Development of Spectroscopy Toolkit for Spectrum Measurement Experiments Using a CsI(Tl)/PIN Diode Detector

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The spectroscopy toolkit has been developed and tested. The toolkit consists of a CsI(Tl)/PIN diode detector, integrated electronics, and a multi-channel-analyzer and its size was 40 cm(width) by 20 cm(length) by 6 cm(high). It is compact, very portable and simpler and cheaper compared to the conventional spectroscopy system. The gamma energy resolutions of the toolkit were 7.9% for the 660 keV of ^{137}Cs and 4.9% for 1,332 keV of ^{60}Co respectively. The linearity for gamma energies was good. When the energy spectrum of a ceramic sample containing ^{232}Th was measured with the spectroscopy toolkit for 20 minutes, there were significant peaks of the heavy metal. These results show that the resolution of the spectroscopy toolkit is sufficient to accumulate a quality spectrum in a few minutes by using weak, encapsulated commercial sources. Furthermore a toolkit experiment that how to measure energy spectra using the toolkit, and how to identify specific isotopes in a pottery piece, could be widely adopted for education and even for more sophisticated and higher level experiments.

Keywords : Spectroscopy toolkit, Nuclear education, Gamma spectrum, ^{137}Cs, ^{60}Co

INTRODUCTION

Regarding spectroscopy experiments in a laboratory, it is needed a spectroscopy system which consists of a detector and NIM modules. Generally, these quality gamma ray detection systems are appropriate for educating radiation professionals, but not for students' experiments. Conventional NIM modules for γ-ray spectroscopy have some drawbacks for educational use, being neither cheap nor simple. In addition, they are generally fragile and require high voltage or a cooling system, so they should be operated by professionals for safety concerns.

Hands-on experiments involving radiation in schools would be an effective way to enhance students' understanding and perception of nuclear science and radiation technology. If there were a simpler and cheaper spectroscopy system, it would be an effective piece of equipment for educating students in radiation fields. R. M. Anjos, et al,[1] earlier pointed out the role a simple γ-ray detector can play in education. Recently, a spectroscopy system including a NaI(Tl) scintillation detector was recently commercialized by the name of 'USC30 Advanced Spectrometer System' from the Spectrum Techniques, LLC.[2]. In this system, the scintillation detector is based on PM tube and separated from the spectrometer, so it is not quite compact and cheap.

In this paper, for the above mentioned purposes a simple spectroscopy toolkit consisted of a CsI(Tl)/PIN diode detector was developed and its performance test was conducted.

MATERIALS AND METHODS

1. CsI(Tl)/PIN diode detector

The CsI(Tl)/PIN diode detector was developed by Kim H.S. et al.[3]. To fabricate the CsI(Tl)/PIN diode detector, a CsI(Tl) scintillator and PIN diode were used. Firstly, the CsI(Tl) ingot was cut into 10 mm(length) × 10 mm(width) × 20 mm(thickness) using a diamond string saw. Figure 1 shows the CsI(Tl) scintillators. The density of the CsI(Tl) scintillator is 4.51g·cm^{-2} and hardness is 2 Mohs, and the maximum peak of the emission spectrum is 550 nm. The dimension of the PIN diode (Hamamatsu 3590-08) is 10 mm^2 area with 500 μm thickness and its absorption spectrum is similar to the emission spectrum of the CsI(Tl)

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scintillators, so it matches optically very well. The CsI(Tl) scintillator and PIN diode are assembled into the CsI(Tl)/PIN diode detector using optical grease and PTFE tape, so the CsI(Tl)/PIN diode detector was fabricated as shown in figure 2.

