Charging Capabilities of LED and Fluorescent Light Sources on Photoluminescent Floorpath Marking Systems

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Acknowledgements:

Dr Sean O'Kell:

Dr Sean O'Kell is the Technical Director of STG Aerospace. He holds a degree in Chemistry and Materials Science and a PhD in Materials Engineering. Throughout his career he has specialised in the formulation and application of surface coatings. Dr O'Kell has considerable experience in the development of organic and inorganic coatings for advanced material applications.

In his role as technical director of STG Aerospace, Dr O'Kell oversees the development of all new products, liaising with the key aviation authorities, operators and customers on all technical levels. He is recognised as a technical expert in the formulation, testing and application of photoluminescent materials for use in aircraft.

STG Aerospace:

STG Aerospace Ltd is a UK based company with subsidiaries in the USA and Australia. It has been in the photoluminescence business since 1986. In 1995 STG developed and patented products and protocols for high performance photoluminescent products in aircraft emergency evacuation guidance. STG has been FIRST in every aspect of the application of this technology on aircraft. It has won worldwide recognition for pioneering innovation, with multiple Queen's Enterprise Awards (the UK's most prestigious business award) and a Crystal Cabin award for Innovation in Cabin Safety. STG has built its business and reputation on innovation and the practical development of products based on that innovation.

STG's SafTGlo is the leading photoluminescent brand in the aviation market, with over 7000 commercial aircraft currently using its products worldwide.

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Introduction:

Photoluminescent floor proximity emergency escape path-marking systems (PL FPEEPMS) are well established as an excellent means of providing low maintenance, highly dependable cabin way guidance in an emergency. However, the effectiveness of the system in providing this is not only dependent on the quality of the product supplied but also in the installation, operation procedures and continued airworthiness of the system. One key property for the safe operation of the system is the ability of the incident light source to charge the floor path marking system. This document compares the charging of the photoluminescent emergency egress system with older fluorescent lighting systems compared to newer LED based lighting systems.

With the move in the cabin lighting market from fluorescent lighting to LED lighting due to the improved reliability and lower energy usage, a comparison is needed. This review aims to provide an understanding of photoluminescent technology; specifically how photoluminescent pigments are charged and how the spectrum of differing incident light sources affects this.

The Science and Technology of Photoluminescence:

Photoluminescent products use inorganic pigments that can be incorporated into a number of materials such as paint, coating solutions, varnishes, films and plastic parts. There are many novelty products on the market today, which profess to "glow in the dark", but these should not be confused with the formulations used for emergency way guidance. Typical safety products include screen-printed signage, self adhesive metallic strips and rigid PVC products.

Photoluminescence Explained

Luminescence occurs if a material exposed to a source of excitation absorbs energy, and then emits that energy as visible or invisible light. The energy can be derived from a number of sources, including electrical, chemical, tribological or electromagnetic radiation. Electromagnetic radiation, visible, UV and IR light, can cause two phenomena: photoluminescence and fluorescence. Many people confuse the two.

Fluorescence is a phenomenon in which the electron transition back to the ground state occurs within a millisecond of excitation. Because of this timescale, the emission from a fluorescent material ceases the instant the excitation source is removed.

Photoluminescence also occurs by electromagnetic excitation and the material does emit while the energy source is present. But with photoluminescence the relaxation of the electron back to the ground state and subsequent emission of photons of light continues long after the excitation source is removed. Photoluminescent materials can emit a glow tens of hours after the light source has been removed. This is termed the "afterglow".

Photoluminescent Excitation

Doped Strontium Aluminate is currently the highest performing photoluminescent material readily available. It has a peak charging sensitivity at 365nm, in the ultraviolet region, with an emission spectrum peak at 500nm in the visible region (green/yellow light). The afterglow decays rapidly after the excitation source has been removed, with the rate of decay reducing over time. The electrons in the metastable state can remain there from seconds to many hours after the charging source has been removed, before relaxing back to the ground state with a photon emitted.

