Gamma-ray spectroscopy based on a $LaBr_3$:Ce scintillator to detect various kinds of radionuclides simultaneously with high resolution

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Introduction

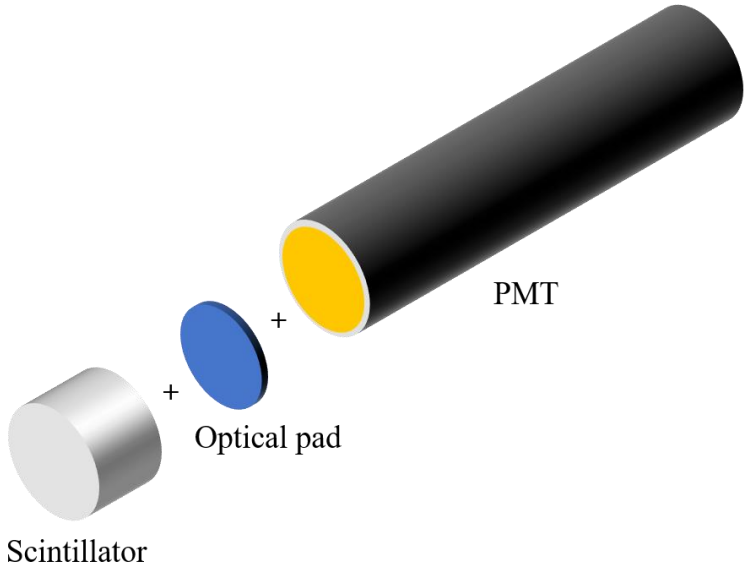
As the research on nuclear power plant decommissioning and decontamination (D&D) has actively proceeded worldwide, the concern about **the radioactive aerosols** which can inhaled by workers during D&D is increasing.

Especially the primary radionuclides in the aerosols from metal cutting processes **vary according to D&D strategies and cutting methods**.

Also, it is important **to identify the radionuclides and measure their activities and doses** for managing the internal exposure of the workers.

In this study, to develop the radioactive aerosol monitoring system, we fabricated **a gamma-ray spectrometer** based on **a $LaBr_3$:Ce scintillator** coupled to a photomultiplier tube (PMT) and performed the gamma-ray spectroscopy using various kinds of gamma-ray sources with high resolution as preliminary research.

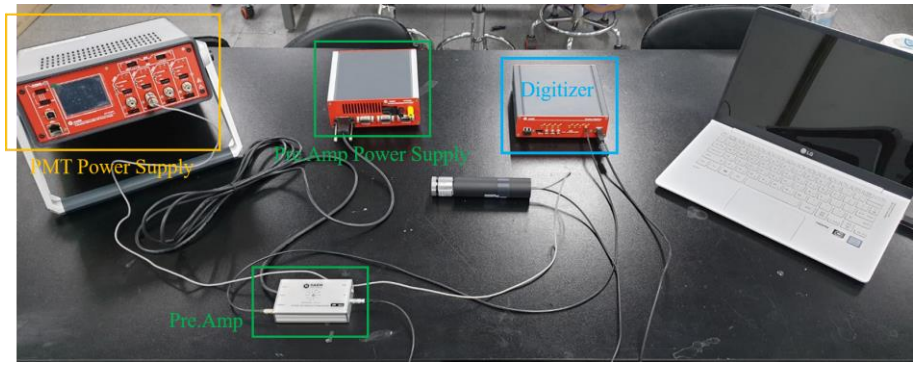
Experimental setup



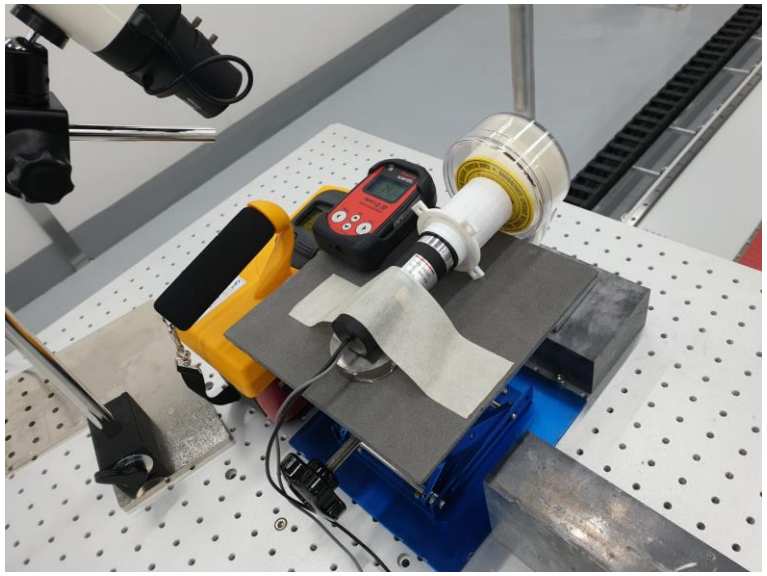
- Scintillator : 1” × 1” cylindrical shape, encapsulated LaBr3:Ce (Epic crystal)
- Optical pad : EJ-560 (Eljen technology)
- PMT : H6533 (Hamamatsu)
- The connecting part was triple wrapped with Teflon tape, aluminum foil, and black insulation tape for optimizing scintillation light collection.

