Recent improvements in on-site detection and identification of radioactive and nuclear material

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Introduction – Objectives

Threat
Loss or theft of radioactive respectively nuclear material – illicit trafficking
malevolent acts, in particular terrorist’s threat with such material (→ dirty bomb)

Counter Measures and Protection
methods and procedures for fast search and, after detection, identification and quantification of the material in situ
Sensitive portable measuring systems giving meaningful results within short time
In Field Measurements with Gamma Detectors

Examination of suspicious Object (abandoned trolley)

Detectors Used:
- Micro Detective (Left and Right)
- InSpector 1000 (Center and Right)
Characterized Gamma and Neutron Detectors

<table>
<thead>
<tr>
<th>γ - Detectors</th>
<th>neutron - Detectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>InSpector 1000 with LaBr$_3$-probe</td>
<td>Fission Meter neutron source identification system</td>
</tr>
<tr>
<td>Micro Detective (electrically cooled HPGe)</td>
<td>N-Probe fast neutron spectrometer</td>
</tr>
</tbody>
</table>

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γ-spectra obtained with different detector crystals

- source: $^{239}$Pu (84 %)
- distance: 15 cm
- no shielding
- spectra normalized to the same measurement time
### InSpector 1000 with LaBr₃- Probe

#### LaBr₃- Probe Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight [kg]</td>
<td>0.7</td>
</tr>
<tr>
<td>Dimensions [cm]</td>
<td>26 x 5 x 5</td>
</tr>
<tr>
<td>Crystal size (diameter [cm] x length [cm])</td>
<td>3.8 x 3.8</td>
</tr>
<tr>
<td>Energy Resolution [%]</td>
<td>2.4 (at 1332.6 keV)</td>
</tr>
<tr>
<td>Relative Efficiency [%]</td>
<td>12.6 (IEEE Std 325-1996)</td>
</tr>
</tbody>
</table>

#### InSpector 1000 Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight [kg]</td>
<td>1.7</td>
</tr>
<tr>
<td>Dimensions [cm]</td>
<td>26 x 7 x 7</td>
</tr>
<tr>
<td>Battery Life [h]</td>
<td>9</td>
</tr>
</tbody>
</table>

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InSpector 1000 Search Mode

Screenshot of “Locator Mode”
Search for a gamma source
X-axis: time line
Y-axis: gamma intensity
Bar below: current gamma intensity

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InSpector 1000 Identification Mode

Screenshot of “Identification Mode”

Name of the nuclide (isotope)
Type of the nuclide (typical use)
Probability of identification

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Energy Spectra: LaBr versus NaI Scintillator

<table>
<thead>
<tr>
<th>Energy [keV]</th>
<th>LaBr₂₅</th>
<th>Nal</th>
</tr>
</thead>
<tbody>
<tr>
<td>122 keV</td>
<td>8.4</td>
<td>24.6</td>
</tr>
<tr>
<td>662 keV</td>
<td>3.3</td>
<td>6.8</td>
</tr>
<tr>
<td>1332 keV</td>
<td>2.4</td>
<td>5.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crystal Size</th>
<th>LaBr₂₅</th>
<th>Nal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5“ x 1.5“</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4“ x 2“</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Relative Efficiency</th>
<th>LaBr₂₅</th>
<th>Nal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14.3 %</td>
<td>8 %</td>
</tr>
</tbody>
</table>

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**Micro Detective – High Resolution Gamma Detector**

Electrically cooled HPGe with battery power supply and integrated software for analysis.

**Detector Specifications**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight [kg]</td>
<td>6.9</td>
</tr>
<tr>
<td>Dimensions [cm]</td>
<td>37.4 x 14.6 x 27.9</td>
</tr>
<tr>
<td>Battery Life [h]</td>
<td>&gt; 3 (at 25 °C)</td>
</tr>
<tr>
<td>Cool Down Time [h]</td>
<td>&lt; 12 (at 25 °C)</td>
</tr>
<tr>
<td>Energy Resolution [keV]</td>
<td>1.99 (at 1332.6 keV)</td>
</tr>
<tr>
<td>Energy Resolution [%]</td>
<td>0.15 (at 1332.6 keV)</td>
</tr>
<tr>
<td>Relative Efficiency [%]</td>
<td>10.2 (IEEE Std 325-1996)</td>
</tr>
</tbody>
</table>

produced by Ametek / ORTEC
High-Resolution Germanium Detector Systems

Survey with Electrically-Cooled Detective

LN$_2$-Cooled Germanium Detection System
Micro Detective - Display Readings

Identification Mode

Search Mode

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© Wolfram Berky
# The Fission Meter System