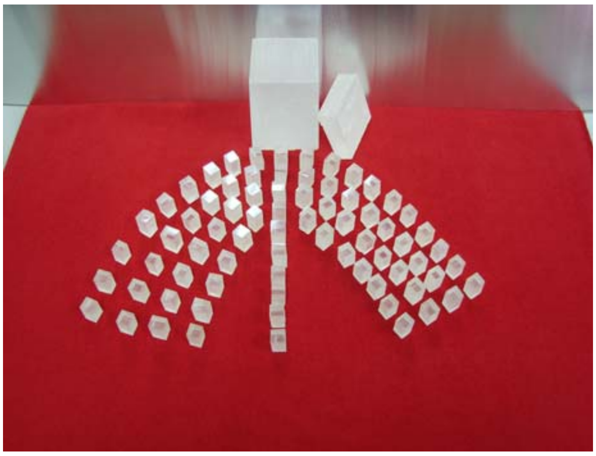

Fig. 1. CsI(Tl) Scintillators.

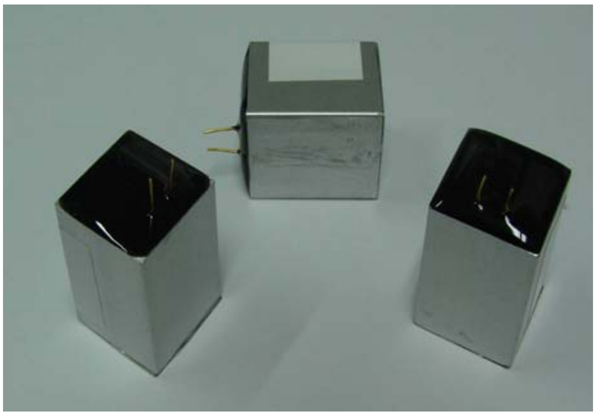

Fig. 2. CsI(Tl)/PIN diode detectors.

2. Design of the spectroscopy toolkit

Figure 3 shows the components of the tool kit.

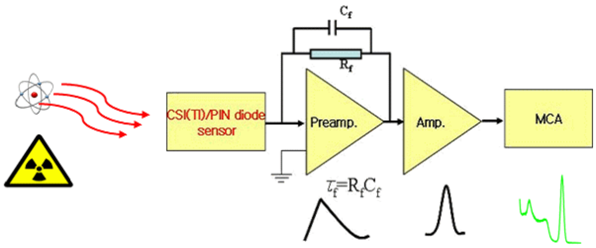

Fig. 3. Component layout of the spectroscopy toolkit.

Owing to the use of a PIN diode, rather than a PM tube, we were able to mount the whole system in a small aluminum chassis. The system consists of a detector, preamp, amp, and multi channel analyzer. The decay time constant of the preamplifier and the shaping time of the shaping amplifier were 140 ns and 6 µs respectively, and the resolution of the used MCA was 2048 channels. A Cremat CR-110 and a CR-200 hybrid chip were used respectively for the preamplifier and shaping amplifier and an Amptek potable MCA was used for the MCA. In figure 4, the developed toolkit was compared with conventional system.

In a conventional system, the detector is separated from the NIM modules. The NIM modules are generally big and complicated; they require high voltage and/or a cooling system, which means they are not suitable for use in secondary schools. In the case of the developed toolkit, all electronics and the detector were integrated inside a

