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A novel method for estimating the 3-D distribution of radioactive isotopes in the material

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In recent years, various gamma-ray visualization techniques (gamma camera) have been proposed. These techniques are extremely effective for identification of "hot spots,"i.e., regions where radioactive isotopes accumulate in nuclear disaster-affected areas in Fukushima and around a nuclear reactor. However, the images acquired with a gamma camera do not include the distance information between radioactive isotopes and the camera and hence are "degenerate"in the direction of the isotopes. Moreover, depth information in the images is lost when isotopes are embedded in materials, such as water, sand, and concrete. Here, we propose two novel methods of obtaining depth information of radioactive isotopes embedded in materials by comparing (1) their spectra and (2) the images of incident gamma rays scattered by the materials and direct gamma rays. In the first method, spectra of radioactive isotopes and the ratio of scattered to direct gamma rays are obtained. We verify experimentally that the ratio increases with increasing depth, as predicted by simulations. In the second method, the spatial extent of images obtained for direct and scattered gamma rays is compared. By performing detailed simulations using Geant4, we verify that the spatial extent of the position where gamma rays are scattered increases with increasing depth. For demonstration, we are developing various gamma cameras to compare low-energy (scattered) gamma-rays images with a fully photo-absorbed gamma-ray image. We also demonstrate that the 3-D reconstruction of isotopes/hotspots is indeed possible with our proposed methods.
These methods have potential applications in the medical field and in severe environments such as disaster-affected areas in Fukushima.

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