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of tubes</td>
<td>15 per panel =&gt; 30 per device</td>
</tr>
<tr>
<td>Tube diameter</td>
<td>2.54 cm</td>
</tr>
<tr>
<td>Tube length</td>
<td>48.26 cm</td>
</tr>
<tr>
<td>Gas characteristics</td>
<td>$^3$He (7.6 $\cdot$ $10^5$ Pa)</td>
</tr>
<tr>
<td>Active area</td>
<td>$\sim$1800 cm$^2$ (15 tubes, 0° geometry)</td>
</tr>
<tr>
<td>Moderator</td>
<td>Polyethylene, on one side (minimum 2.54 cm)</td>
</tr>
<tr>
<td>Weight</td>
<td>26 kg</td>
</tr>
</tbody>
</table>

Fission Meter system with detector unit
Fission Meter – covert neutron search
Localization of a neutron source outdoors

unshielded $^{252}$Cf source, several distances

![Graph showing count rate vs position for unshielded $^{252}$Cf source at different distances.]

shielded $^{252}$Cf source in 1 m distance

![Graph showing count rate vs position for shielded $^{252}$Cf source with different shields.]

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ntr 09-29
Multiplicility plots – type of neutron source

Fission source (Cf)  Industrial neutron source (Am/Li)

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Detection of shielding: Feynman variance plots

Cf-source unshielded

Cf-source shielded with 10.4 cm PE

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Benefit from Neutron Spectroscopy on site

Gives significant more information than pure neutron counting, essential for assessment of possible risk and counter measures:

- Indicates type of neutron source: industrial or fission
- Indicates existence of shielding material, in particular neutron moderating material
- High neutron sensitivity for handheld system

Further advantages:

- Non-contact measurements on the complete object without moving it
- Correct neutron dose measurement using the corresponding spectral fluence to dose conversion factors
- Detection of material inhomogeneity
- Shielded nuclear material (like HEU or Pu) is only detectable by neutrons
N-Probe Neutron Spectrometer

N-Probe Specifications

- weight: 4.1 kg
- NE213 liquid scintillator for high energy neutrons detection
- He$_3$ detector for low energy neutrons detection
- measuring results: neutron spectra, flux, fluence, dose rate and accumulated dose
Neutron Spectrometer N-Probe: Displays

Display of the neutron spectrum (neutron fluence)

Display of the calculated results for the spectrum above

H*(10) dose = 464.49 uSv
Dose rate = 23.2 uSv/h
Total Fluence = 1.24e+006 n/cm²
Total Flux = 1.72e+001 n/(cm² s)
Hit a key (or H for help)>>

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N-Probe: Neutron Spectra

Neutron spectra for different neutron sources

Energy (MeV)

Fluence (Neutron/cm²)

- AmBe
- AmLi
- Cf-252

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Neutron – radiography, compared to X-ray

Radiography with thermal neutrons, IED is identified unambiguously

D – T tube  neutron intensity up to $3 \times 10^8$ n/sec in $4\pi$
D – D tube  neutron intensity up to $2 \times 10^6$ n/sec in $4\pi$
Work in progress: Mobile Neutron radiography

Inspected object made of polyethylene with pipes of different material

Cooperation with: Bundesanstalt für Materialprüfung (BAM), Berlin
Technische Universität München

X-rays

fast neutrons

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Conclusion – Perspective

With innovative portable devices for detection and identification of gamma and neutron radiation fast and reliable measurements are possible in the field, determining the presence of radioactive or fissionable materials in suspect objects, as well as, within certain limits, type and quantity of this material.

This gives information on the possible risk potential and recommendations can be established on further actions to be taken to minimize the possible injury.

In order to gain even more comprehensive information on the inner structure of a suspected device we will improve mobile imaging techniques, i.e. mobile neutron radiography in future.

Furthermore these portable devices may be used in the scope of on-site inspections of combating and preventing nuclear proliferation.