- To imitate a ventilation system which filters the radioactive aerosols, a 3D-printed plastic cap covered with HEPA filter was fitted on the scintillator.

Experimental setup

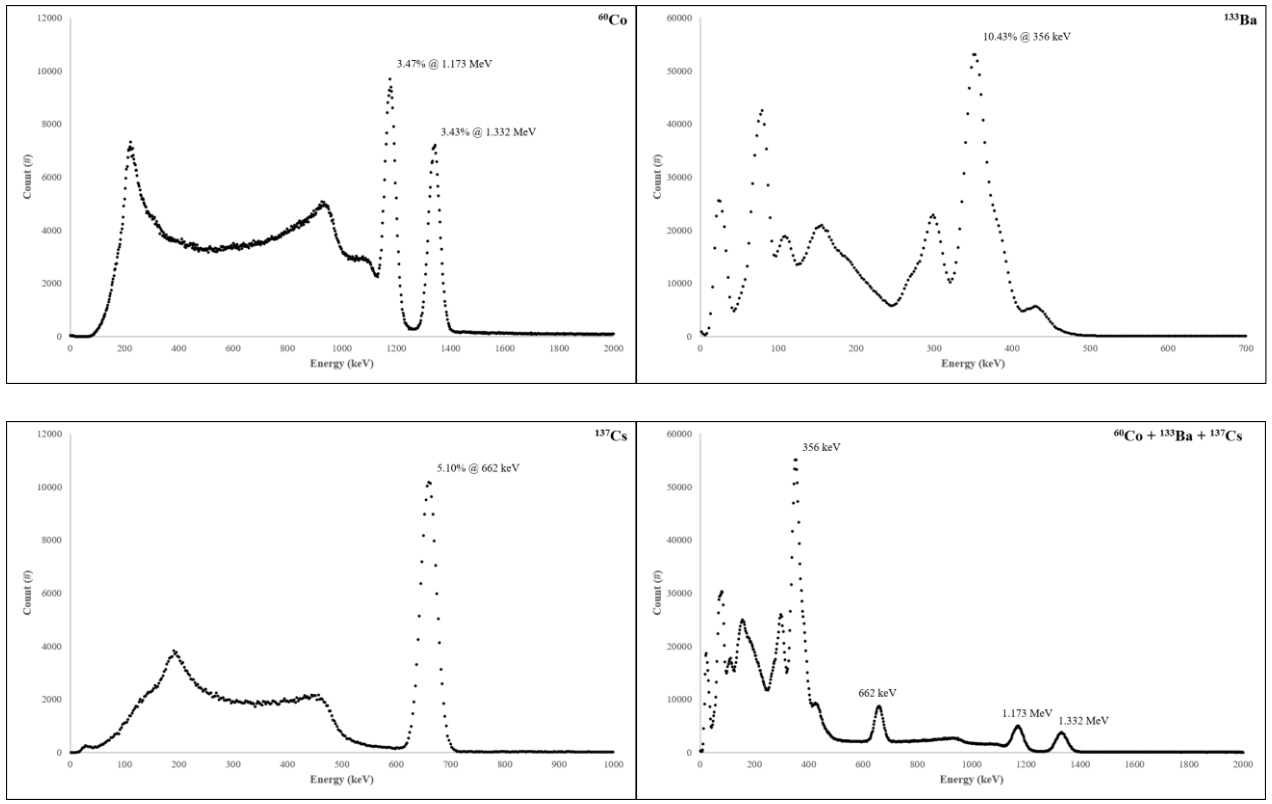


- The signal output of the PMT was integrated by a charge-sensitive preamplifier (A1424, Caen) and fed to a digitizer (DT5725, Caen).
- The signal was handled with a digital pulse processing method which utilizes a trapezoidal pulse shaping filter.



- The gamma-ray spectroscopy was performed using gamma-ray emitting isotopes such as check sources and a mixed source.
- As the check sources, 0.61 μCi ^{60}Co, 0.70 μCi ^{133}Ba, and 0.22 μCi ^{137}Cs were used.
- The mixed source used in this experiment contained ^{113}Sn, ^{88}Y, ^{60}Co, and ^{137}Cs.
- The gamma sources were neighbored on the head of the scintillator.