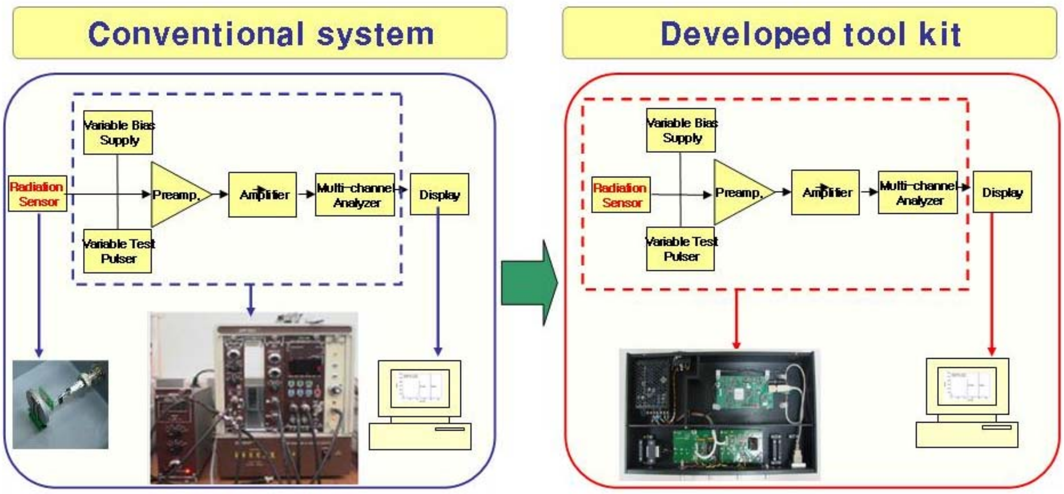

Fig. 4. Comparison between a conventional system and the developed spectroscopy toolkit.

(a) (b) (c)

Fig. 5. Prototype of the spectroscopy toolkit with the lid closed and opened.

small box. Furthermore, the small portable spectroscopy toolkit would have a similar function to a conventional spectroscopy system.

3. Fabrication of the prototype of the spectroscopy toolkit

Figure 5 (a) shows the exterior view of the prototype, the size is 40 cm by 20 cm by 6 cm. The diagram of the pulse amplification chain was displayed on the top lid for teaching purposes. Double lids are used to reduce noise, and the top lid (5mm) slides easily. There is a rectangular opening on the left for replacement of the source/sample. The Interior view of the prototype is shown in figure 5 (b). There are BNC connectors which are able to check pulse shape from the preamplifier and amplifier. There are a high voltage power supply connector for optional diode bias supply and a USB connection for data acquisition. Figure 5(c) shows a gamma spectrum display via a laptop measured with the toolkit.

RESULTS AND DISCUSSION

The ^{137}Cs and ^{60}Co energy spectra were measured for energy calibration in figure 6 and figure 7 respectively. The resolution for the ^{137}Cs 660 keV was 7.9% and for the ^{60}Co 1,332 keV was 4.9%. The efficiencies are sufficient to accumulate a quality spectrum in a few minutes using weak, encapsulated commercial sources. The energy of the gamma spectrum was calibrated using three lines from these sources.

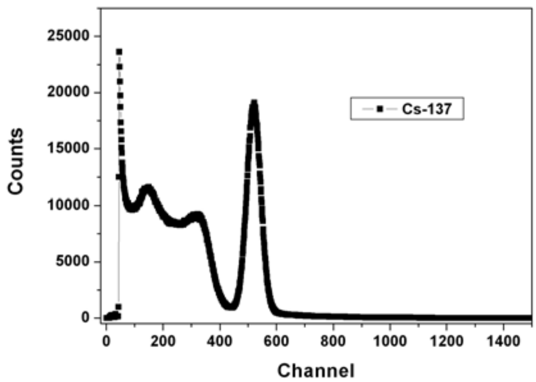

Fig. 6. The spectrum of ^{137}Cs measured by CsI(Tl)/PIN diode detector.

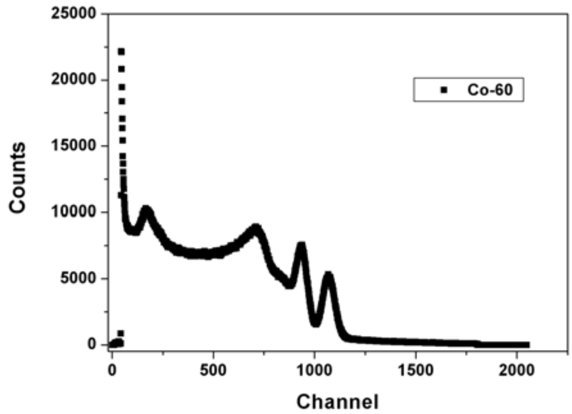

Fig. 7. The spectrum of ^{60}Co measured by CsI(Tl)/PIN diode detector.

Figure 8 shows a background spectrum without any source measured by the developed toolkit. In figure 9, energy dependence was tested using standard sources such as ^{57}Co 122 keV, ^{137}Cs 660 keV, and ^{60}Co 1,170 keV, 1,330 keV. The results show that the reduced chi-square value was 1, so the linearity for gamma energy was excellent.

