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Impact of current controlled dimming on spectral characteristics of high power LEDs

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HIGHLIGHTS

- LED can be dimmed by two ways (i) linear dimming (ii) PWM technique.
- The effect of increase in forward current on peak wavelength is reported.
- All LEDs shows increase in light output due to increase in forward current.
- Red LED shows red shift whereas blue, green and white LED shows blue shift.

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ABSTRACT

Conventional light sources are reproducible with consistency in light output and colour points, whereas LEDs do not provide output level stability. The lumen output changes with temperature and age. The process of reducing the light output of LED is called dimming. LED can be dimmed by two different ways one by changing the forward current called linear dimming and secondly by modifying the pulse width called PWM technique. Typically the current through LED is controlled by a variable resistor. This paper reports the effect of variation of forward current on spectral characteristics of one watt red, green, blue and warm white LEDs. Red LED shows red shift while blue and green LED shows blue shift for increase in forward current. Warm white LED shows blue shift for lower as well as higher peak wavelengths.

1. Introduction

Conventional light sources are reproducible with consistency in light output and colour points while LEDs on the other hand does not provide output level stability. The lumen output changes with temperature and age [1–3]. Method of reduction of light output of LED is called dimming. Now a days solid state lighting devices, LEDs are the best option compared to conventional light sources for artificial lighting. High power LEDs are used for lighting application. Dimming is generally used for saving energy, reducing the maintenance and increasing the life span over the traditional light sources. LED can be dimmed by two different ways one by changing the forward current called linear dimming and secondly by modifying the pulse width called PWM technique. Typically the current through LED is controlled by a variable resistor. In current reduction dimming process, LED is operated from minimum forward current to maximum forward current. In PWM technique, pulse width is modulated so that LED is ON for this duration. Both these techniques of dimming affect chromaticity. In different task lighting, dimming of light sources is essential to fulfill the requirements [2]. In most of workspaces it is observed that light intensity is kept constant throughout the day, but different task requires different illumination level. For example, performance of the visual task with high contrast and large size requires 30 fc (300 lx) while performance of the visual task with low contrast and large size or high contrast and small size requires 50 fc (500 lx). Yemini Gu et al. reported the spectral shift and luminous efficacy vary with different dimming methods [2]. With a reduction in forward current, self heating decreases, this causes an increase in the lifespan. In this paper the shifting in peak wavelength with the forward operating current has been reported. The forward current determines the relative luminous flux, i.e. brightness of the LED. The effect of change in forward current over the light output has also been studied and analyzed.

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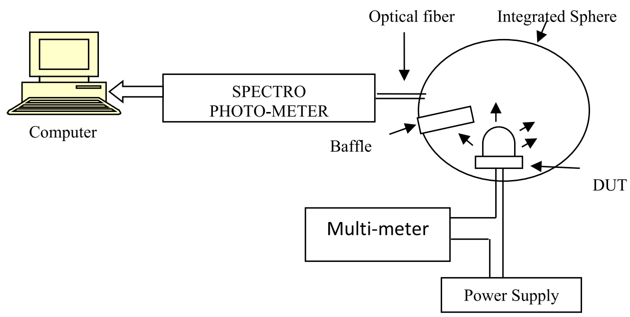

Fig. 1. Experimental arrangement for the measurement of spectral response.

2. Experimental setup

Commercial one watt red, green, blue and warm white LEDs having recommended forward current I_{max} = 350 mA have been chosen for the experimentation. A constant +5 V voltage power supply whose output current varies from 0 mA to 500 mA has been used to drive the LED. The spectral characteristics of all LEDs are studied at ambient temperature by varying the forward bias current from 10 mA to 350 mA. The light output of red, green and blue LEDs have been recorded at different operating currents by keeping fix distance of 15 cm between LED and LUX meter. Spectral characteristics have been observed by using StellarNet USB spectrophotometer and 6″ diameter integrating sphere. The experimental setup for the study of spectral response is as shown in Fig. 1.

3. Result and discussion

Light output of LED can be affected by several factors such as power delivered to p-n junction, temperature of the junction and spectral shift. The light output for all the LEDs increases with increasing operating current. Results are as shown in Fig. 2a–c.

Total emitted flux is an important criteria in designing any task light. When forward current is supplied to LED it emits an incoherent narrow spectrum of light. The peak wavelength emitted depends on the material of LED chip. Fig. 3(a) shows variation of peak wavelength with increasing forward current for red LED. Increase in forward current increases junction temperature, which is responsible for the red shift. Thermal expansion increases lattice spacing. This may result into narrowing the energy band gap which leads to red shift. The energy gap at different temperature is given by Varshini equation [1],

$$E_{g(T)} = E_{g(0K)} - \frac{\alpha T^2}{T + \beta} \tag{1}$$

where α and β are Varshini parameters.

Fig. 3(b) and (c) shows blue shift for blue and green LED. The literature on blue shift indicates that it occurs due to band filling and quantum confined stark effect(QCSE) [4–7].

