WHITE PAPER

Why High-Purity Germanium (HPGe) Radiation Detection Technology is Superior to Other Detector Technologies for Isotope Identification

Synopsis: High Purity Germanium (HPGe) is the only radiation detection technology that provides sufficient information to accurately and reliably identify radionuclides from their passive gamma ray emissions. HPGe detectors have a 20-30x improvement in resolution as compared to that of Sodium Iodide (NaI) detectors. In addition, NaI detectors, unlike HPGe detectors, have been shown to perform poorly in mixed isotope, shielded, stand-off, and high background scenarios. Whether in a secondary detection role providing portable positive identifications in response to gross radiation alarms, or in combined primary/secondary detection mission (such as a HPGe portal monitor), HPGe technology, coupled with state-of-the-art real-time spectral analysis algorithms and field proven supporting electronics, can accurately identify and ascertain whether alarms were caused by innocent radiological sources, or if true nuclear or radiological dangers are present.

Background Information on Radiation Detection and Identification

Radiation detectors fall into two categories: gross counters and energy sensitive. Gross counters count each event (gamma or neutron) emission the same regardless of energy. Energy sensitive detectors -- used in radio-isotope identification devices (RIIDs) -- analyze a radioactive isotope's distinct gamma energy emissions and attempt to identify the source of the radiation.

Due to the prevalence of naturally occurring radioactive material (NORMs) present in legitimate commerce -- kitty litter, ceramic tiles, fertilizer, along with radionuclides used in industrial or medical applications -- gross monitors can "alarm" quite often. This type of "false positive" is actually not a true false positive because the material is indeed radioactive. These alarms caused by NORM or legitimate radioisotopes are frequently referred to as a nuisance alarm, because they inhibit the flow of legitimate commerce. Many of these nuisance alarms require the resolution of a High Purity Germanium Detector to determine the true cause of the radiation alarm. If vehicles, packages, or people were stopped every time an increased radiation level was detected, commerce would be halted and the resulting negative economic impact would be huge. The Port Authority of New York estimated that if a single terminal were to be closed for 1 hour while a false positive signature is investigated more thoroughly, the cost of the shutdown would be $500,000.

When an alarm is triggered, response personnel must be able to quickly ascertain if the alarm was caused by a legitimate commercial radioactive source, a NORM, an industrial or medical isotope, or a potential terrorist weapon. To determine the identity of the radioactive source, it is necessary to do a spectroscopic analysis of the suspicious package, cargo container, or vehicle that caused the alarm. All radioactive materials emit unique gamma energies that are conceptually similar to "fingerprints." These emissions can be analyzed to determine exactly what type of radioactive material is present.

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<u>Types of radiation detectors available to identify potential radiological terrorist devices</u>

The figure below (Figure 1) shows a comparison of natural background radiation as collected by four different types of radiation detectors. Plastic scintillator detectors have no ability to resolve gamma peaks. Sodium iodide (NaI) and cadmium zinc telluride (CZT) detectors have limited abilities to resolve the gamma lines. High Purity Germanium (HPGe) has high resolution ability.