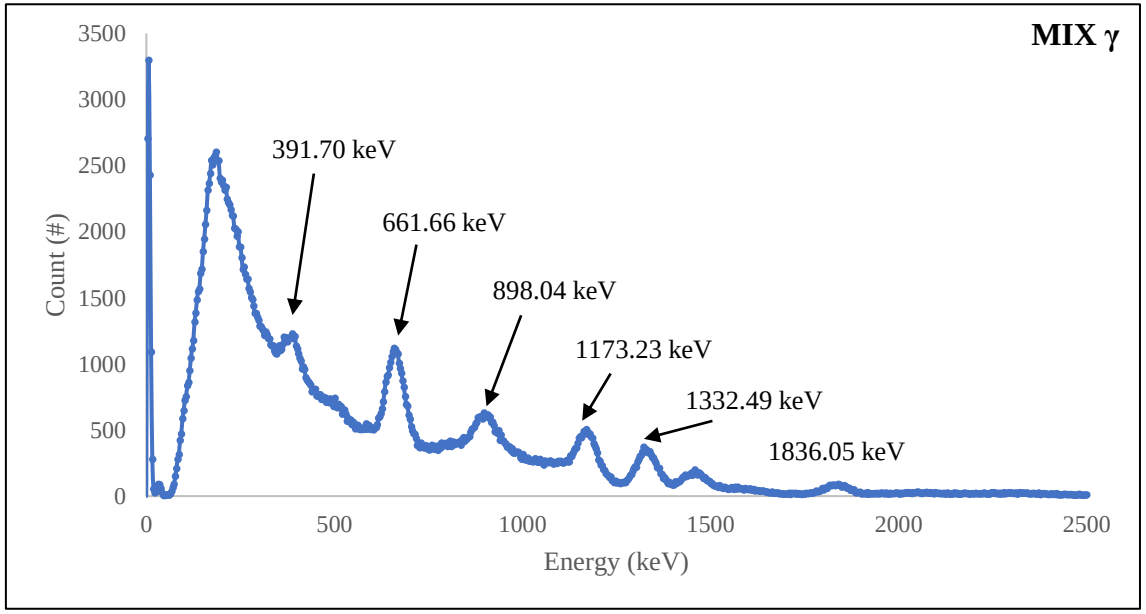
Results



- Figure shows the measured energy spectra of the gamma-ray check sources.
- The full-energy peaks of the radionuclides were clearly observed.
- The energy resolutions at the peaks,
  - 3.47% for ^{60}Co 1173 keV
  - 5.10% for ^{137}Cs 662 keV
  - 10.43% for ^{133}Ba 356 keV
- Additionally, the full-energy peaks of all nuclides were clearly observed in simultaneous measurement with those three sources.

Results

The mixed gamma-ray source consisted of a single paper filter that contains radionuclides and is sealed with a plastic cover. This is equivalent to measuring the radionuclides filtered through the filter.



- As shown in the figure, the full-energy peaks of the radionuclides contained in the mixed source are obviously measured.
- Particularly in the case of ^{113}Sn, whose activity was only 176 Bq, the peak at 391.70 keV was clearly discriminated.
- According to the results, it is confirmed that the fabricated spectrometer has the capability to measure very low activity and the energy region which is from 391.70 keV to 1836.05 keV.

Conclusion

In this study, we fabricated a small-sized gamma-ray spectrometer based on a $LaBr_3$:Ce scintillator coupled to a PMT and performed the gamma-ray spectroscopy with several gamma-ray sources.

Further studies will be carried out to perform the gamma-ray spectroscopy and radioactivity calculation with gamma-ray sources that can be involved in radioactive aerosol and emit lower energy gamma-ray.

Acknowledgements

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References

1. George J. Newton, Mark D. Hoover, Edward B. Barr, Brian A. Wong, and Paul D. Ritter, Collection and Characterization of Aerosols from Metal Cutting Techniques Typically Used in Decommissioning Nuclear Facilities, American Industrial Hygiene Association Journal, Vol. 48, Issue 11, pp. 922-932, 1987.
2. Nakkyu Chae, Min-Ho Lee, Sungyeol Choi, Byung Gi Park, Jong-Soon Song, Aerodynamic diameter and radioactivity distributions of radioactive aerosols from activated metals cutting for nuclear power plant decommissioning, Journal of Hazardous Materials, Vol. 369, pp. 727-745, 2019.
3. William R. Leo, Techniques for Nuclear and Particle Physics Experiments, Springer, pp. 205-207, 1994.
4. Valentin T. Jordanov, Glenn F. Knoll, Digital synthesis of pulse shapes in real time for high resolution radiation spectroscopy, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Vol. 345, Issue 2, pp. 337-345, 1994.

Thank you.