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Development of Portable Safeguards Equipment based on Quad-CZT Array for Verification of Uranium Enrichment On-site

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1. Introduction

Generally, HPGe and NaI detectors are applied for IAEA inspection. Although HPGe is characterized by its high energy resolution and efficiency, it is inconvenient to transport due to LN_2 dewar for cooling. NaI is featured by its simple components and user convenience, however suffers from its lower resolution [1, 2].

Thus, the demand exists for development of a new safeguards inspection device which has higher resolution than NaI and better mobility than HPGe. Korea Institute of Nuclear nonproliferation and Control (KINAC) has developed a new safeguards system based on the quad-CdZnTe (CZT) array in order to verify uranium enrichment on-site. CZT is typically limited by its physical size so the present authors combined four CZT detectors (Ritec CZT/500), which are daisy-chained and function as a single detector.

Three different systems have been developed based on types of inspection materials. Specifications of each system are presented Chapter 2, and the performance test results show in Chapter 3.

2. Description of the Equipment

2.1. 1st Quad-CZT Array

1st array was developed to verify uranium enrichment for low activity materials. Thus, all components including a lead shield were placed in a carrier (All-in-One system) in order to reduce the disturbance from background radiation.

Fig. 1. 1st Quad-CZT Array (All-in-One System)

The array was designed and built with a size of 50 cm (W) x 39 cm (L) x 23 cm (H) and its weight is 25 kg. Operating program of the 1st system was featured by user-friendly interface to analyze the output signals. The signals, moreover, from the CZT array were delivered to the personal computer through a USB port for display and analysis [3].

2.2. 2nd Quad-CZT Array

Target materials of 2nd Quad-CZT array were intermediate activity samples such as a UF_6 cylinder, fuel rod, powder, and pellet. The 2nd array were developed detachable lead collimator unlike the 1st system. The major features of 2nd Quad-CZT array, thus, were compact size and light weight

Considering the detection geometry of different uranium samples, polyethylene holders were manufactured and shown in Fig. 2; (a) is for BWR pellets, (b) is for PWR pellets, (c) is for a fuel rod, and (d) is for a UF_6 cylinder and powder.

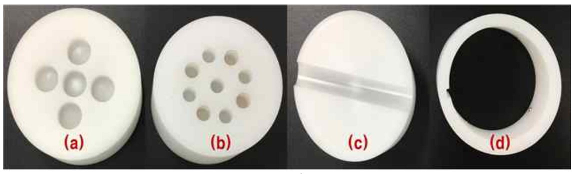

Fig. 2. Holders of 2nd Quad-CZT Array

The 2nd array was built with a weight of 5 kg except for lead collimators and a size of 19.2 cm (W) x 32.4 cm (L) x 18.2 cm (H) [Fig. 3]. Since the lead collimators are detachable, the portability are enhanced [4].

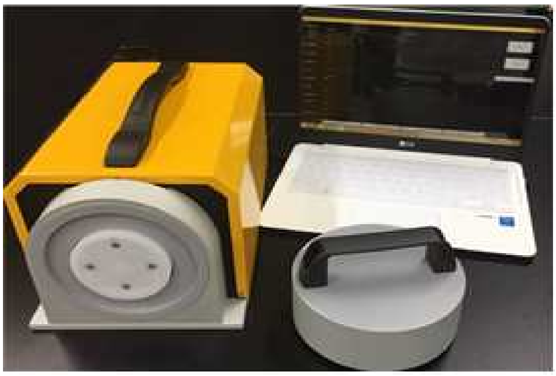

Fig. 3. 2nd Quad-CZT Array

2.3 3rd Quad-CZT Array

In most cases, safeguards equipment and the two developed arrays consist of a detector, related electronics and laptop computer for data analysis. The laptop computer is used for detector calibration, operation (measurement), spectra acquisition, and data processing. However, some activities for safeguards inspection in field are typically limited by those peripherals since those physical configurations have limited mobility and also requires longer preparation time for setup.

A wireless network system was proposed to enhance the mobility of the array. Comparing to the 2nd array, the most important design factors are: 1) data accuracy, 2) security, and 3) delivery time (wireless data rates, Mbit/s).