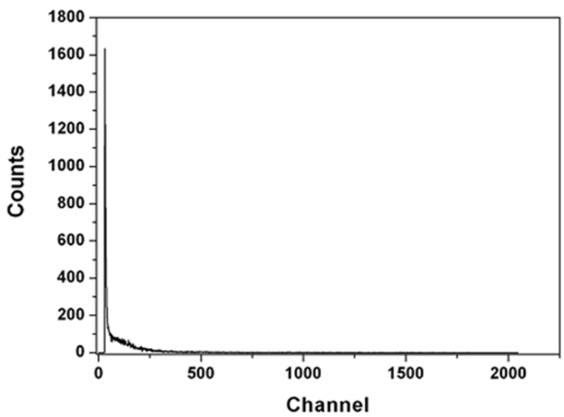

Fig. 8. Background spectrum without any source.

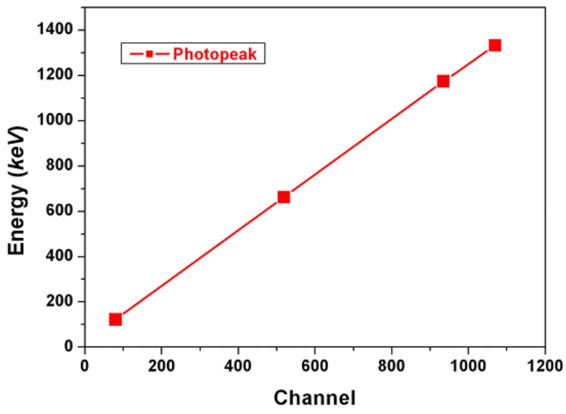

Fig. 9. Energy dependence using standard sources.

This energy spectrum of a ceramic piece containing ^{232}Th was measured with the spectroscopy toolkit for 20 minutes in figure 10. In the measured spectrum, there were significant peaks of the heavy metal. The simplicity and safety in operation, inexpensiveness, and convenient portability make the spectroscopy toolkit suitable for radiation experiments such as ambient background radiation observation, monitoring the intensity of selected radioactivity, and linearity of γ-ray energies for calibration of detector system. So these spectrum measurements using the toolkit are quite suitable for educational purposes in secondary school experiments and beyond, especially the simple application to the pottery.

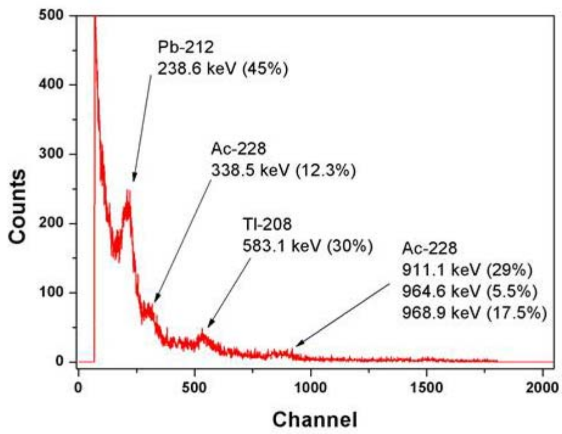

Fig. 10. Spectrum of a ceramic piece.

Furthermore, a calibrated spectroscopy toolkit can be used by science teachers to illustrate how γ-rays are used to identify specific isotopes at training courses. The technique used to identify materials, mostly very heavy metal in a piece of pottery, can be presented to the delight of the audience.

CONCLUSION

A spectroscopy toolkit using a CsI(Tl)/PIN diode detector has been developed and tested. The toolkit is simpler and cheaper compared to a conventional spectroscopy system. In addition it is safe to operate, inexpensive to procure, and very portable.

The results measured from the prototype show that its resolution and efficiency are good, making it quite suitable for purposes such as, ambient background radiation observation, monitoring intensities of selected radioactivity, and demonstration experiments in secondary schools and up. The toolkit can replace Geiger-Muller counters in many traditional basic experiments with the pulse height analysis capability.

Toolkits based on this prototype could be widely adopted for education and even for more sophisticated and higher level investigations.

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