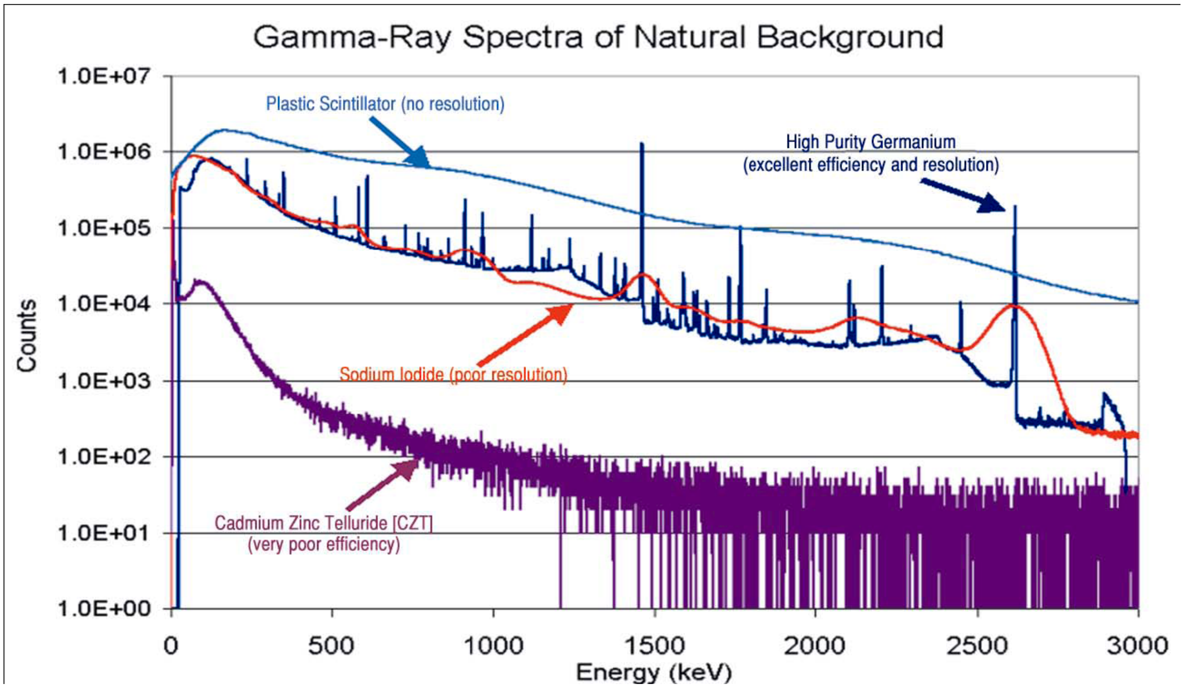

Figure 1

Every radionuclide of concern in homeland security naturally emits a unique set of one or more gamma ray energies from which it can be uniquely identified not unlike a fingerprint uniquely identifies an individual person. These energies are measured in units of electron volts (eV) or Kilo-electron volts (KeV) and most are found within the range of 30 KeV to 3000 KeV. They are not however uniformly spread across this range. Many are tightly spaced with only a few KeV or less between them. To make identifications accurately, one needs to be able to measure these energies to approximately 1/10th of 1 percent. HPGe detectors can provide this level of accuracy while NaI detectors provide only about 6 parts in 100. This problem is obvious when you look at the comparable spectra produced by NaI and HPGe detectors.

<u>HPGe (high resolution) detector versus NaI (low resolution) and CZT (medium resolution) detectors in distinguishing dangerous nuclear material</u>

The figure below (Figure 2) is a comparison of three "fingerprints" of the two types of radioactive material (plutonium and iodine) captured using a low resolution NaI detector (Blue), a medium resolution detector CZT (Black), and a high resolution HPGe detector (Red). The "peaks" in these graphs represent the unique fingerprints of the two radioactive materials.

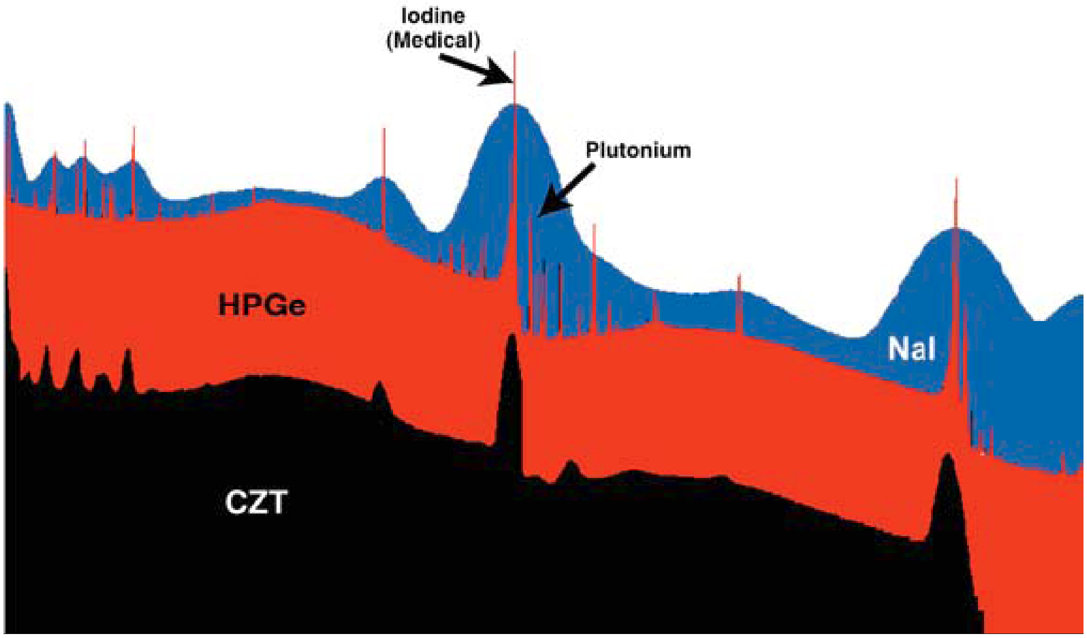

Figure 2: Radioactive Material Fingerprints of Same Material Viewed with Three Types of Technology

The characteristic peaks (or fingerprints) from iodine and plutonium are very close to one another. However, in the blue (NaI) and black (CZT) graphs, they appear as one peak, whereas in the red graph (HPGe) the peaks are clearly distinguishable. The NaI and CZT systems are unable to find the dangerous nuclear material (plutonium) shipped in a package that also contained a legal shipment of a medical isotope (iodine).

Resolution Problem of NaI

RIIDs based on NaI detectors provide only a rough approximation (analogous to a smudged fingerprint) of the energies emitted from a radioactive source, and very often will misinterpret or incorrectly analyze the radioactive materials. As demonstrated in the above graph, low-resolution detectors would have difficulty identifying the presence of Special Nuclear Material (SNM) that has been hidden inside one of the thousands of legal radioactive shipments occurring every day. The resolution problems will accompany NaI technology in whatever setting it is used (such as a RIID or portal monitor).

