Advanced Hand-Held Detection System for On-Site Localization and Identification of Nuclear and Radioactive Material

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1. Abstract

Scintillation crystals for hand-held detection systems made of Lanthanum Bromide (LaBr) provide better resolution than common NaI crystals. An example of a detection system featuring a LaBr crystal is the InSpector 1000 (manufactured by Canberra). It is a light-weight instrument suitable for mobile search applications to localize and identify both nuclear and radioactive material. It comprises two detectors: a LaBr probe for gamma ray detection and a He-3 tube for neutron detection. Its low weight enables the user to perform thorough on-site inspections of areas where the presence of nuclear or radioactive material is suspected. Its performance clearly surpasses that of common NaI hand-held detectors, showing a resolution better than NaI by a factor 2 at least. Therefore this system shows considerably better results in localization and identification of suspicious material than NaI detectors of a similar size.

Two especially important aspects for on-site applications are the time required for the localization of the material and the ability of the device to identify the radioactive nuclides correctly. As for the first aspect, the system's search mode (featuring both acoustic and optical signals) works in a satisfactory manner and is suitable to be applied even in the case of small amounts of (unshielded) radioactive or nuclear material. As for the identification, in the case of energy lines which are too close to one another and can therefore not be properly resolved, the results may become inconclusive possibly because the analysis sequences used for the InSpector 1000 were originally written for semiconductor detectors with considerably better energy resolution. To obtain a more reliable isotope identification one would have to use detectors featuring Germanium crystals which are usually of higher weight and are more expensive. Therefore, the InSpector 1000 system serves as a compromise between lighter NaI hand-held detectors which commonly provide identification of poor quality and heavy-weight Germanium detectors with good or excellent means of identification.

2. Introduction

The scope for On-Site measurements of radioactive sources can vary. Two main topics are localization and identification. These two aspects lead to different requirements concerning design, capacity, operation time, efficiency, resolution etc. The best resolution of all available detector systems is provided by detector systems using germanium semiconductor crystals. Hence this leads to the best identification result. The large disadvantage of such kind of systems is in the need of crystal cooling. This can either be done with liquid nitrogen or electrically. Both ways lead to detector systems with higher weights. The standard crystal material used in detector systems which requires no cooling was for a very long time the Sodium Iodine scintillator (NaI(Tl)). Using this type of material, light weight hand-held devices can be designed. The disadvantage is the poor resolution which may lead to bad identification results. LaBr crystals show clearly better resolution and have no need for cooling. In this paper the InSpector 1000 with a LaBr crystal was compared to a detection system with a NaI scintillator and one with a Germanium crystal. The performance of these devices concerning search and identification was tested.

3. Measuring Systems

3.1. Detector material for γ-measurements

For a good identification result it is essential to have a good detector resolution. If the energy lines can not be resolved, a corresponding analysis can not lead to a result. Figure1 shows a comparison of spectra obtained with three different measurement systems and a ^{239}Pu-source [1].

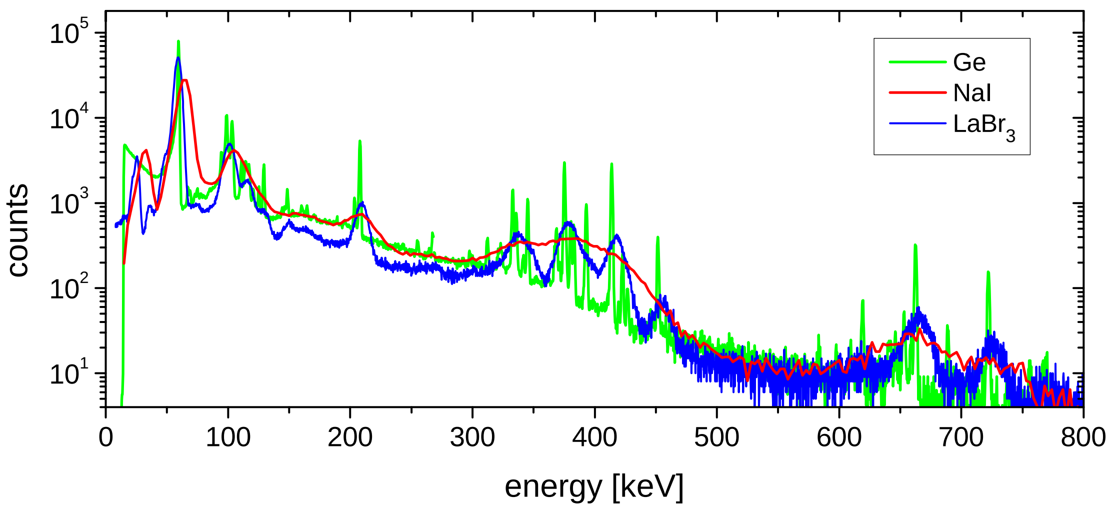

Figure 1: Measured ^{239}Pu spectrum with Ge, NaI, and LaBr-detector for resolution comparison.