White light can be produced in two different ways in LED. One is the additive colour method in which proper mixture of red, green and blue light produces white light. The second method is phosphor white method in which single LED combines UV or Blue LED and yellow phosphor. Most of the white LEDs in the market utilize yellow phosphor excited by blue LED. Spectral characteristics of white light show two peaks, blue emission from semiconductor LED and longer wavelength emission due to phosphorescence [1,5,6]. Lower narrow peak having a peak wavelength around 450–470 nm and higher broad peak, which emitted by phosphor containing the emissions of wavelength from 500 nm to 700 nm. This higher peak has a peak wavelength around 550–580 nm as shown in Fig. 4(a).

The emission spectra of phosphor based white LED consists of blue emission from semiconductor LED and longer wavelength emission due to phosphorescence [1,5,6]. When photons from the blue LED pass through the phosphor, some of them are unaffected, but others are absorbed by the phosphor and re-emitted in the yellow part of the spectrum. The eye perceives the combination of blue and yellow light as white. Blue shift observed in blue LED with an increase in forward current as shown in Fig. 4(b). Higher broader peak also shows blue shift as shown in Fig. 4(c). Phosphor excitation depends on blue emission in white LED so blue shift in excitation is responsible for blue shift in phosphorescence. Blue LED shows effect of blue shift at a faster rate up to about 70 mA current, whereas green and broader peak of the white LED show this effect up to about 200 mA then after peak wavelength remains constant up to 350 mA.

4. Conclusion

All LEDs shows increase in light output with forward current. Initially for increase in forward current light output increases faster and when forward current exceeds 250 mA all LEDs shows a slow increment in the light output. Red LED shows red shift while blue, green and white

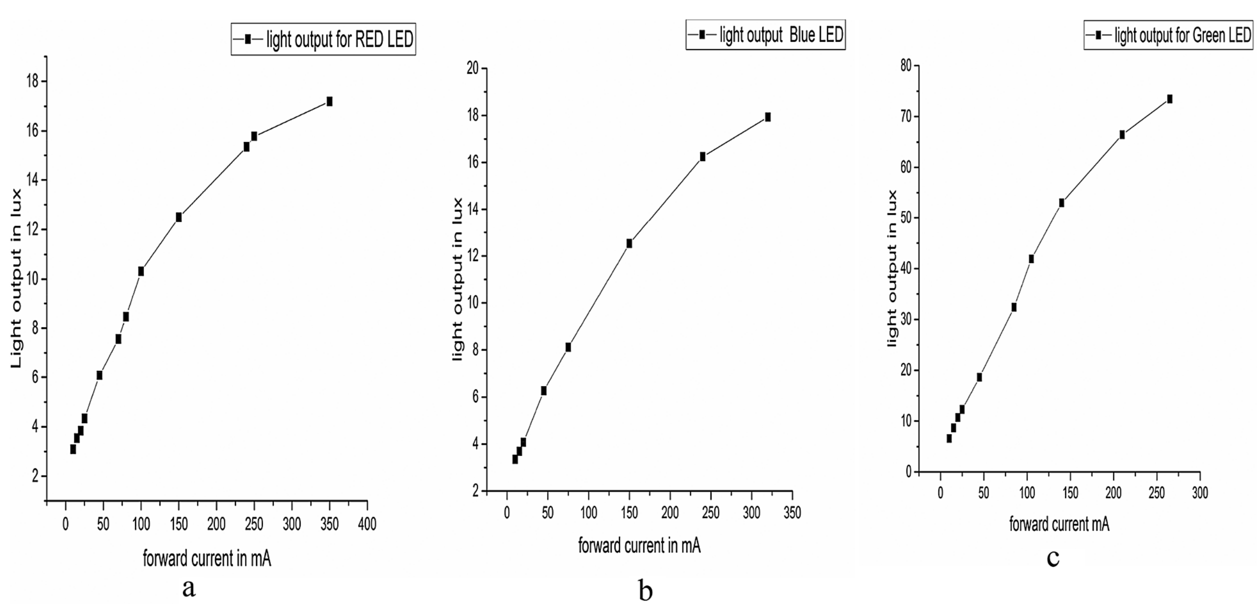

Fig. 2. a, b, c shows variation of light output with forward current (a) RED (b) Blue (c) Green LED.