8.4″ PDA was employed for this array, the size of the array is 19.2 cm (W) x 32.4 cm (L) x 18.2 cm (H), and its weight is 6 kg. Comparing to the 2nd array, the total weight slightly increases due to an adopted PDA [Fig. 4].

Fig. 4. 3rd Quad-CZT Array (Wireless Network System)

3. Performance Test of Quad-CZT Arrays

Performance test for 1st and 2nd arrays has been conducted and compared with results of NaI(Tl) (3″ x 3″), $LaBr_3$ (2″ x 2″), HPGe (64.6 x 63.5 mm), and a single CZT detector. A test sample was 4.5 wt% UO_2 powder and measurement time was set up 600 seconds [Fig. 5].

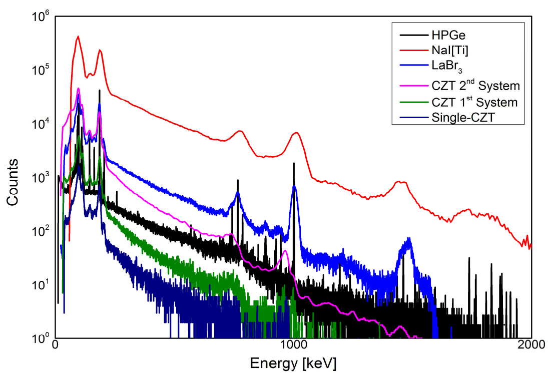

Fig. 5. Comparison of Spectral Distributions of 4.5 wt% UO_2 Powder

Performance evaluation of 3rd Quad-CZT array was currently being conducted. The detector linearity was firstly conducted at 122 keV (Co-57), 511 keV (Na-22), and 662 keV (Cs-137) [Fig. 6, Table I]. Performance test will be carried out along with safeguards inspection and the results will be compared with NaI(Tl), $LaBr_3$, HPGe, and other other arrays.

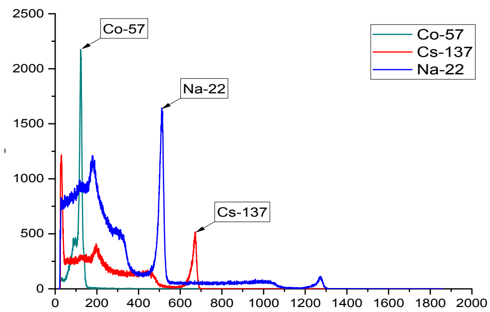

Fig. 6. Linearity Test of 3rd Quad-CZT Array

Table I. Result of Linearity of 3rd Quad-CZT Array

Isotope	Channel	Expected Energy	Measured Energy	Error
Co-57	243	122 keV	123 keV	0.8 %
Cs-137	1449	662 keV	667 keV	0.7 %
Na-22	1105	511 keV	512 keV	0.2 %
Na-22	2789	1274 keV	1271 keV	0.2 %

4. Conclusions

Quad-CZT arrays for verification of uranium enrichment with the purpose of safeguards inspection on-site have been designed, built, and tested. The design concepts were to enhance mobility, user convenience, and detector efficiency. Moreover, those arrays can be expected to be used in various safeguards activities such as the IAEA PIV (Physical Inventory Verification).

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Table II. Characteristics of Quad-CZT Arrays

	1st Array	2nd Array	3rd Array
Weight	25 kg	5 kg	6 kg
Size	50 cm x 39 cm x 23 cm	19.2 cm x 32.4 cm x 18.2 cm	19.2 cm x 32.4 cm x 18.2 cm
Sample Types	Low-level activity (Environmental samples)	Intermediate-level activity	Intermediate-level activity
Characteritics	❖ All-in-one system (a hard field case) ❖ For measurement of low concentration sample ❖ Attached lead collimator with detecting part	❖ Compact size ❖ Various uranium holders ❖ Detachable shielding ❖ Good portability and advanced availibity	❖ Compatibility with 2nd system ❖ Wireless network system ❖ Compact size ❖ Various uranium holders ❖ Detachable shielding
Complements	❖ Low mobility due to heavy weight and large volume ❖ Limited to UF_6 cylinders and fuel rod ❖ Limited by its peripherals	❖ Limited by its peripherals in nuclear facility	❖ A few test of on-site applicability