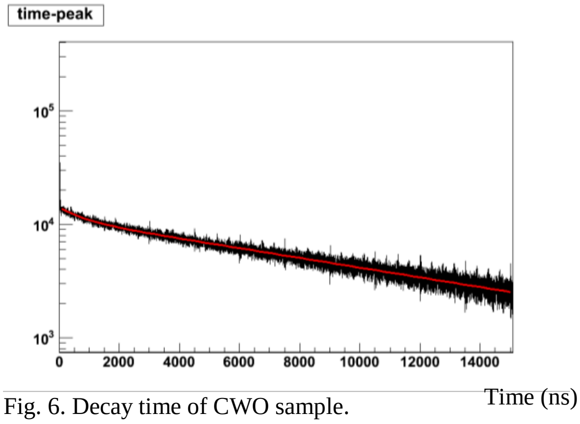

Fig. 6. Decay time of CWO sample.

Fig. 6 shows decay time curves measured by using ^{137}Cs. The CWO has two kinds of decay time because it is made of two components. Therefore the curves are fitted by two exponential functions. As a result, average decay time of the sample is measured to be 10.12 μs. This result is consistent with general property.

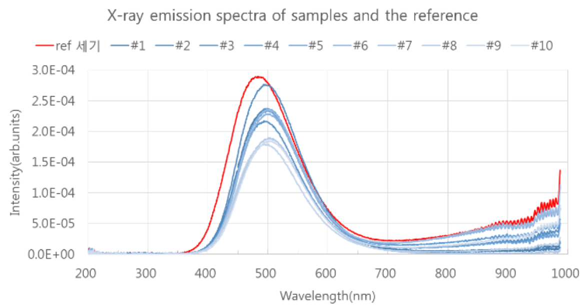

Fig. 7. Wavelength of CWO samples (blue line) and reference (red line).

Fig. 7 shows emission wavelength by 20 keV X-ray. The wavelength of all samples are measured to be about 500 nm, which is in the photo sensitivity range of the PD. And also it is consistent with general property.

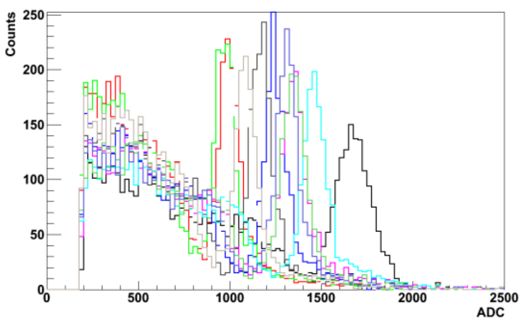

Fig. 8. Distribution of relativity light yield. Ten CWO samples (color line) and reference sample (black line).

Fig. 8 shows measured light yield by ^{137}Cs. The light yield of ten test samples (color line) are low compared to the reference's light yield (black line). The average light yield of ten samples is 1200 ADC and it has 13.3% error, which shows bad uniformity compared to reference crystal.

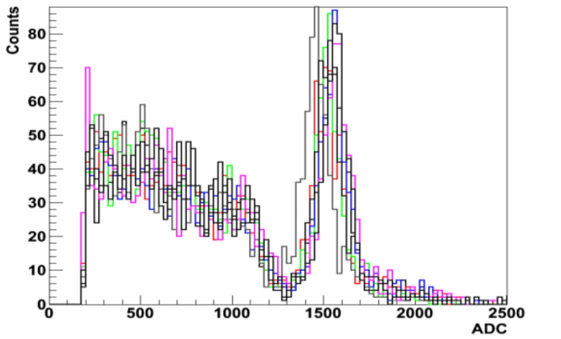

Fig. 9. Systematic error of light yield. One of CWO sample is selected and measured eight times.

To check the systematic error, one sample that has largest light yield is selected and the measurement is repeated many times. As a result, systematic error is 2.8%. 13.3% error of the test samples is larger than systematic error.

4. Summary and Plan

We study characteristics of CWO crystal and PD. The SNR and energy resolution with CsI(Tl) about ^{137}Cs 662 keV γ-ray are measured to be 228 and 17.5%, respectively. The CWO samples have 10.1 μs decay time and 500 nm emission wavelength. Average light yield of samples is 1200 ADC, which is about 70 % of reference sample's light yield. Also uniformity of light yield is not good compare to reference crystal.

We plan to measure γ-ray by using combined CWO and PD.

REFERENCES

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[2] G. H. Chae, *et al*, J. Korean Phys. Soc. **63**, 1455 (2013)