Fluorescence spectra of alpha emitting isotopes for stand-off detector development

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ABSTRACT

- Several isotopes of natural and man-made radioactive materials give off only alpha radiation.
- Although easily stopped by skin, ingestion of alpha emitting materials is most hazardous to humans.
- ➢ A specific alpha detector is required to ensure all radioactive sources can be detected,
- ➢ Essential to safeguarding the wellbeing and security of the population from unwitting or malicious exposure.

- Alpha particles travel only a short distance, typically 50 mm depending on energy.
- Traditional detectors therefore require close proximity to the source for direct detection;
  - This places personnel in close proximity to radioactive sources,
  - Makes detection time consuming,
  - Makes checking complex morphologies difficult.
- ➢ A stand-off detector moves personnel away from the radiation source to a safer distance,
- ➢ Reduces scanning time.

- Emitted alpha particles transfer energy to the surrounding atmosphere, causing gas atoms to excite and emit photons.
- The alpha particle travels only a few centimetres, where the photons travel much further, meaning they can be detected from a distance.
- The photons may be scattered and reflect off surfaces, therefore aiding detection when the alpha source is out of view.
- ➢ A stand-off detector could use this fluorescence to detect alpha radiation from a distance, even without a direct line of sight.

PRINCIPLE OF UVTRON OPERATION

- The Ni photocathode of the UVTron (Figure 1) is insensitive to photons of wavelength > 260 nm; effectively solar blind (see Figure 2).
- Photons between 185 - 260 nm wavelength when incident on the photocathode cause a photon to be emitted (photoelectric effect).
- Voltage difference between the cathode and anode causes the free electron to be accelerated towards the anode.
- Electron ionises gas in the UVTron, generating positive ions which are attracted to cathode, and negative free electrons attracted to anode.
- This increase in free electrons cause an avalanche reaction which generates a signal at the anode.
- Signal interpreted by driver circuit and pulse is outputted when this avalanche phenomenon occurs.

Figure 1. UVTron model R9533 (http://www.hamamatsu.com/resources/pdf/etd/R9454_R9533_TPT1019E.pdf)

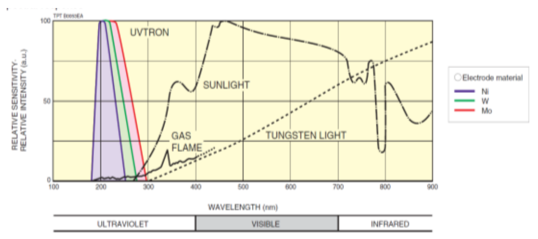

Figure 2. Spectral response of UVTron in comparison to sunlight, tungsten light and gas flame by electrode material. (http://www.hamamatsu.com/resources/pdf/etd/UVtron_TPT1034E.pdf)

EXPERIMENTAL METHOD

The experimental system comprises of;

- A Po-210 source was placed in close proximity to the UVTron detector, approximately 20 mm separation between the source and detector.
- Experiments were run with the source inside a gas flow box with a fused silica window.
- The output directly from the UVTron was recorded using an oscilloscope which recorded the shape of the direct pulse.
- The output of the UVTron driver was connected to an Arduino which counted the number of output pulses from the driver per second.
- A second channel on the oscilloscope was also connected to the output of the driver circuit which recorded the time and shape of the driver output pulse in relation to the direct output pulse.
- The experimental set up is shown in Figure 3.
- Where the effect of gas atmosphere was tested, the gas was flowed across the surface of the source from a pipe placed above the source.
- The lab in which the experiments were carried out had no windows and conventional strip lighting. This lighting remained on for the duration of all experiments.

Experimental set-up

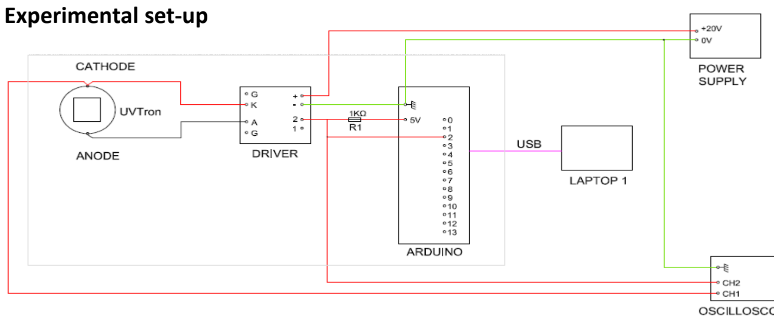

Figure 3. Schematic of equipment set up

RESULTS

Background count of the UVTron when operated indoors is extremely low –

- The background count of the UVTron was measured in the lab over a period of approximately 75 min (4496 sec). 10 pulses were recorded, giving an average of 2.2 x 10^{-3} cps. The pulses were randomly spread throughout the time and did not show any pattern.
- Due to the low count there is an uncertainty of 32%. However, as this background count was less than 1% of the detected signal output with the source, this is negligible.
- This is line with other background count experiments completed in other indoor locations, which vary from 1.5 x 10^{-3} to 3.6 x 10^{-3} cps.
- Although low, the background count will influence the minimum sensitivity of the UVTron in alpha detecting applications.

