

Development and performance evaluation of a List-mode Compton suppression gamma spectroscopy system for safeguards nuclear material accountancy

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A gamma spectroscopy is widely used for non-destructive inspection such as inspection of contaminated foods, decommission of nuclear related facility, and nuclear safeguards. Peak-to-Compton Ratio (PCR) including the energy resolution, Compton Suppression Factor (CSF), and Minimum Detectable Activity (MDA) are main performance parameters. Small photo-peaks in the Compton continuum cannot be seen because gamma spectra are ruined by the Compton scattering in the detector. One of the method to improve PCR and MDA is the Compton suppression method to reject the Compton scattering using guard detectors surrounding a main detector which operates in the anti-coincidence mode with the guard detectors. In this study, cylinder-shaped NaI and block BGO scintillation detectors as the guard detector were chosen and optimally designed to detect the scattered gamma by Monte Carlo simulation for safeguards application, in which measures gamma-ray from spent fuel, and determine burnup of spent fuels and isotope ratio of special nuclear materials such as Plutonium and Uranium. The NaI, which has higher light output and relatively lower density, is used to detect back-scattered gamma from the main HPGe detector, while the high density BGO is used for detect the front-scattered gamma of relatively higher energy. The developed Compton suppression gamma spectroscopy system consists of 1) a slit or pin-hole collimator, 2) a HPGe main detector, 3) NaI/BGO guard detectors, 4) 4 channel 100 M/s digitizer which readouts the preamplifier signals for digital signal processing, and records the energy and time information, and 5) a post-processing program which handle the energy and time data for anti-coincidence data processing. The post data processing with list-mode data of energy and time information can help to select the optimum anti-coincidence time window for the Compton suppressed spectra. The performance of the developed list-mode Compton suppression gamma spectroscopy system was evaluated with several check gamma sources such as Ba-133, Co-57, Cs-137 and Co-60 in terms of PCR and CSF. And it was also tested with a few spent fuel samples having different burnup. It is expected that the developed system can improve the measurement uncertainty and time in the isotopic ratio determination and nuclear material accountancy of spent fuel.