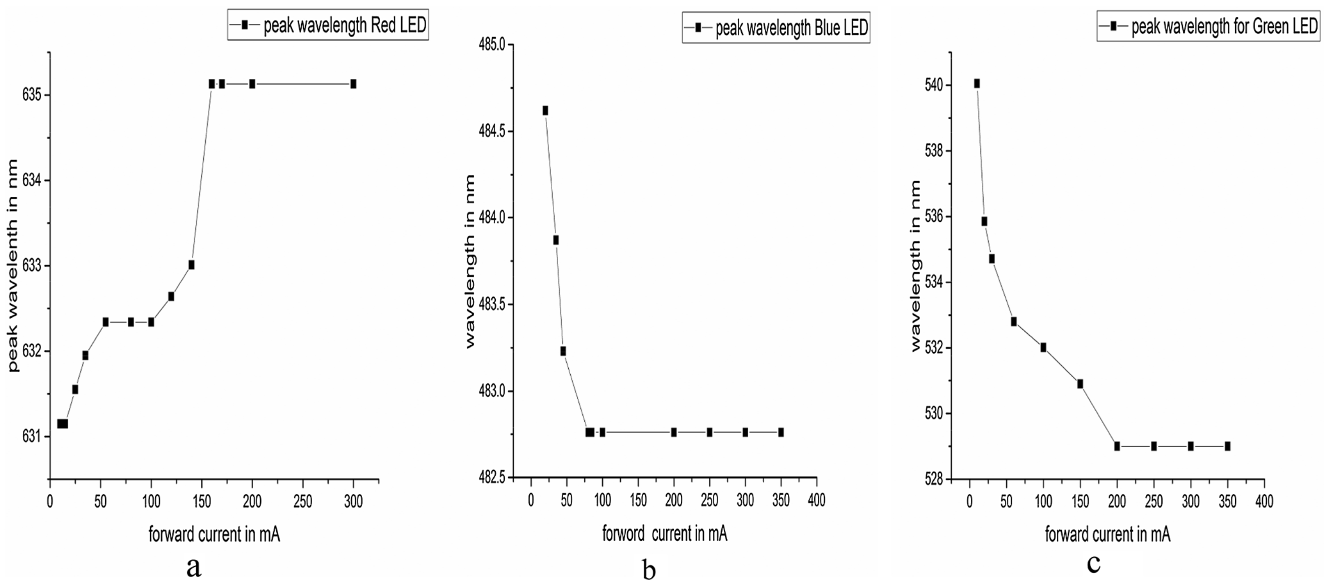

Fig. 3. Variation of peak wavelength with forward current (a) Red LED (b) Blue LED (c) Green LED.

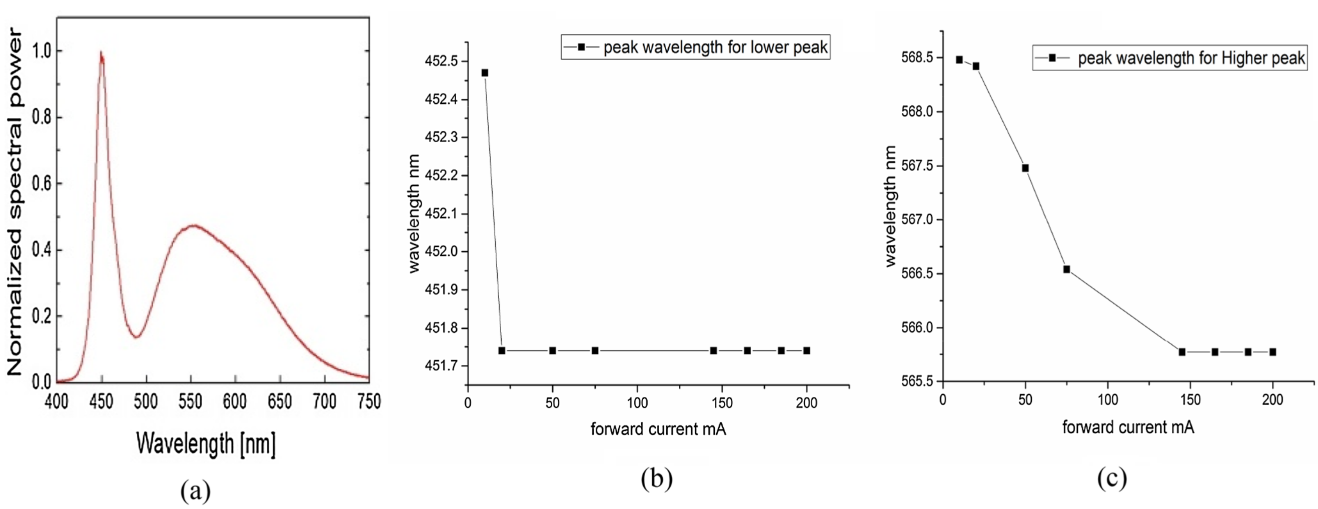

Fig. 4. (a) Spectral power distribution of phosphor based white LED. (b) Blue shift in lower narrow peak (c) Blue shift in higher road peak. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

LED show blue shift. Blue shift predominantly takes place due to band filling and AlInGaP red LED shows red shift due to increase in temperature of junction. Red and blue shift are faster for lower current and peak wavelength is almost constant for higher currents. Phosphorescence in white LED also shows the blue shift. At low current, the light looks 'warmer' (more yellow). However, at high current, the phosphor becomes less efficient and the blue emission becomes more dominant, making the light 'cooler' or bluish.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.optlastec.2019.02.010.

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