Alpha radiation induced luminescence in solar blind spectral region

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Alpha Radiation Induced Luminescence in Solar Blind Spectral Region

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Abstract: Intense luminescence in the solar blind spectral region is produced by modifying the gas atmosphere around an alpha emitter. This enables standoff detection of alpha radiation under daylight conditions.

Alpha radiation is hard to detect due to the very short range of alpha particles in air (approx. 4 cm), effectively limiting the detection range of techniques that rely on direct interaction. This range limitation can be overcome by utilizing the radioluminescent light that alpha particles induce in air. In principal, detection of radioluminescence is a technique capable of remotely detecting all ionizing radiation by optical means. However, it is particular well-suited for standoff alpha radiation detection, given the strict limitations the particle's travel distance imposes.

Radioluminescence in air is created when highly energetic, charged particles traveling through air cause the creation of secondary free electrons. Those electrons lose energy by inelastic collisions with air molecules. A small fraction of the deposited energy is reemitted as luminescence, while most of it disperses as heat due to collisional quenching processes. Air luminescence, for the most part, originates from N_2 and N_2^+ molecules, which emit light in the spectral range of $280 - 430$ nm [1, 2].

Nitrogen radioluminescence has proven to be a reliable indicator for the presence of alpha radiation in open air, making its detection the central mechanism at the core of modern technology that aims to make alpha radiation threat detection safer for personnel and equipment [3]. This approach only works in environments where natural light is not present, though. Natural light contains UV components with wavelengths shorter than 400 nm, which easily obstructs a reliable detection of N_2 radioluminescent light. Fig. 1 illustrates this by contrasting the solar spectrum reaching the earth's surface with the emission lines of molecular nitrogen in the UV region of the electromagnetic spectrum.

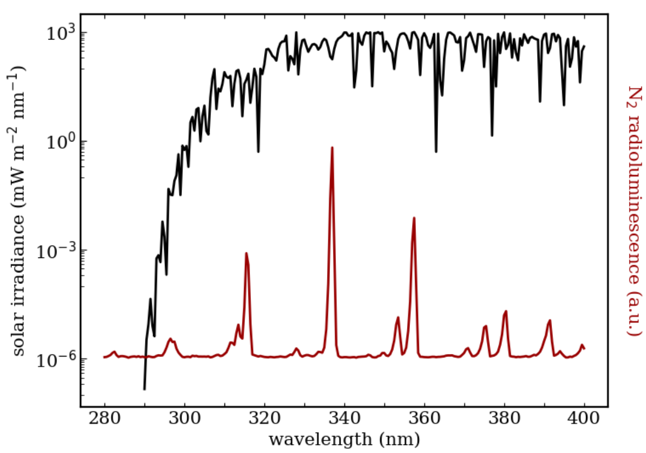

Fig. 1. The spectrum of the sunlight reaching the earth's surface (black) contrasted with the radioluminescence of N_2 (red) in the wavelength range 280 nm to 400 nm. The solar irradiance (AM1.5 Global tilt [4]) is displayed on a logarithmic scale, while the N_2 emissions are shown on a linear scale. For wavelengths longer than 300 nm the spectra overlap. For wavelengths shorter than 300 nm the solar irradiance starkly declines.

One possibility to overcome this limitation is by utilizing radioluminescence from molecules other than nitrogen that emit light in the so called solar blind spectral region. The solar blind spectral region comprises light of wavelengths shorter than 300 nm. In this wavelength regime the solar spectral irradiance reaching the earth is drastically diminished, which is due to absorption of these wavelengths in the upper atmosphere by ozone [5]. Radioluminescence with wavelengths shorter than 300 nm does not get superseded by natural lighting and thus can still be used for remote detection of alpha radiation.

Nitric oxide (NO) has been shown to emit UV light as a form of radioluminescence when exposed to alpha radiation [6]. These emissions originate from ground-state transitions that form the NO γ-band, which is located between 220 nm and 305 nm in the electromagnetic spectrum. This makes nitric oxide radioluminescence a prime candidate for standoff detection of alpha radiation under daylight conditions.

In this conference contribution we demonstrate that with little modification of the gases surrounding an alpha emitter intense radioluminescence in the solar blind spectral region can be produced. In Fig. 2 we show the radioluminescence spectrum we recorded after adding a few ppm of nitric oxide to an otherwise pure nitrogen atmosphere. We also show that by carefully selecting the gas composition, the nitric oxide emissions in the solar blind spectral region can reach levels that are up to 50 times more intense than nitrogen emissions that occur in ambient air.

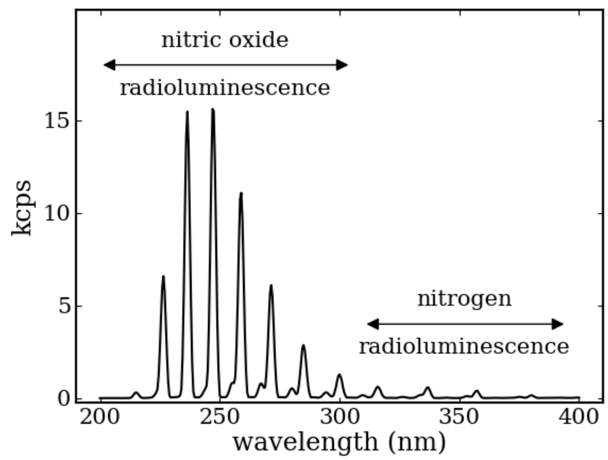

Fig. 2. Radioluminescence spectrum from 200 nm to 400 nm under a constant flow of 18 ppm of NO diluted in N_2. The NO γ-band emissions make up most of the detected light. Almost all of the NO emission lines are in the solar blind spectral region.

We highlight potential use-cases of this technique with an emphasis on making processes in decontamination facilities vastly more efficient. When processed, radioactive waste is often placed in glove boxes or hot cells which is filled with pure nitrogen in an attempt to make the N_2 radioluminescence more pronounced. Then, in absence of any light source, alpha contamination is optically detected. This process can be costly and we pose that by adding small amounts NO to the already present N_2 it can be made to work under normal lighting conditions. Lastly, we outline steps to further develop the technique and combine it with other remote alpha detection approaches.

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