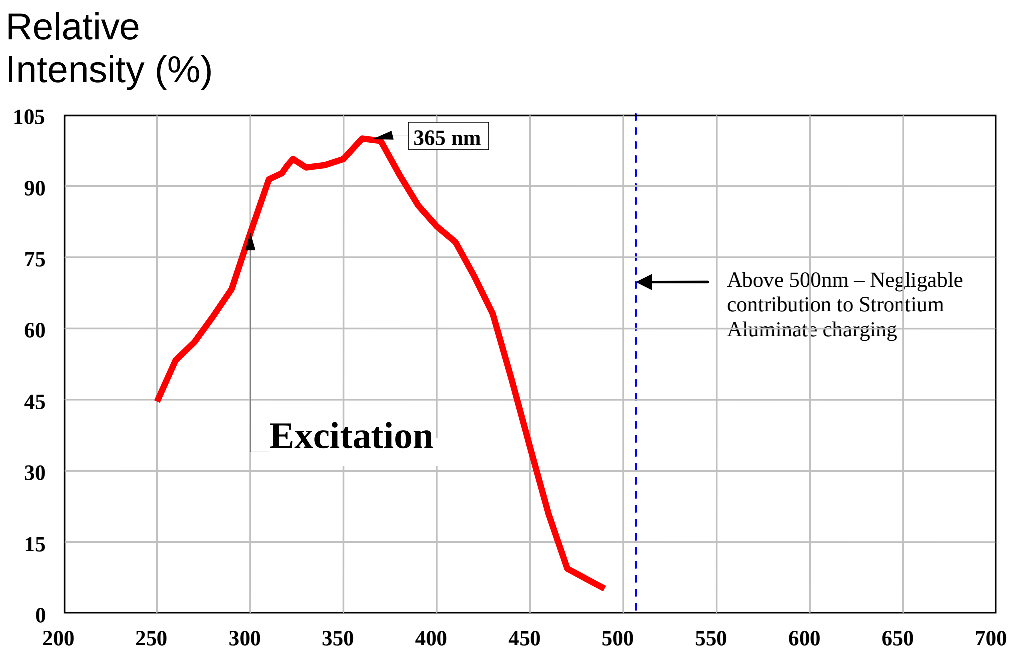

Figure 1: Excitation spectrum for doped Strontium Aluminate pigment

The excitation characteristics of the doped Strontium Aluminate used in floor path marking systems can be seen in Figure 1. The peak excitation sensitivity is at 365nm and it should be noted that incident light with wavelengths above 500nm, results in little contribution to the charging of these photoluminescent materials used in floor path marking systems.

Photoluminescent Emission

Stokes' Law of fluorescence states that for a photoluminescent material, the emitted light is at longer wavelengths than the excitation source applied. The emission wavelength is dependent on the chemical composition of the material rather than the excitation source applied. Ordinarily, pure materials do not show photoluminescent effects. Impurities need to be introduced in very controlled concentrations to induce a metastable state for the electrons and generate the photoluminescent effect.

Figure 2 shows the emission spectra for doped Strontium Aluminate. It can be seen that Stokes law is followed with a peak emission at 500nm, whereas the absorption peak is at 365nm.