Air atmosphere with a Po-210 source (approx. 7 MBq) generates recordable output pulses –

- 18, 890 counts were recorded over a 16 hour period, giving an average cps of 0.3280.
- Average cps per hour varied from 0.3097 to 0.3503 (see Fig 4).
- The total cps and the variability will also influence the minimum sensitivity of the UVTron in this application.

Other gas atmospheres increased the cps –

- 5 gases were flowed across the Po-210 source and their effect on the cps was recorded (see Fig 5).
- All gases increased the cps – Xenon (+ 52%), P10 (+32%), Neon (+26%), Krypton (+23%) – *(P10 is 90% Argon/ 10% Methane mixture).*
- Nitrogen caused the smallest increase, 3.6%, which was unexpected as this gas increases fluorescence in other wavelength ranges.

Pulse shape appears to be dependent on the UVC photon source –

- The pulse shape was recorded by the oscilloscope. For the Po-210 source the curve was the same for all of the atmospheres tested, including air (Fig 6).
- The pulse shape of emissions from a UVC bulb were compared and there was a difference in terms of peak amplitude and pulse duration (Fig 6).

Other observations -

- During set up a decrease in the cps was observed when the separation between the detector and source was greater.
- A second fused silica window was placed between the source and detector, which reduced the cps.

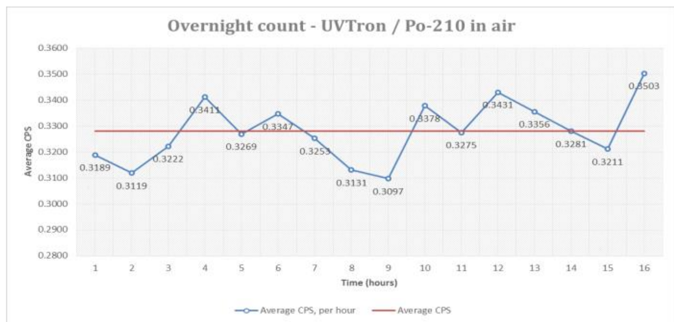

Figure 4. Average cps per hour – Po-210 source in air

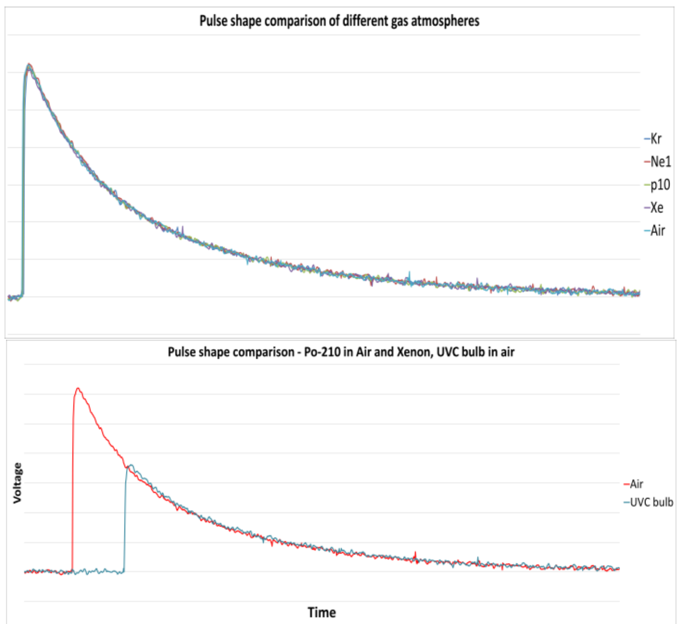

Figure 6. Pulse shape comparisons 1) different gas atmospheres 2) Po-210 in air and xenon, in comparison with UVC bulb in air

CONCLUSIONS

- UVTrons appear to have the potential to detect alpha-induced fluorescence in the field. Their low background count in daylight conditions means that they can be deployed without special lighting conditions.
- The minimum sensitivity at which they can operate will be a function of the background count, the variation in pulse frequency over time, separation of detector from source and the activity of the source.
- Further work will involve carrying out experiments to;
  - catalogue the UVTron response to potential field conditions (indoor and outdoor environments),
  - different alpha emitting isotopes and activities,
  - the effect of distance from the source,
  - quantify the minimum sensitivity of this and other UVTron models,
  - identification of UVC photon sources through pulse shape,
  - and where possible identifying the mechanism behind the observed phenomenon.
- Now that a significant signal has been detected and viability for detection determined through the UVTron experiments the second trench of work in relation to this project will include;
  - quantifying the number of photons from the source,
  - identifying the spectra of this fluorescence in the UVC range.

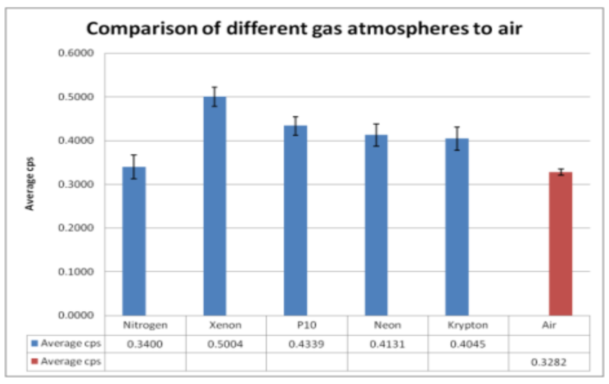

Figure 5. Comparison of average cps in different gas atmospheres

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