In testing over the past several years, low resolution systems were not capable of satisfying the minimum requirements of identifying shielded radioactive materials (ITRAP, .Illicit Trafficking Radiation Detection Assessment Program., Final report, ARC Seibersdorf. February, 2001). Other systems have attempted to use Cadmium Zinc Telluride (CZT) detectors to identify radiological materials, but these “medium resolution” detectors are very small (typically 15mm x 15mm x7mm) and they are therefore very inefficient. Count times using a CZT based detector would be orders of magnitude longer than NaI or HPGe detectors. Time is of the essence in performing analysis of an unidentified radioactive source. It is simply not feasible to perform a measurement that may last an hour or longer and still be unable to provide a definitive answer.

Los Alamos National Laboratory did an evaluation of seven commercially available NaI and CZT hand-held gamma ray detectors (including the GR 135) with isotope identification ability. The full study can be found at http://www.ortec-online.com/papers/la_ur_03_4020.pdf. The conclusion was "as a group, the instruments included in the study performed quite poorly in identifying radioisotopes."

> "We have found the intrinsic efficiencies of the detectors examined in this study to be quite similar, suggesting the differences in absolute efficiency can be attributed to crystal size. We have also found the resolution profiles of the detectors to be very similar for the NaI and CZT detectors. Classifying an instrument's identification of the radioisotope responsible for a gamma spectrum is complicated and categories to perform such a classification are presented. As a group, the instruments included in this study performed quite poorly in identifying radioisotopes. One of the contributing factors to this poor performance may be due to calibration drift. Work is needed to improve both calibration stability and isotope identification algorithms."

HPGe provides positive identifications

Due to its far superior resolution, HPGe is the only radiation detection technology that provides sufficient information to accurately and reliably identify radionuclides from their passive gamma ray emissions. HPGe detectors have 20-30 times better resolution than NaI detectors. Also, unlike NaI detectors, HPGe detectors are resistant to information (signal) degradation caused by changes in background radiation, shielding, multiple radionuclide interference, and temperature variations. Such ever present variations result in both false positives and false negatives and endanger our ability to interdict illicit radiological and nuclear materials before they do harm. HPGe is also much more effective than NaI detectors in stand-off radionuclide identifications such as are encountered in vehicle or shipping container inspections

What is HPGe?

HPGe detectors are made by highly refining the element germanium and growing it into a crystal. The crystal goes through a series of processing steps culminating in the attachment of positive and negative contacts which turn it into an electronic diode. The special property of this diode is that it conducts current in proportion to the energy of a photon (gamma ray) depositing energy in it. The relationship between energy and current is so precise in HPGe detectors that energies are determined to better than $1/10^{th}$ of 1 percent.

Past impediments to HPGe field deployment

HPGe detectors have been used for over quarter of the century. However, because they operate at cryogenic temperatures and they require highly accurate supporting electronics, HPGe detectors have been large and expensive laboratory instruments, not very suitable for field use.

Recently, two advances in technology have revolutionized the applications of HPGe. First, advances in solid-state electronics and particularly in a digital signal processing over the past ten years have dramatically reduced the size, complexity, operating power, and cost of the electronics required to support HPGe detectors. Second, and much more recently, miniature, low-power, high reliability cryogenic coolers have been developed that replace liquid nitrogen as the cooling.

Current HPGe deployment

Portable, electromechanically cooled HPGe detectors have now been commercially available for over two years and are being acquired and utilized by various federal and state government agencies including DoD, DOE, FBI, DHS/CBP, RAP Teams, State Emergency Operation offices, local bomb squads, UK and Canadian security services, and others. Prior to 2004 when the field portable non-LN cooled HPGe detectors became available, virtually all of the HH-RIID's deployed by government agencies used NaI detectors. As a result of the terrorists acts on 9/11/01, there were numerous government purchases of HH-RIID's in 2002 and 2003. Unfortunately, this was before the higher performance electromechanically cooled HPGe detectors were available.

HPGe detectors can also be deployed in fixed monitors, such as portal monitors. In this configuration, HPGe detectors also provide numerous benefits over plastic scintillators or NaI-based radiation portal monitors. As part of the "Advanced Spectroscopy Portal" project, the Domestic Nuclear Detection Office (DNDO) has tested HPGe detectors in a portal monitor configuration. The standoff detection capability and the accuracy of radionuclide identification has proven to be excellent for HPGe detectors.

Also of note, the Defense Threat Reduction Agency (DTRA) is in the second year of an HPGe RIID deployment evaluation.

It Is More Than Just HPGe
In addition to using the best available detector technology, ORTEC portable and portal radionuclide identifiers use state-of-the-art, real-time, proprietary identification software and stable, field proven electronics. Originally developed by Lawrence Livermore Laboratory, the software used in the ORTEC DETECTIVE Series portable identifiers provides answers as quickly as they are statistically significantly. This means the operator can usually get answers in a few seconds with statistical certainty -- not a minute or more with highly questionable statistical significance as is typically of competing technologies.

Federal Government References for Detective and Detective-EX

Available upon request.

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