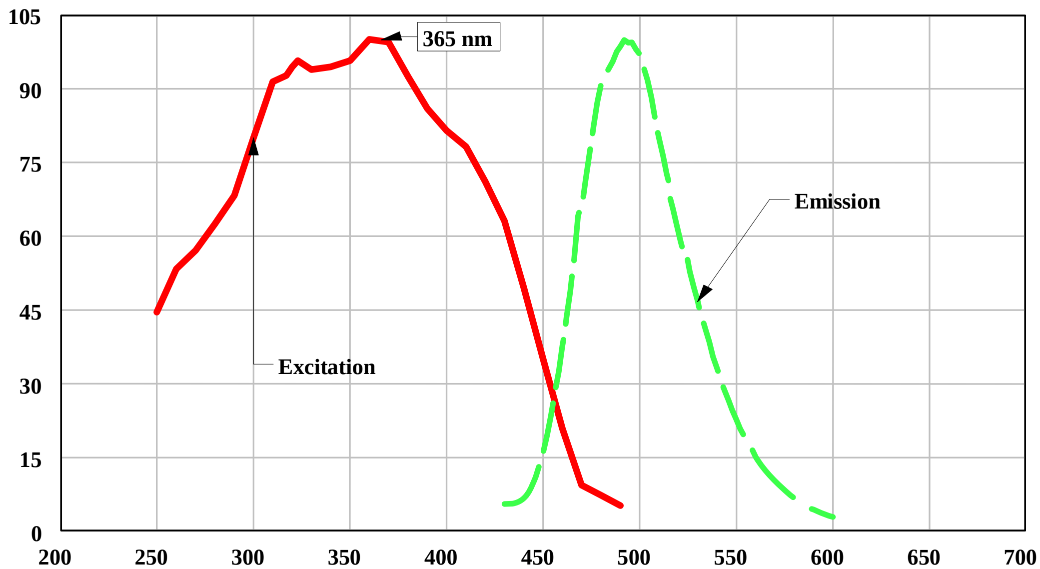

Figure 2: Excitation and emission spectra for strontium Aluminate pigment, showing the peak emission at 500nm (green)[1]

Charging Light Sources

This report has previously shown that the excitation wavelengths of the photoluminescent pigments in the PLFPEEMS are in the UV and blue region of the visible spectrum (below 500nm). With this understanding, it is clear that the incident light spectrum of the charging light sources is a critical parameter in the charging efficiency.

Fluorescent Light Sources

The overall intensity of two light sources can be the same when measured with a Lux meter even though they have very different spectral emissions. The light emitted will have different spectral intensities in the critical UV and blue visible regions of the spectrum. Figures 3 and 4 shown two fluorescent light sources and how the light generated is very different. A Lux meter simply measures the total number of photons hitting the sensor over the visible spectrum and a set time period, it cannot distinguish between the two sources. The graphs show the number of counts vs. wavelength. It can clearly be seen in both plots that there a peaks and troughs in the spectra, even though the overall impression for both sources, is "white light."

