Remote detection of alpha radiation via UV photons

Alpha emitting radiation sources are typically difficult to detect with conventional detectors due to the short range of alpha particles in air. Therefore, the localization of the contamination is a laborious task. Detection of alpha radiation from long distances is possible by measuring the ionization-induced fluorescence of air molecules. This has several applications in nuclear safety, security and safeguards.

UV photons induced by alphas

- Alpha particles excite the nitrogen molecules in air. The excitation decays through emission of UV photons.
- One alpha decay yields about hundred UV photons in the air, allowing high detection efficiency.
- The range of UV photons in air is significantly larger than the range of an alpha particle (kilometres vs. centimetres).
- Single UV photons can be detected with a photomultiplier.
- Optics provide good collection efficiency (see Fig. 1).
- Beta and gamma radiation do not produce localized molecular excitation like the alpha particle.

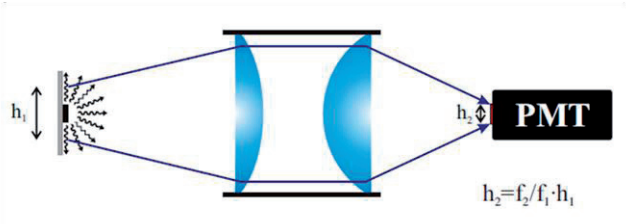

Fig. 1. Photomultiplier tube (PMT) and optics for collection of UV photons induced by a radioactive source emitting alpha particles.

HAUVA (Hand-held Alpha UV Application)

- First prototype of an operational alpha contamination detector (see Fig. 2).
- Spectral filtering for operation in specially selected room lighting.
- Optimized for alpha sources at 40-cm distance from the detector. Can separate a 1-kBq alpha emitter from the background lighting (LED) with a 1-second integration time.
- Background light measurement for significance calculus (alarm).
- Sharp focus (diameter ~5 cm).
- User interface through laptop or mobile phone.

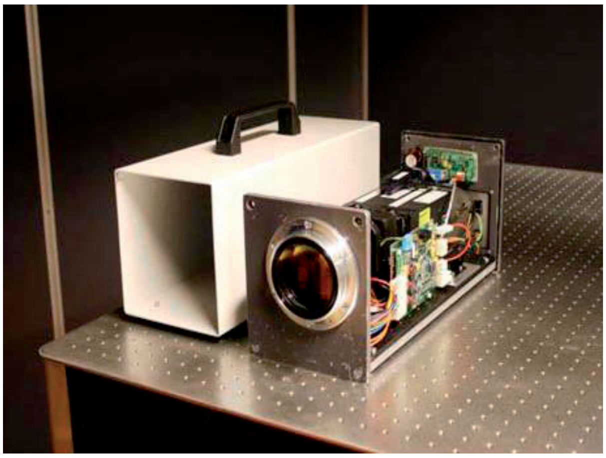

Fig. 2. HAUVA device for optical remote detection of alpha radiation.

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Spectral filtering

The energy spectrum of the UV photons produced by nitrogen is well known (see Fig. 3). This allows the use of wavelength-specific filters to reduce the background signal caused by lighting.

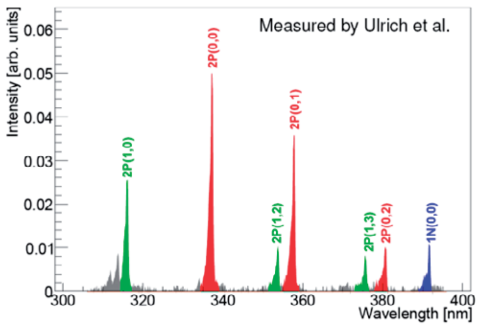

Fig. 3. N_2 fluorescence emission spectrum [H. Ulrich, PhD thesis, University of Karlsruhe, 2004].

Background estimation

To allow the correct estimation of the significance of the signal, the UV background not caused by alphas must be known. This is especially challenging, since both the level and shape of the background spectrum varies. One possibility is to split the signal and measure the nitrogen emission and background wavelengths independently (see Fig.4).

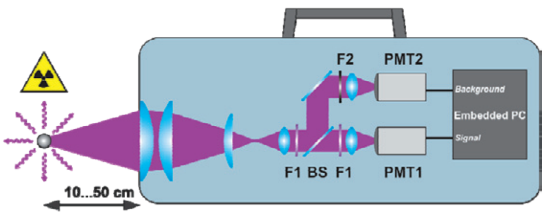

Fig. 4. Schematic model of signal and background measurement system in HAUVA.

UV signal in different gases

In air, the UV signal of nitrogen is significantly decreased due to quenching caused by molecules other than N_2. Therefore, in pure nitrogen, the fluorescence signal is multiple times higher. The fluorescence yields in other gases, like argon, can be even larger than in pure nitrogen.

Optimization of the collection optics

Due to the finite range of alpha particles in air, the UV photons originating from an alpha point source on a surface are born in a hemisphere (see Fig. 5a). The UV photons are emitted in random directions (see Fig. 5b). This makes the designing of effective collection optics a challenging task.

Fig. 5. Model of point alpha emitter on surface. a) Locations of ionization. b) Tracks of emitted fluorescence photons.

Coincidence detection

UV coincidence measurement is based on the detection of multiple photons from a single radioactive decay. The fluorescence photons in air are induced in a 5-ns time window. The probability of a background coincidence event in the 5-ns scale is very rare compared to the number of background photons. Thus, utilization of UV coincidence discriminates the background effectively.

Further reading

- Sand J, Hannuksela V, Ihantola S, Peräjärvi K, Toivonen H, Toivonen J. Remote optical detection of alpha radiation. In: Symposium on International Safeguards. 2010 Nov 1-5: Vienna, Austria.
- Hannuksela V, Toivonen J, Toivonen H. Optical remote detection of alpha radiation. In: Proceedings – Third European IRPA Congress, 14–18 June 2010, Helsinki, Finland. Helsinki: Nordic Society for Radiation Protection; 2011.
- Hannuksela V. Remote detection of alpha radiation by fluorescence of nitrogen (in Finnish). Master's Thesis. Tampere University of Technology, 2009.

Technology Readiness Level 5

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