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Gamma Imagers for Nuclear Security and Nuclear Forensics

Natural Resources Canada (NRCan) has responsibility within Canada for mobile survey operations in the event of a nuclear emergency. Our research team, which includes researchers from NRCan, the National Research Council Canada, Defence Research and Development Canada, the Canadian Nuclear Safety Commission, and other Canadian Universities and Federal agencies, has benefitted from close association with the NRCan nuclear emergency response team and has over ten years of experience in conducting mobile radiation survey operations in nuclear security exercises and in support of nuclear security operations.

Radiation detection equipment used in security operations at major events and at borders, and in response to radiation incidents, is typically capable of detection of radioactive substances, with some ability to characterize the strength of the radiation field at the location of the detector, and with some ability to identify the source of radioactivity using the measured energies of emission, but with limited ability to determine the location of the source. In recent years, advances in technology have taken place which have the capability to dramatically improve radiation detection operations. It is now possible to create an image of the field of radiation emitters using the gamma rays which accompany radioactive decay. This radioactivity image can be overlaid on a regular photograph, video, or three-dimensional representation, to dramatically improve response efforts by showing the locations of radioactive sources superposed on locations of objects surrounding the observer.

Gamma imaging technologies have traditionally arisen out of methods developed for medical physics, experimental particle physics and astrophysics applications. This has resulted in the proliferation of different technological approaches, each with different strengths and weaknesses. Some imagers emphasize the ability to identify the radioisotope, or to measure radioisotope ratios, by using materials with superior energy resolution. Other imagers have been developed to have as high sensitivity as possible with low cost materials. Our research group has extensive experience in developing advanced radiation detectors including Compton gamma imagers, specifically for nuclear security operations.

In this presentation we review the current status of gamma imaging worldwide with particular reference to nuclear security and nuclear forensics applications. We discuss quantitative measures which can be used to benchmark different imagers against each other - even if the imagers are based on dramatically different concepts. We present quantitative comparison of the performance of multiple gamma imager designs and technologies, and show which approach is preferable in different scenarios. We present real radioactivity spectra and images, and radioactivity maps, taken in tests and exercises in a variety of conditions: indoor versus outdoor in various weather, mobile versus stationary, single versus multiple viewpoints, point versus multiple or extended sources, discrete observance vs overt observance. We discuss the impact of gamma imaging information products on nuclear security operations and on nuclear forensic investigation. Finally, we give an outlook on future directions for gamma imaging technological and methodological advances.

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