The resolution of the Ge-detector spectrum is clearly the best one; the various lines can clearly be resolved. The LaBr-detector spectrum show clear structures, however the energy lines can not be resolved in detail. The spectrum obtained with the NaI-detector depicts only the rough structure of the energy spectrum. It is obvious, that the analysis result obtained with the Ge-detector spectrum leads to the best results. But nevertheless the characteristics of the spectrum even with the worth resolution of the two other spectra Plutonium can be identified. The results depend also on the quality of the evaluation routine.

Table 1 lists some characteristic properties of the investigated detectors.

		Ge	**NaI**	**$LaBr_3$**
Resolution at [%]	122 keV	1.1	24.6	8.4
	662 keV	0.3	6.8	3.3
	1332 keV	0.2	5.8	2.4
crystal size		2” x 1,2”	1.4“ x 2“	1.5“ x 1.5“
rel. efficiency		16 %	8 %	12 %

Table 1: Specifications of the detector materials Ge, NaI and $LaBr_3$ used for the measurements shown in figure 1.

3.2. Inspector 1000

The InSpector 1000 is a modern hand-held detector with La_2Br_3 scintillator crystal. It consists of a control unit and an external LaBr probe containing the scintillator, see figure 2. The probe can also be attached directly to the control unit. Alternatively to the LaBr probe, a neutron detection probe may be used. The probes also include the accompanying high voltage supply and the pre-amplifier. The InSpector 1000 automatically recognizes the attached probe and chooses the correct operating parameters (voltages etc.). The power may be supplied by a mains adapter or by a built in rechargeable lithium battery with a charging time of 3 hours and an operating time of approximately 9 hours when the display is switched off. The here employed La_2Br_3 crystal has a diameter of 3.8 cm (1.5”) and a length of 3.8 cm. The length of the complete LaBr probe is 26 cm and the diameter 5 cm, the weight is 0.7 kg. The complete system of probe and control unit has a weight of 2.4 kg and may be carried in one hand.

Figure 2: InSpector 1000 with control unit and external probe.

The InSpector 1000 can be run in different operation modes. Figure 3 shows pictures of the display during search mode and identification mode. In several search scenarios the InSpector 1000 has proved its worth [2].

Figure 3: Left: Search mode, gamma counting rate versus time. The displayed peak represents a source which was passed during the searching process. Right: Identification mode with name of found nuclide, kind of nuclide and correlation to database. The example shows a measurement with ^{137}Cs, ^{60}Co and depleted uranium.

3.3. Micro Detective

The Micro Detective (manufactured by Ametek/ORTEC) is an electrically cooled Germanium detector with an operating time of approximately 3 hours. It features a crystal of 3 cm in length and 5 cm in diameter. The weight of the device is 6.9 kg. It is 37 cm long, 28 cm high and 15 cm wide. Figure 4 shows a picture of the detector. It is equipped with a search and an identification mode. Additionally, it features acoustic signals for search measurements.

Figure 4: Electrically cooled HPGe detection system Micro Detective.

3.4. IdentiFINDER

The IdentiFINDER (manufactured by ICx Radiation) is a medium-weight hand-held detector equipped with a NaI crystal. The crystal is 5.1 cm in length and 3.6 cm in diameter. The device itself is 25 cm long, 9 cm wide and 8 cm high. It weighs 1.3 kg and has a battery life of approximately 8 hours. It is also equipped with a search and an identification mode and features acoustic signals to support the display readings during search measurements. The device is shown in figure 5.

Figure 5: IdentiFINDER detection system.

