Prototype RadICAL Detector for Nuclear Security

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The Concept

The RadICAL (Radiation Imaging Cylinder Activity Locator) concept aims to enable the mapping of a 360° area in order to locate radioactive sources.

To achieve this, RadICAL makes use of a specially-shaped rotating slab of scintillation material coupled to a photomultiplier tube (PMT). As a result, the ever-changing surface area and thickness of the scintillator, presented to a radioactive source, causes the PMT count rate of interacting photons to change as the scintillator is rotated about its central axis. This produces a Standard Response Curve (SRC), from which the direction of the source can be located via the minimum of the SRC.

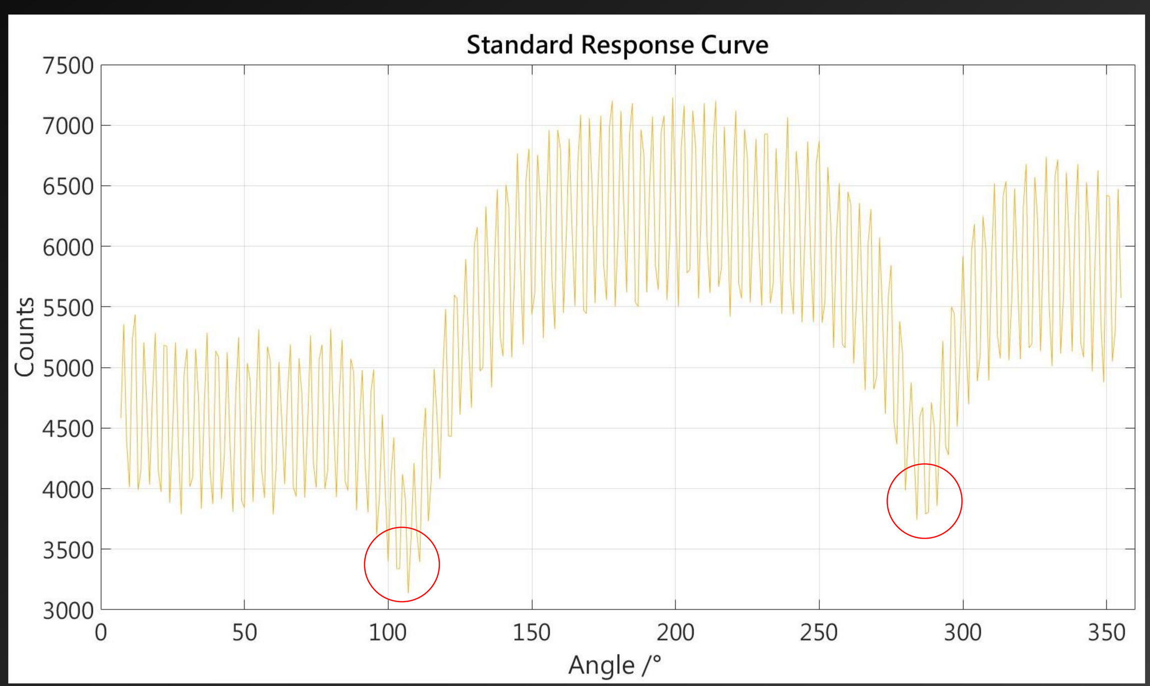

Figure 1 – A RadICAL SRC of ^{137}Cs, obtained during testing, clearly showing two minima at approximately 180° apart. Using two RadICAL detector SRC graphs, a source location and distance could be determined.

The fraction of incident photons absorbed by the rotating detector at various angles can be expressed through the following equation[1]:

$$\frac{N}{N_0} = e^{-\int \mu_{en}(E)\cdot x(\theta)dx} \qquad (1)$$

where N is the number of non-interacting photons incident on the scintillator, N_0 is the number of incident photons, $\mu_{en}(E)$ is the attenuation coefficient, which varies as a function of different photon energies, and $x(\theta)$ is the radiation path-length presented to the radioactive source as a function of angle.