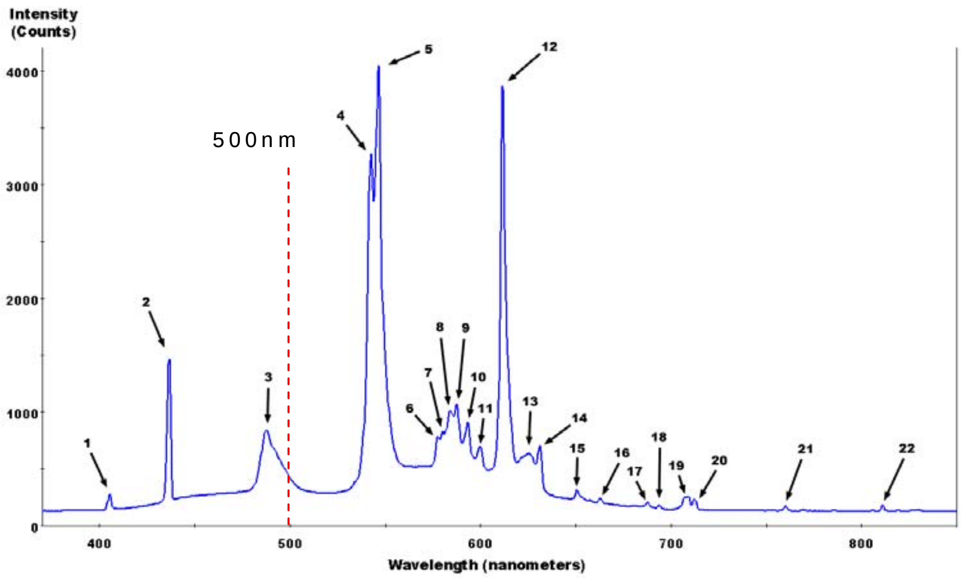

Figure 3: Typical emission spectra of "cool white" fluorescent lights

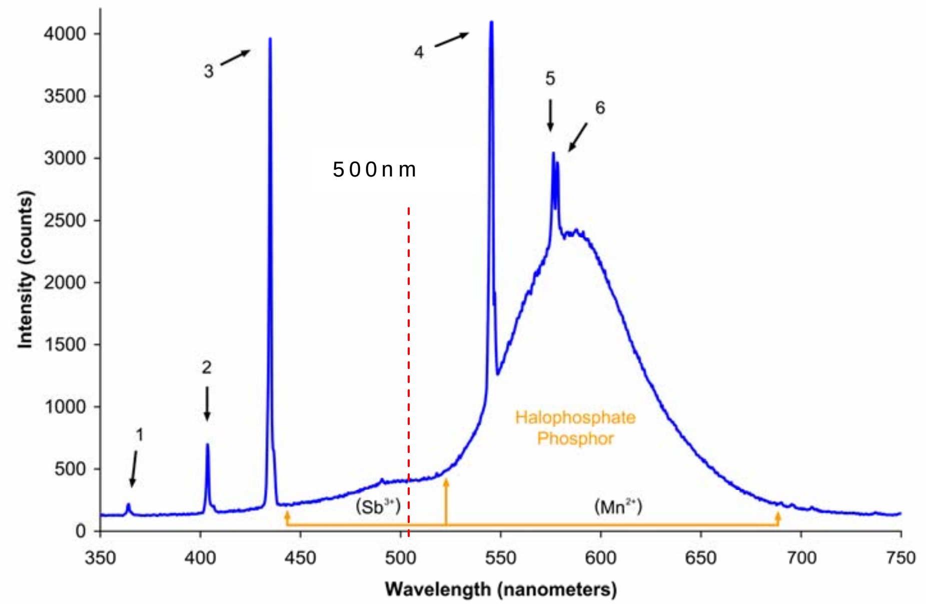

Figure 4: Typical emission spectrum of old style (halophosphate phosphor) fluorescent lights

For the excitation of Strontium Aluminate, the most important feature is how little of the emission spectra of both types of fluorescent light are below the 500nm value (red line). This is the portion of the spectrum used to charge the photoluminescent materials. It has been estimated that less than 10% of the total white light available and measured is capable of charging the Strontium Aluminate. Therefore, when a minimum light level is defined for a cabin lighting system as acceptable for charging the photoluminescent floor path marking system, actually less than 10% of that amount is actually required (at the correct wavelengths).

LED Light Sources

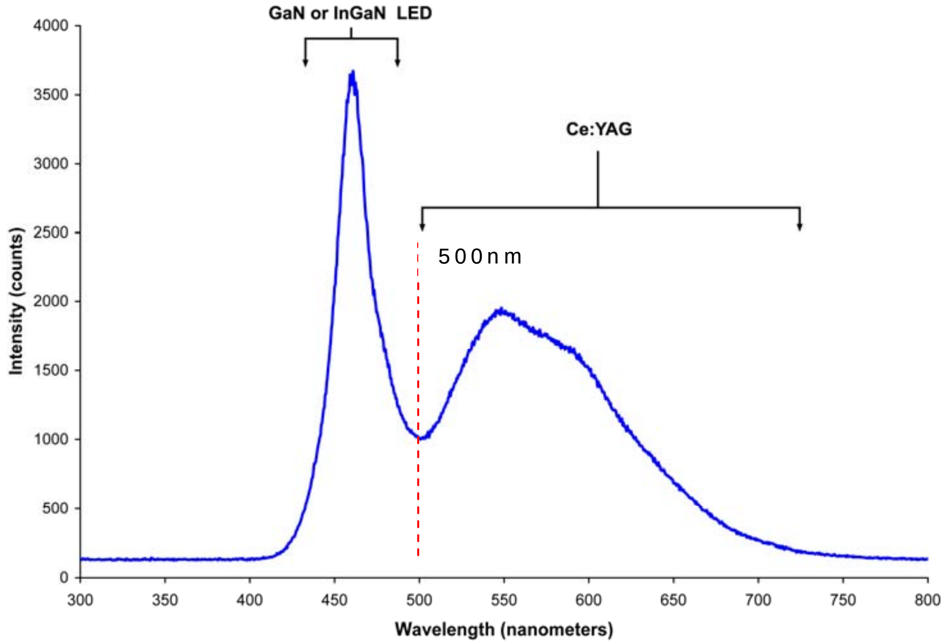

Figure 5: Emission Spectra of White LEDs (Blue LED + phosphor)