4. Measurement Results

4.1. Search Measurements

The qualification of the three detection systems was systematically tested to compare the practicability of detectors featuring NaI, LaBr, and Ge crystals for search measurements in on-site surveys. Therefore, seven persons with different measurement experience had to localize and identify a Co-60 source with an activity of 350 kBq (representing covert radioactive material) which was hidden at several spots in a lab at our institute. The lab served as an area for on-site surveys where nuclear or radioactive material is suspected. Figure 6 shows the results of these measurements for the three detection systems. All detectors showed reasonably good results at localizing the source. The InSpector 1000 turned out to be the detector with the shortest mean search time, but the differences of the detectors' results are minor.

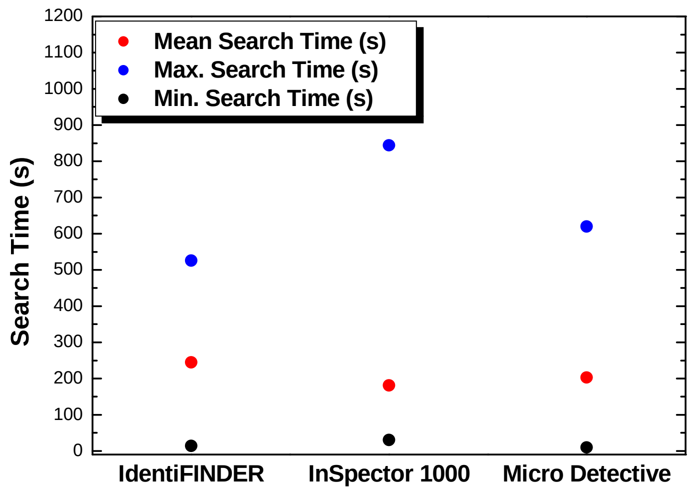

Figure 6: Comparison of mean, maximum and minimum search times for all detection systems.

4.2. Identification Measurements

After the localization of the Co-60 source had been completed, identification measurements were performed. In the case of the InSpector 1000 and the IdentiFINDER, the running time for these measurements had to be set in advance. As for the Micro Detective, Identification measurements run until they are manually stopped by the operator. As soon as a nuclide has been identified with certainty, it is listed as "found". In the case of the other two detectors, the identified nuclides are listed after the end of the running time. These detectors also list "confidence factors" referring to the degree of

certainty the nuclide was identified with. The Micro Detective does not list such a factor; however, a nuclide listed as “found” refers to a factor of 99.9 % according to the manufacturer.
All detection systems showed satisfactory results at identification. The mean values of the confidence factors varied in the range of 90 % in the case of the IdentiFINDER to 99.9 % for the Micro Detective. So the detection systems have shown to be quite reliable when it came to identification in the given test situations.

5. Summary

The detection systems with NaI, LaBr and HPGe crystals were investigated concerning their energy resolution and efficiency as well as their performance at localization and identification of radioactive material. The relatively new LaBr crystal type features energy resolutions which are superior to the NaI type commonly used for hand-held detectors by a factor of 2-3. The Ge type of crystal provides a distinct better energy resolution, but needs to be cooled to temperatures of liquid nitrogen for operation. Electrically cooled HPGe systems are now more suitable for hand-held measurements in situ.
The localization measurements showed only slight differences in the quality of the three detection systems. The InSpector 1000 proved that detectors featuring a LaBr crystal can provide at least a comparable accuracy for localization of radioactive material. As for the identification of the material, all detection system showed comparable results as well. The Micro Detective managed to identify the source within the shortest time (a couple of seconds), but the identification time of the other two detectors were acceptable, too. In this simple test, the source was identified correctly in all cases, and no false identifications occurred. So the LaBr crystal type detection system InSpector 1000 turned out to be a reliable instrument for on-site surveys as well as the two other detection systems featuring NaI and HPGe crystals, respectively.

6. References

[1] Risse, M.; Berky, W.; Köble, T.; Rosenstock, W.: **Identification of nuclear material with different gamma spectroscopic devices** In: Institute of Nuclear Materials Management: INMM 48th annual meeting: Proceedings of the Institute of Nuclear Materials Management. Madison, Wisconsin: Omnipress, 2007, 8 S.
[2] Berky, W.; Chmel, S.; Friedrich, H.; Köble, T.; Risse, M.; Rosenstock, W.: **Searching and identifying radioactive material with hand-held high resolution gamma detectors** In: Institute of Nuclear Materials Management: INMM 50th annual meeting, 2009 (to be published).