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#6-45 3D-Printed Modular Radiation Sources for Testing Radiation Detectors and Advancing Radioisotopes Identification Algorithms

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The international radiological and nuclear (RN) community recognizes Improvised Nuclear Devices (INDs) as a significant security threat. Therefore, efficient, and reliable detection solutions at points of entry, our first line of defense, are critical for maintaining secure yet open borders. Screening of containerized cargo for INDs, and RN materials in general, is primarily done using drive-through radiation portal monitors (RPMs). RPMs scan containers and trigger an alarm if the analysis of gross counts and ratios in specific energy windows exceed a set threshold. Globally, advanced computing algorithms, including machine learning and artificial intelligence, are being developed and enhanced to improve the consistency and accuracy of RN materials identification and reduce the burden of unnecessary inspections for containers with naturally-occurring radioactive material. However, these data analytics algorithms require augmentation with true positive sample scan data covering the full threat space, including data representing INDs of various intensities and shielding materials. The scarcity of, and strict access to, large quantities of special nuclear materials (SNM) in various geometries and isotopic compositions have led to RPMs and other portable detectors being deployed without testing their performances against INDs, resulting in a high number of false alarms which require a significant amount of time to manually resolve.
Self-shielding in bulk SNMs, such as those occurring in INDs, limits the detection of gamma/X-rays originating more than a few millimeters below a sample's surface, leaving mostly high- energy gamma rays and surface low-energy gamma/X-rays detectable in search scenarios. Thus, a thin layer of nuclear material deposited on a metallic or plastic shell could be designed to precisely match the gamma-ray emissions, in terms of energy spectrum and rate, as a bulk-quantity of nuclear material. Hence, versatile, well-characterized, optimized, and traceable radiation sources could be fabricated for the envisioned applications by controlling the geometry, thickness of the deposited layer, overall dimensions, and isotopic composition.
Canadian Nuclear Laboratories (CNL) is exploring the applicability of additive manufacturing technologies for making modular radiation sources using natural uranium (NU). The 3D-printed thin layers of NU within plastic shells have been demonstrated at CNL. Using less than a hundred grams of NU, careful balancing of the shape and size has permitted for accurate replication of the gamma spectrum and emission rate of a bulk NU sample with a mass of a few kilograms. This presentation highlights the Geant4 simulations for designing and optimizing the radiation source's shape and size while minimizing the NU mass, the fabrication techniques, and the first experimental comparisons between the 3D-printed source and a bulk mass of NU. Based on that, it is believed that these modular radiation sources will enable the creation of true positive datasets that mimic those expected from a real IND, and therefore the development of an algorithm to help assess the significance of the alarms. Work is still underway to fabricate thin and modular highly enriched uranium (HEU) and U-233 radiation sources to match the gamma/X-ray emissions of a bulk mass of 25kg HEU and U-233 respectively.

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