Figure 5 shows the output from a "white" LED. The spectrum clearly showing blue light which is directly emitted by the GaN-based LED (peak at about 465 nanometers) and the more broadband stokes shifted light emitted by the Ce^{3+}:YAG phosphor which extends from around 500nm up to the infra red region.

In contrast to the fluorescent light sources, it can be seen that a much greater proportion (over 20%) of the photons emitted in this white LED have the wavelengths below 500nm to charge the photoluminescent pigment in SafTGlo. Therefore, if the minimum cabin lighting level for a floor proximity lighting system is constant, the LED based lighting should give better performance for the same charging duration, or give the same performance for a shorter charging time.

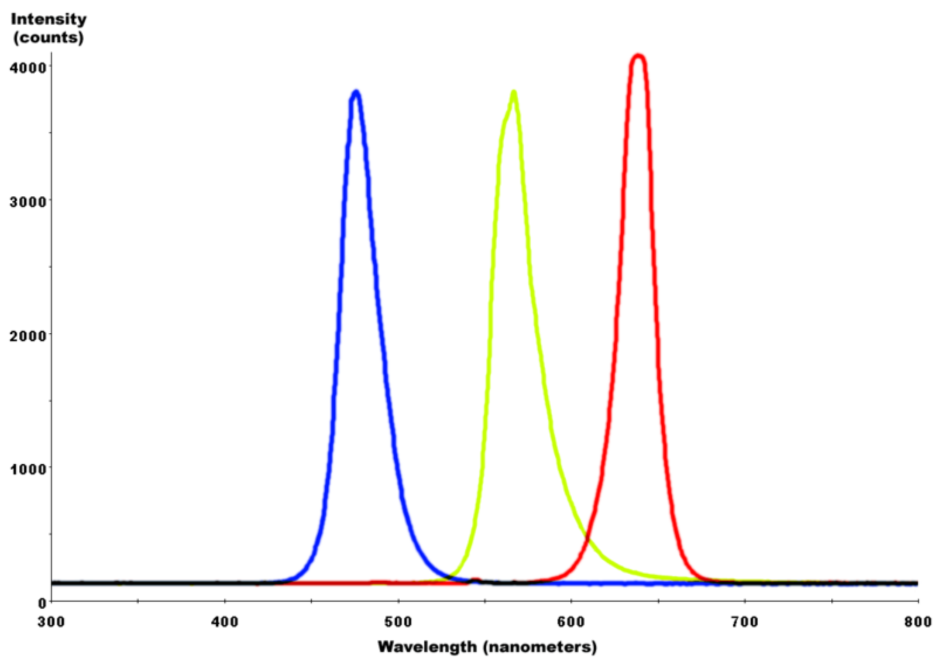

Figure 6: A mixed LED light source (RGB) showing the distinctive peak of emission from the blue, green-yellow and red LEDs.

Performance of Fluorescent and LED charged Photoluminescent Floor Path Marking Systems

The theoretical approach to determine the effectiveness of the LED vs fluorescent light sources, assuming the same overall lux level, is to examine the proportion of the emission spectra below the 500nm level to give an indication of the percentage of the spectra that will excite the PL material. This gives LED light sources a significant increase in the number of photons capable of charging the photoluminescent pigment at a given Lux level over fluorescent light sources. To experimentally validate this hypothesis, two “white light” sources (LED and Fluorescent) at the same Lux level have been provided, and the resultant performance of a PLFPEEPMS evaluated.