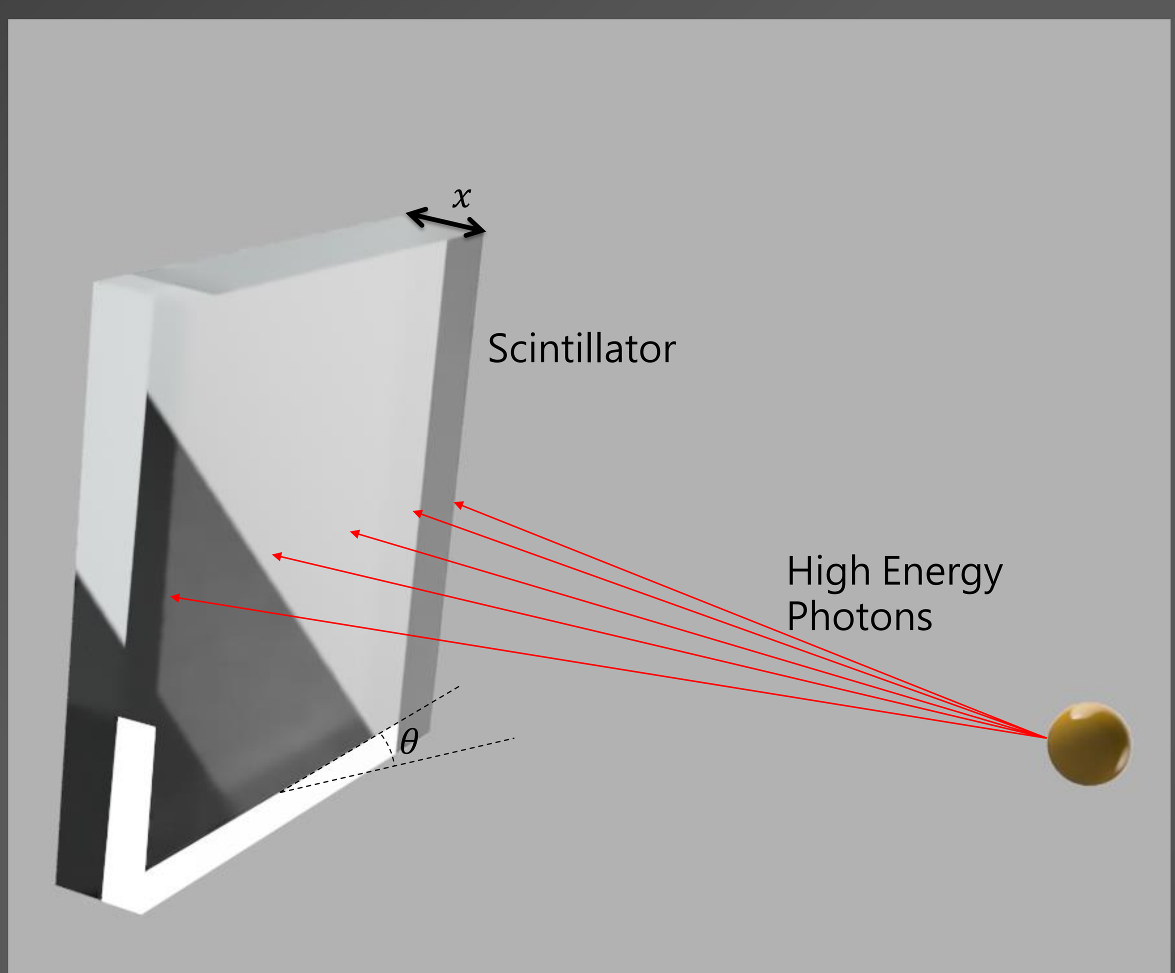

Figure 2 - Variation in the scintillator thickness and surface area as a function of angle. The maximum scintillator thickness occurs when the lowest surface area is presented to the radioactive source; this however, has an insignificant effect when compared to the effect of surface area.

Applications

RadICAL detectors have potential applications in four key areas:

1. Nuclear Decommissioning

During deconstruction of nuclear facilities, RadICAL has the potential to map regions of high and low radioactive contamination, reducing the potential of accidental exposure to people operating in these high risk areas.

2. Homeland Security

Multiple RadICAL detectors placed in stations, ports, etc. have the potential to detect, pinpoint and therefore help intercept the transportation of radioactive sources that may be used in the development of 'dirty bombs'.

