A Study on a Nuclear Material Analysis Capability of the Gamma Imaging System, i-PIX

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01 Introduction

Gamma imaging systems are able to identify the location of gamma-ray sources by overlapping images with their location information using semiconductor detectors such as CZT, CdTe, or HPGe. In this paper, the research on nuclear material measurement for the application of iPIX Gamma imaging systems to the field of national safeguards is described. In particular, it is described for the analysis capability of the i-PIX for less than 4.5% of low-enriched uranium, which is mainly used in Korea nuclear power plants.

02 Materials and Methods

2.1 Radiation Measurement System

The i-PIX (Portable Gamma-Ray Imaging System, MIRION) is a type of semiconductor detector using CdTe that can detect and image gamma rays emitted from radioactive materials. iPIX is based on a Timepix CMOS readout photon counting chip,

Figure 1. The i-PIX (Portable Gamma-Ray Imaging System, MIRION) and the operating software

Table 1. Characteristics of the i-PIX, Gamma-ray imaging system

Characteristics	Value
Dimensions	19 x 11 x 11 cm
Weight	2.5 kg
Field of view, degrees	41.4° – 44.8°
Imaging energy range, keV	30 - 1200
Energy resolution, % 662 keV	< 2.5
Detector type	Semiconductor
Imaging technology	Coded-aperture
Detector material	CdTe
Detector type	2D Position sensitive
Detector size	14 x 14 x 1 mm
Number of detector elements	256 x 256 pixels

2.2 Nuclear Materials

The uranium samples with various enrichment from 0.3 to 4.5 % were prepared to measure the analysis capability of the nuclear material for i-PIX. Fig. 2 is the schematic of the uranium sample containers. The aluminum container contains uranium dioxide powder. The U235 enrichments of the samples were 0.3 U235%, 0.7 U235%, 1.9 U235%, 2.9 U235% and 4.5 U235% respectively

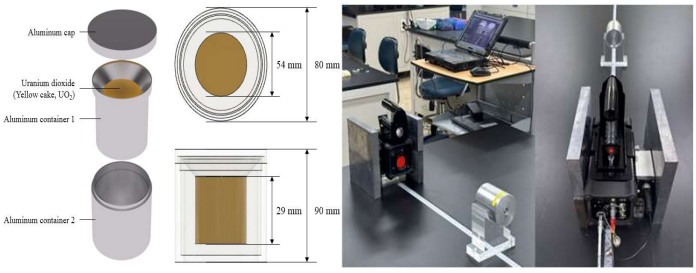

Figure 2. Schematic of the aluminum uranium container. Uranium dioxide powder with 0.3, 0.7, 1.9, 2.9 and 4.5 U235% of the U235 enrichment respectively, The experiment geometry is that the Uranium sample located in front of the Gamma imager and the distance between detector and sample was 30 cm

2.3 Experimental Geometry

The UO2 sample was fixed with a PMMA holder at a distance of 30 cm from the detector. The i-PIX was shielded using four lead shields to reduce noise signals from other sources located in the laboratory. The measurement time was measured according to the time automatically determined by the equipment. The coded aperture masks(Yellow and Red) used, which is a Tungsten mask with a modified uniformly redundant array, MURA engraved on it. Mirion's NDI nuclide analysis module was not installed separately.

03 Result and Conclusion

Single nuclear material

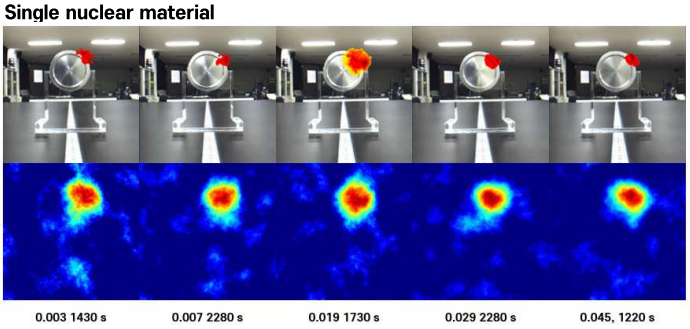

Figure 3. The superimposed images (top) and the decoded gamma images (bottom) of the single nuclear material sources with different uranium enrichment (0.3 – 4.5 %).

In tracking the location of nuclear materials using i-PIX, it was easy to find if only one nuclear material existed. In particular, DU and NU also had no difficulty tracking their location by capturing gamma rays emitted from uranium-238. However, the automatically calculated measurement time in i-PIX was set very long from 1200 to 2280 seconds, making immediate location tracking difficult.

Multiple nuclear materials

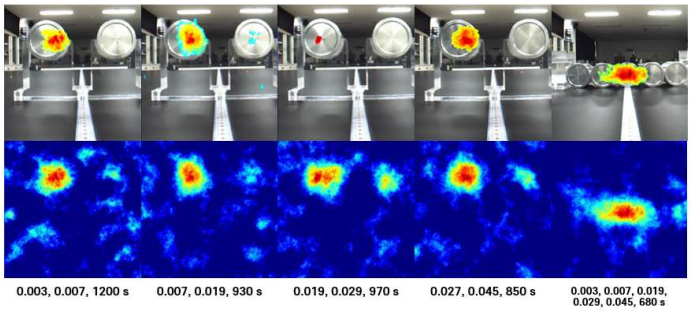

Figure 4. The superimposed images (top) and the decoded gamma images (bottom) of the two and five nuclear material sources with different uranium enrichment (0.3 – 4.5 %).

When locating a number of nuclear materials, i-PIX failed to locate them accurately. When two nuclear materials were located and measured at a distance of 30 cm, only two case was found to be accurate. In addition, the measurement time is also set very long, ranging from 680 to 1200 seconds, making it difficult to use it to detect immediate nuclear materials in the field. In particular, when UO2 powder samples with five different concentrations were measured at a distance of 50 cm, it was determined that the nuclear material was located in the center of the sample location as shown in the fig. 4.

04 Discussion and Future work

Through further experiments, radionuclide analysis will be attempted using the i-PIX NDI module. In addition, gamma-ray imaging systems manufactured by other companies (e.g., Neosis' Wepsilon, H3D's H-Series, etc.) will be measured under the same conditions and the results will be compared.

05 Acknowledgement

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