The results presented below show the performance of a single sample of photoluminescent material and its discharge characteristics, when charged at a constant Lux levels using the two different light sources.

Discharge Time	Flourescent Lighting	LED Lighting	Percentage Difference
minutes	mcd/m2	mcd/m2	
1	1608	1748	108.7%
5	564	630	111.7%
10	307	344	112.1%
15	206	231	112.1%
20	154	172	111.7%
25	121	135	111.6%
30	100	111	111.0%
35	86	95	110.5%
40	71	80	112.7%
45	63	71	112.7%
50	55	62	112.7%
55	50	56	112.0%
60	45	50	111.1%
		Mean	111.6%

Table 1: Mean luminosity data for batch 05/818 of SG8181 Photoluminescent Floorpath Marking System over 60 minutes discharge

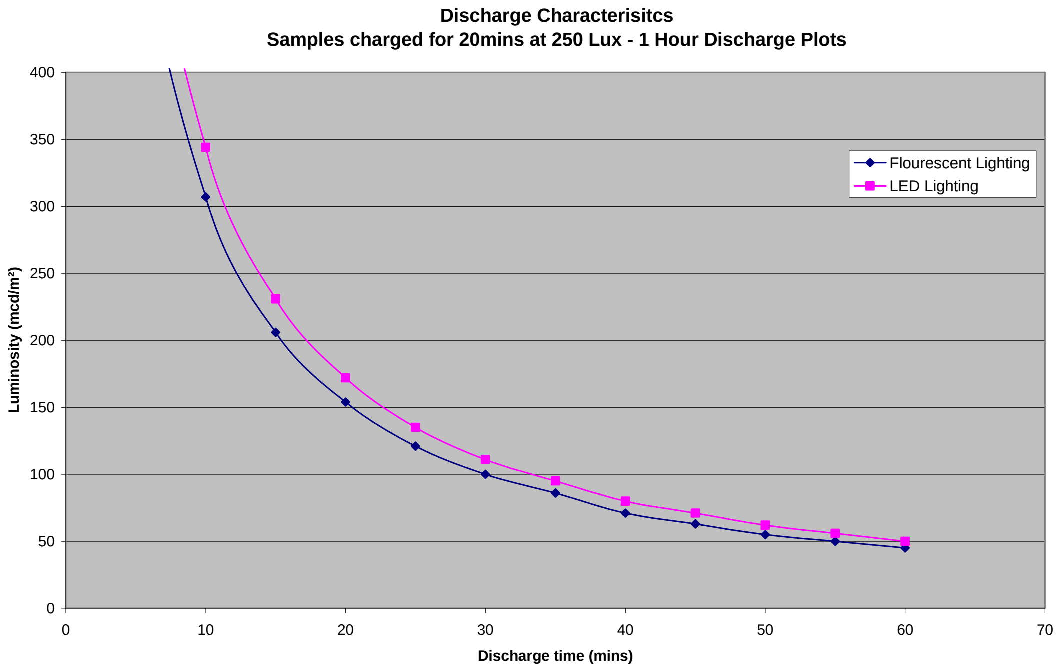

Figure 7: Comparison of the luminous output of Strontium Aluminate based photoluminescent floor path markings when charged with fluorescent and “white” LED light sources.

It can be seen from the raw data and the plot above that the output from the LED charged photoluminescent strip is consistently higher than the fluorescent charged equivalent. The improvement in luminous output from the LED based illumination has been calculated to be close to 12%. This is a significant improvement in performance, when there has been no increase in the measured illumination level.

Conclusions

- LED lighting is better than fluorescent lighting at charging the Strontium Aluminate
- The improvement in luminous output in moving from fluorescent lighting to LED lighting has been measured at 12%
- Moving from fluorescent lighting to LED lighting provides the potential for shorter charging times or longer dark duration performance
- For RGB LED based lighting systems, the Blue LED will provide the majority of the charging
- Light source emissions above a wavelength of 500nm provide little or no charging of the Strontium Aluminate photoluminesent pigment