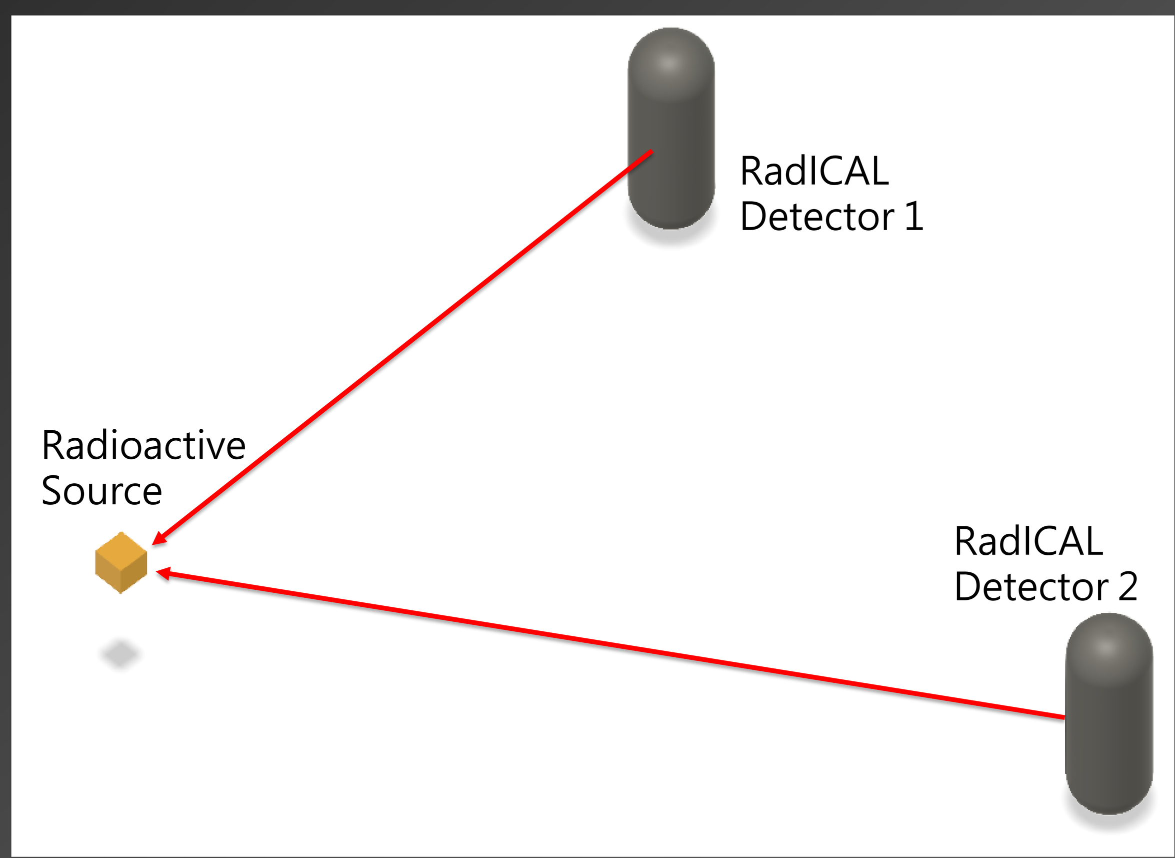

Figure 3 – Two or more RadICAL detectors could be used to determine the location of a radioactive source. This could be useful in the monitoring of ports and stations for homeland security.

3. Radioactive Contamination (CBRNE, landfill, etc)

A RadICAL detector, placed in areas with the potential for contamination, could be used to continuously scan for radioactive waste. This would negate the need for checks from conventional human-operated radiation detectors.

4. Monitoring high risk areas e.g. labs and hospitals

A RadICAL detector, placed in a laboratory, hospital room or factory, that may be subject to radioactive contamination such as spills and leaks, could be used to continuously map these areas, improving safety for those working there.

Figure 4 – RadICAL has applications in the mapping of radioisotopes during the transport of illegal radioactive materials, the monitoring of hospitals & laboratories, as well as in the decommissioning of radioactive facilities.

Design

A RadICAL detector is composed of the following key features:

- A scintillator – such as EJ-200 or EJ-276.
- A Photomultiplier Tube to establish a count rate at certain angles, and thus determine source location .
- A light-tight housing to reduce the photomultiplier tube's background noise.
- A Stepper Motor used to rotate the scintillator to the required angles.
- A control Interface, such as MATLAB, to control the PMT and stepper motor, as well as record data.

Figure 5 – a) A cross-section of RadICAL rendered in CAD software showing the basic elements of the RadICAL detector. b) A rendering of the outer housing of RadICAL. c) The functioning RadICAL detector prototype.

Tests were carried out using radioisotopes - primarily ^{137}Cs with an activity of 3.7MBq, which was investigated using a variety of acquisition times and angular increments. This resulted in SRCs, where it was observed that the resolution of the minima increased for longer total acquisition times.

Short scans however, (<20mins) still yielded high resolution SRCs allowing location of a source with significant accuracy, thus allowing for potential applications in homeland security.

In real-world scenarios there may often be multiple radioactive sources present, such as in areas set for nuclear decommissioning; whilst in ports and stations, radioactive sources may be moving during their illegal transportation.

As such, work has been carried out in order to identify these using SRCs.

In order to do this, count rate data from radioisotope sources had to be deconvolved in order to determine a Bragg distribution, and thus find a maximum energy deposition point.

Acknowledgments

[1] Randall, G., Iglesis, E., Wong, H. and Speller, R. (2014). A method of providing directionality for ionising radiation detectors — RadICAL.
Journal of Instrumentation, 9(10), pp.P10011-P10011.

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