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Wide Color Gamut Backlight from Three-band White LED

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A Wide Color Gamut Backlight system was studied using a three-band white Light-Emitting Diode. A three-band white light-emitting diode (LED) was fabricated using an InGaN-based blue LED chip that emits 445-nm blue peak, and a green phosphor and red phosphor that emit 535-nm green and 621-nm red peak emissions, respectively, when excited by 450-nm blue light. Using for this three-band white LED, wide color gamut backlight unit (BLU) was attained. The luminance of BLU and CIE 1931 chromaticity coordinates was 1,700 Cd/m^2 and (0.337, 0.346). Color filter matching simulations for this configuration show that the three-band white LED backlight can be enhanced by up to 16% over conventional white LED backlight color gamut.

OCIS codes : 250.0250, 160.3710, 230.3670, 330.1730

I. INTRODUCTION

Recently, tremendous progress has been achieved in GaN based light-emitting diodes (LEDs). This has been used in a variety of applications such as LED illumination field, full color displays and general lighting [1]. For this technical background, the use of an LED array as a backlight unit for a liquid crystal display (LCD) is rapidly emerging in various applications [1]. But this type of conventional white LED backlight (BLU) has a weak point of color gamut. Actually, color gamut is very important for backlight. Color gamut means a 'range of colors produced by a coloration system' [2]. This color gamut is produced by the BLU spectrum and by the Color filters of the LCD module. Color Filter of LCD is the fundamental structure of the thin-film transistor liquid crystal display (TFT LCD) modules consisting of three-primary colors; red (R), green (G), and blue (B). The function and performance of color filters include high contrast, high color repetition, high color saturation, high color purity, fast response time, wide viewing angle and so on [3]. So, if you have achieved a good color filter but poor BLU spectrum matching, you can get a dull color for the LCD module. Obviously, you can get the same results by means of a poor color filter and good BLU spectrum matching. So, color gamut is very important for the LCD module.

For enlargement of low color gamut, three-color LED and color filter has been investigated [1]. But a three-color LED BLU needs an LED driving circuit unit, color sensor and more complex optical structures.

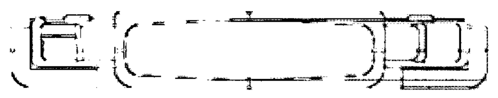
In addition, the three RED, GREEN and BLUE LEDs lead to high cost. Finally, control of the color filter leads to low brightness of the LCD module.

To solve this problem, we investigated wide color gamut backlight from a three-band white LED.

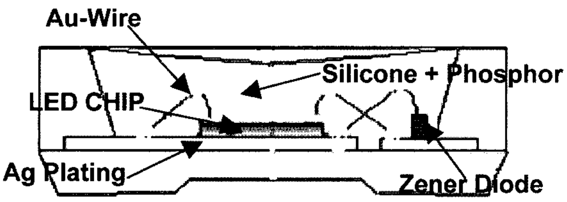
II. EXPERIMENT

At first, we fabricated a three-band white LED using an InGaN-based blue LED chip and a silicate series green phosphor and nitride series red phosphor. To fabricate the three-band white LED, the green phosphor and the red phosphor were mixed, and then the mixed phosphor was blended with silicone epoxy in order to be dispensed on the LED package [4]. Fig. 1 shows a schematic side view of the LED package. This package had a 450 nm blue dominant wavelength. To compare to the properties of this three-band LED, a conventional type of LED was also fabricated. The conventional type LED was blended silicon and Terbium Aluminates-Garnet series phosphor. This phosphor emits a yellow peak spectrum. And the conventional type LED had a 465 nm blue dominant wavelength.

Fig. 2 shows a backlight unit (BLU) of a 5-inch Personal Multimedia Player (PMP). A BLU consists of LEDs and Printed Circuit Board (PCB) Module, reflection sheet, a Light Guide Plate (LGP), diffuser sheet,



(a) Top View



(b) Perspective View

FIG. 1. Sideview LED package.

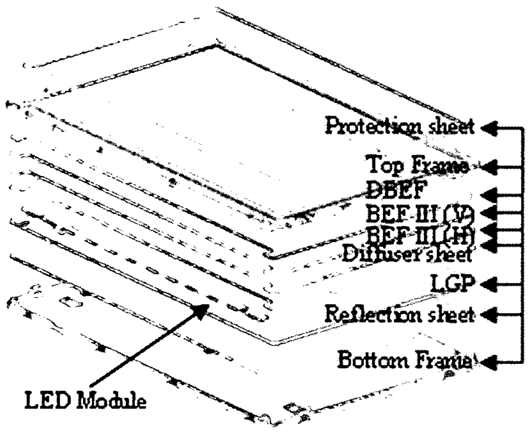


FIG. 2. Structure of BLU for a 5 inch PMP.

