



Lighthouse directional radiation detectors: Proof positive in radiation detection

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According to Leonardo da Vinci, “simplicity is the ultimate sophistication.” This aphorism appropriately fits the Los Alamos National Laboratory’s Lighthouse Detectors. These novel detectors are a broad class of directional radiation detectors that use differential attenuation to reveal the vector components of a radiation field. The name Lighthouse Detector comes from the moving field of view, scanning through a solid angle similar to the beam of light emitted from a lighthouse. In practice, these simple detectors function much like an old-fashioned TV antenna, producing a peak measurement when the detector is pointed at a radiation source. However, the simplicity of Lighthouse Detectors belies their capabilities. The detectors’ directionality, speed and sensitivity afford applications in site survey, assay, inventory, security, situation awareness, process controls, and materials control and accountability (MC&A).

Significance of the work

Directional radiation measurements are useful for identifying the locations and movements of radioactive materials. Directional measurements can verify the location of materials in storage, indicate the movements of materials through portals and along paths, verify the quantities of materials in containers or in use, activate alarms when materials are moved into prohibited areas and even reveal the locations of contaminants at waste sites. Another application just as significant is verifying that an area is free of radioactive materials. By looking for and not finding the signatures characteristic of such materials, Lighthouse Detectors provide “positive evidence of a negative result,” assuring the user that a cupboard is bare or that a space is free of contaminants. Using differential attenuation, the Lighthouse Detectors allow radiation to enter unattenuated through a particular field of view while either blocking or partially blocking radiation entering from outside this field of view. When the unattenuated field of view is lined up with a radiation source, the detector produces a maximum signal. When the detector is turned so the attenuator is between the detector and the source, the detector’s signal goes down. By adjusting the geometry of the attenuating screen, the detectors can have variable fields of view. Directional accuracy of better than 1 degree has been achieved in laboratory demonstrations and by using advanced materials, attenuation of as much as 50:1 has been achieved using lightweight, hand-held detectors. Adding to their capabilities, the research team at the Laboratory has

also built gamma, thermal-neutron and fast-neutron Lighthouse Detectors. Unlike other types of detectors, the Lab's Fast-Neutron Lighthouse Detector achieves directional measurement independent of the scattering inherent in fast-neutron moderation. Unlike pinhole gamma-ray cameras, Lighthouse Detectors have a wide aperture for fast exposure and rapid assay. A wide aperture allows the Detectors to work even in radiation fields having low flux.

Achievements

In partnership with Quaesta Instruments, Lab scientists made a major step forward in 2015 with the miniaturization of its Gamma Lighthouse Detector through a Cooperative Research and Development Agreement (CRADA). Quaesta brought expertise in radiation measurement and industrial electronics, collaborating with the team to miniaturize their detectors, explore new view-frustum geometries, and lower the Detectors' noise floor for improved speed and sensitivity. This TRL-9 instrument features improved noise floor with silicon photomultiplier electronics, power over Ethernet for unlimited operation in remote locations, digital interface for customizable software control, and a built-in web server for data access using only a laptop with a web browser.

Because the technology also works with neutrons, Lighthouse Detectors enable direction measurements of neutrons to locate neutron sources. This patented technology is creating new research opportunities and enables survey, inventory and security applications for neutron sources.

The Laboratory has demonstrated Lighthouse Detectors in several field applications. The Lab's Emergency Response group uses Gamma Lighthouse Detectors on its HAZMAT robots.

These radio-controlled all-terrain robots can survey field sites without requiring personnel to enter those sites, permitting isotopic-survey and radiation-field measurements while achieving minimum-radiation-exposure safety objectives. Benefits include minimizing radiation exposure by keeping humans out of harm's way while performing secure surveys, assays and inventories with knowledge gained by the robots on where radioactive materials are located. The Lab's Earth System Observations group uses the Gamma Lighthouse Detectors for geologic surveys across northern New Mexico and the Nuclear Materials Science group uses Thermal-Neutron Lighthouse Detectors in research for inventory and measurement applications. In partnership with Phoenix International Holdings and the Sexton Corporation, the Lab is currently developing Lighthouse Detector sensor systems to survey radioactive materials in the oceans.

Lighthouse Detectors move the state of the art forward in radiation detection, saving humans from harm in the process, performing positive surveys where radiation is present and positive evidence of a negative result where radiation is absent. The team currently has a portfolio of 5 projects with a total budget of over \$11m using Lighthouse Detectors and has also developed software to support the technology. The custom software includes data-acquisition modules for Quaesta gamma and neutron systems, and geographic-information-system mapping modules for site-survey applications. The next step for the team will be to hold demonstrations for specific field applications. They will then use the lessons learned from the demonstrations for the next phase of improvements and to develop a follow-on set of applications for end users. In the

area of radiation detection, the proverbial sky is the limit for this innovation team. They expect to begin testing not in space but rather on the ocean floor later this year where 99 percent of the ocean terrain can be accessed using their technology.

The research team

Jonathan Dowell, Adam Kingsley and Mark Wald-Hopkins (International Threat Reduction), Dale Talbott and Thomas Barks (Technology Development), Rick Rasmussen, Rick Rothrock, Sam Salazar and Theresa Cutler (Advanced Nuclear Technology), Kris Hyatt (Weapons Test Engineering), Don Hyatt (High Explosives & Weapons Engineering Tritium Facility), Larry Bronisz and James Thompson (Applied Engineering Technology-1), Chris Chen (Sigma-DO), Damien Milazzo (Earth System Observations), David Fontaine (PF-Laboratory Fabrication Services), James Hemsing (LANL Student), Gary Sundby (retired), Paul Asare Agyapong (U.S. Army), Pete Shifflett, Steve Hamann, David Allen, Gary Womack, Kristopher Savage, and Aaron Clark (Quaesta Instruments, LLC), Peter McKibbin, Dan Pol, Gino Gonzalvez, Robert Lohe, John McCosker and Juan Sevillano (Phoenix International Holdings, Inc.), Jeremy Childress and Kent Fletcher (Sexton Corporation).

Funding

Over the past 6 years, and in concert with their industrial partners, the Los Alamos National Laboratory and the National Nuclear Security Administration have invested over \$11 million in Lighthouse Detectors for a variety of applications, reaching TRL-9 technology readiness.

Technical contact

The technical contact is Jonathan Dowell.

Caption for image below: Lead scientist and Lighthouse Detector inventor Jonathan Dowell is pictured with the HAZMAT Robot and a Gamma Lighthouse Detector in a shock-resistant housing.

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