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INFLUENCE OF DUTY CYCLE ON PROPERTIES OF A PHOSPHOR-CONVERTED WHITE LED

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Pulse-width modulation (PWM) is a popular dimming method of light-emitting diodes (LEDs) because of the linearity of the brightness adjustment. In the PWM, effective current is varied by changing the width (t) of the current pulse, the modulation frequency ($1/T$) being constant. The electrical power is then changed and junction power dissipation is dependent of the pulse width. The junction temperature of LEDs is important parameter because it has a significant influence on the color, luminous flux, and lifetime of LEDs. In Ref. [1], the effective junction temperatures and color shifts of low-power AlGaInP LEDs have been determined during the PWM dimming. The color shifts of dimmed white LEDs have been investigated in [2].

Herein, the photometric, colorimetric and thermal characteristics of a high-power phosphor-converted white LED (1W, Luxeon I) are investigated during the PWM dimming. The light output of the LED was controlled with various duty cycles between 5 % and 95 %. The LED behavior was studied at modulation frequencies of both 180 Hz and 1000 Hz. The drive current of the LED in the PWM was 350 mA. LED characteristics were also tested with a current reduction dimming method at continuous currents of 50, 100, 200, and 350 mA. The LED with a printed circuit board was mounted onto an additional heat sink (aluminum body, 5 cm x 5 cm x 1 cm). The spectral power distributions were measured with a CS1000 spectroradiometer. The integration time of the spectral measurements was more than 40 ms.

The brightness of the LED controlled by the PWM is defined as a product of the duty cycle $D = t/T$ and constant brightness obtained at continuous current. Figure 1 shows the PWM dimming to correlate very well with the ideal case at both modulation frequencies. Instead, the current reduction method gives larger deviation from the ideal straight line.

Spectra of the LED at seven duty cycles with the PWM are presented in Figure 2. The peak wavelength (λ_p) of the blue LED emission shifts roughly by 0.1 nm when the pulse ratio is changed by 10 %. The change in the effective junction temperature of the LED (time averaging over the pulses) was estimated by the peak-wavelength shift method [1]. The junction temperature of the LED was changed approximately by 30 K during the PWM dimming. The relationship between the junction temperature and duty cycle was linear.

The correlated color temperature (CCT) of the LED was determined in the CIE 1960 uniform chromaticity scale diagram. The CCT as a function of duty cycle is presented in Figure 3. The CCT changes by more than 300 K during the PWM dimming. The use of the 180 Hz frequency would cause slightly smaller change in the CCT value. The current reduction dimming has much larger influence on the CCT value.

In conclusion, the color shifts caused by the PWM dimming should be taken into account when designing satisfactory light sources based on phosphor-converted white LEDs.

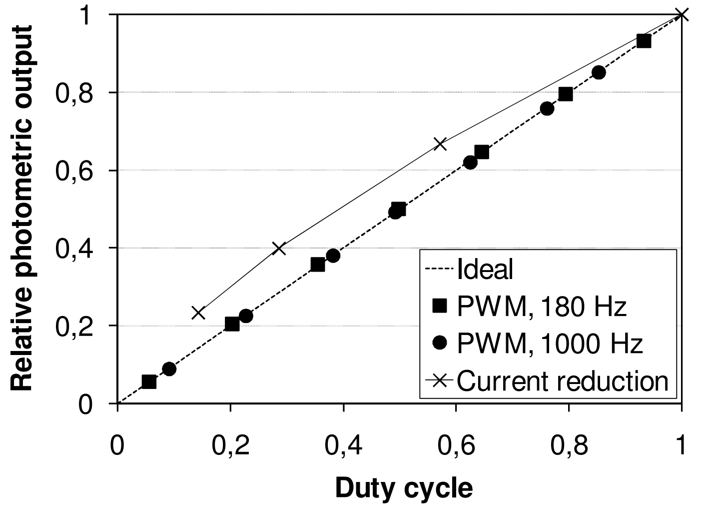

Figure 3. The photometric output as a function of duty cycle of the current. The dependences are presented for the PWM dimming at two modulation frequencies and for current reduction dimming.

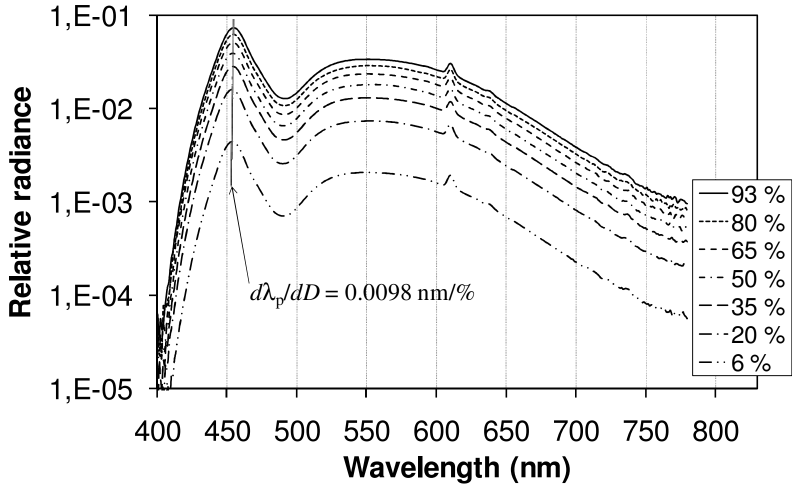

Figure 4. Relative emission spectra with seven duty cycles at 180 Hz.

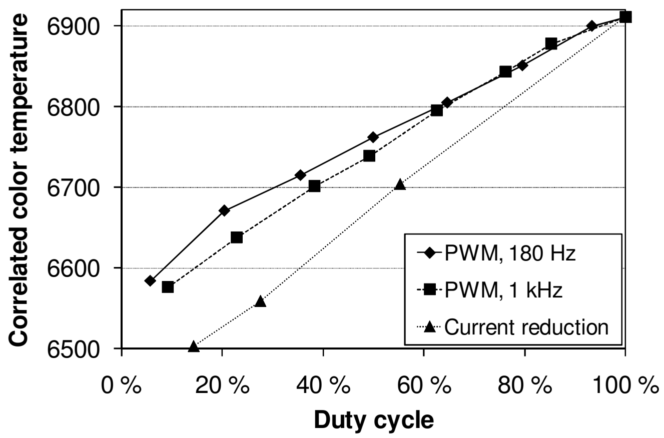

Figure 5. Correlated color temperature as a function of duty cycle of the current.

[1] P. Manninen and P. Orreveteläinen, Appl. Phys. Lett. 91, 181121 (2007).
[2] M. Dyble, et al., Proc. SPIE 5941, 291–299 (2005).