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► **To cite this version:**

Quang-Khoi Nguyen, Shih-Kang Lin, Chi-Shou Wu, Tung-Hsun Yang, Hsu-Yi Huang, et al.. Sensing phosphor temperature in pc-WLEDs using noncontact detection. 12th International Conference on Optics-photonics Design & Fabrication ODF'21, Optics Design Group of the Optical Society of Japan; National Central University - Taiwan, Jun 2021, Taipei, Taiwan. hal-03858579

HAL Id: hal-03858579

<https://hal.science/hal-03858579v1>

Submitted on 17 Nov 2022

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Sensing phosphor temperature in pc-WLEDs using noncontact detection

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Abstract: A practical approach for measuring phosphor temperature in an operating pc-WLED was studied. This brought advancement in managing the heat dissipation of the LED dies and to stabilize the photometric characteristics of pc-WLEDs.

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Keywords: pc-WLEDs, phosphor temperature, noncontact and instant detection.

Phosphor-converted white light-emitting diodes (pc-WLEDs) are a key light source because they have much advantage such as low cost, energy efficiency, high color performance and high reliability [1-5]. A pc-WLED is usually made with a yellow (or green with red) phosphor layer that excited by a blue die to generate white light with different Correlated Color Temperature and Color rendering index. An unavoidable phenomenon in operating pc-WLEDs is the high temperature in the package volume of a pc-WLED that can cause thermal quenching of phosphor, resulting in color drift, which induces blue-light leakage, efficiency droop, and lifetime shortening [6]. It was reported that the hottest spot in the package volume was located at the top of the blue chip or in the phosphor layer (a package with remote phosphor). Thus, managing the thermal effect is critical in extending the lifetime of a pc-WLED. Since the temperature on the surface of samples is primarily measured, rather than the temperature inside the samples, an effective method for measuring the phosphor temperature in pc-WLEDs is a requirement. So far, the thermal dynamics of the phosphor layer/volume in pc-WLEDs still lacks useful support. In this paper, we propose a novel noninvasive method for building a database for a specific phosphor with a specific LED bonding that has been proven to detect phosphor temperature precisely for different pumping blue lights and different phosphor concentrations or CCTs.

In first phase of the method, the analysis of thermal-dependent spectra was conducted. Variations in the emission spectra of the phosphors indicated the phosphor temperature, but a useful signal must be extracted from

the noises and overlapping phenomena. For that purpose, the emission spectrum of YAG: Ce³⁺, which was a yellow phosphor with the maximum peak at approximately 540 nm was analyzed. From the band structure, the down conversion comprised two separate Gaussian contributions in the energy range. The two subbands corresponded to 580 nm (called long band) and 520 nm (called short wavelength band) as shown Fig.1

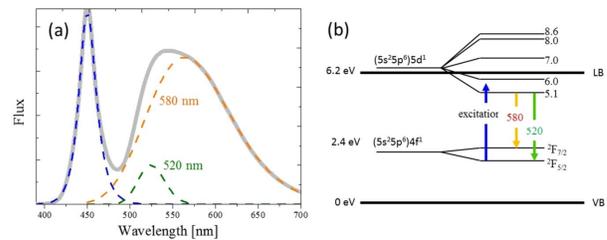


Fig.1 (a) Normalized emission spectrum of phosphor consisting of the transition between two subbands. **(b)** Two subbands corresponding to two specific down conversions.

Nextly, the experimental data for the fitting process are prepared. In the experiment, we attached a blue die to a metal core printed circuit board (MCPCB) and covered it with a silicone layer embedded with YAG:Ce³⁺. An IR camera was used to monitor the surface temperature of the phosphor layer. No heat sink was used to dissipate the heat of the MCPCB; hence, the temperature would increase when the injection current increased.

The fitting results from the experimental data are illustrated in Figs 2 and 3, where the associations between

all four factors are well defined, including the fitting peak wavelengths and the full-width at half-maximums (FWHMs) of the short and long wavelength bands, and the phosphor temperature. This fitting results suggests that the phosphor temperature can be precisely measured by checking variations of the emission spectrum

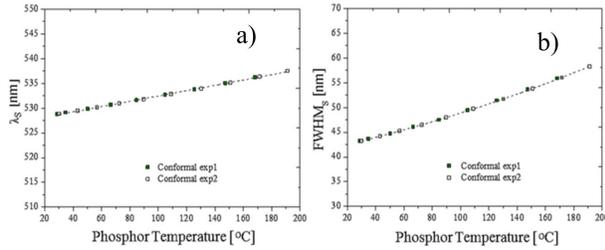


Fig.2 Fitting results of normalized spectrum for the short wavelength band. Correspondence between the (b) peak wavelength and (c) bandwidth of the phosphor.

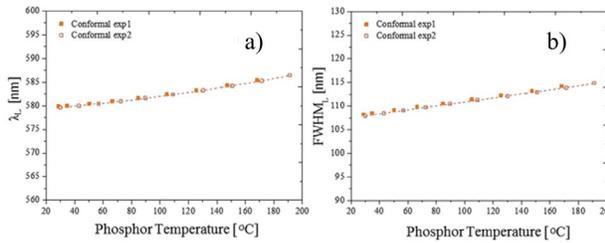


Fig.3 Fitting results of normalized spectrum for the long wavelength band. Correspondence between the (b) peak wavelength and (c) bandwidth of the phosphor temperature.

Fig. 4 shows the experimental measurements, obtained using the proposed detecting model, of the phosphor temperatures with and without lens encapsulation. The conformal coating packaging without lens encapsulation was used to build the database. Then the pc-WLEDs were encapsulated with a silicone lens. The database was used to indicate the temperature of the phosphor layer. The lens encapsulation blocked possible air convection of the phosphor layers; hence, the temperature was higher than the packaging without lens encapsulation. Based on the proposed modeling and the database, we found that the temperature of the sample with lens encapsulation increased by more than 160% compared with the packaging without lens encapsulation under different injection currents. Note that the phosphor temperature as a function of the injection current (Fig. 4) can be adopted only for the same thermal dissipation design.

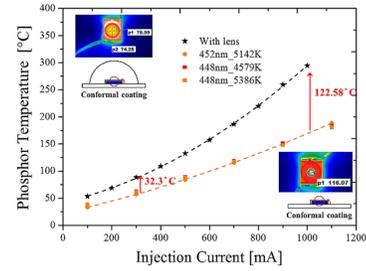


Fig.4. Detection of phosphor temperature for the package with and without lens encapsulation under different injection currents. Black (red) dash line indicates the pc-WLED with (without) lens encapsulation.

In conclusion, based on model of spectrum fitting, it can remotely measure the phosphor temperature of a pc-WLED. We successfully demonstrated a correspondence between the yellow spectrum and phosphor temperature from a white light spectrum with large cross-talk. This study provides a highly effective method for monitoring phosphor temperatures, which can be adopted by the solid-state lighting industry to develop more light sources that are reliable and efficient and have high color stability.

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