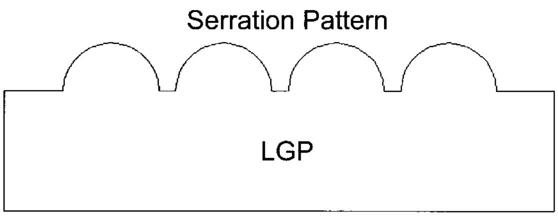


FIG. 3. Serration pattern concept.

a prism sheet, etc. The LGP is the most essential part in a BLU. A large number of dots are distributed at the bottom of the LGP. The pattern also makes a uniform light distribution on the BLU. For that reason, we generated the pattern by an optical simulation tool and found the uniformity of light distribution [5]. Furthermore, to avoid the hot spot of BLU, a serration pattern was determined by the simulation. This serration pattern was located on the edge of the LGP near to the LED module. Fig. 3 shows the serration concept. This serration pattern has 300~500 um size of half sphere.

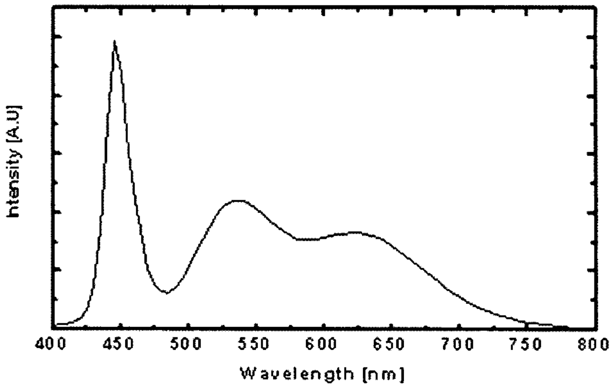


FIG. 4. Emission spectrum of the three-band white LED under DC 20 mA.

TABLE 1. Characteristics of two types of LED under DC 20 mA

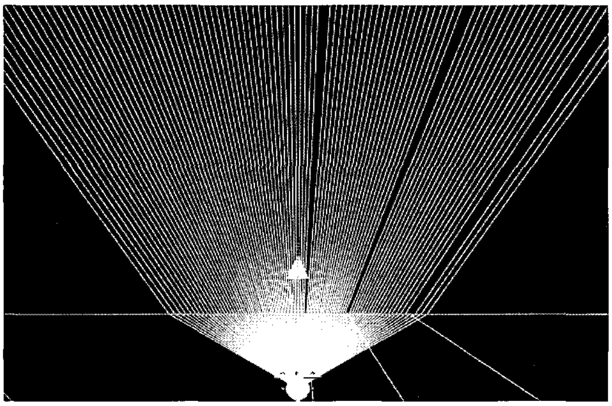
	Three-Band White LED	Conventional White LED
Vf [V]	3.12	3.21
Luminous Efficiency [lm/W]	41.2	55.3
CIE x	0.3163	0.306
CIE y	0.3216	0.299
λp	445.82	460.26
FWHM	20.55	21.08

III. RESULTS AND DISCUSSIONS

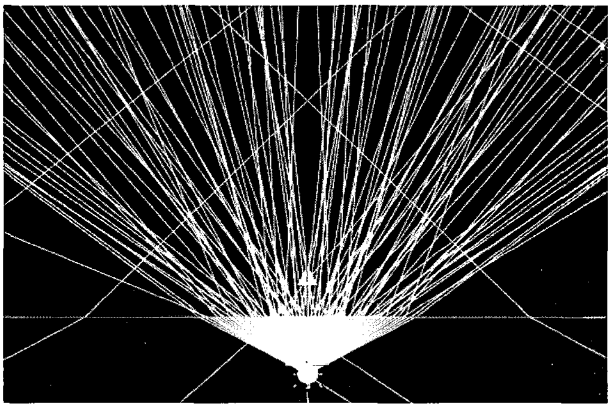
Fig. 4 shows the emission spectrum of the fabricated Red and Green phosphor with 450-nm blue chip, measured by optical spectrometer (CAS140-B, Instrument Systems). The emission peak wavelengths are 445 nm, 535 nm and 621 nm, respectively. Table 1 shows measured properties of three-band white LED and conventional white LED. Comparing the two types of LED, the luminous efficiency [lm/W] of the three-band white LED is lower than that of the conventional white LED.

The serration simulation result is shown in Fig. 5. Comparing the serration LGP and without serration LGP simulation, we can see the light scattering properties of the serration LGP are better than for the LGP without serration.

Table 2 compares characteristics of each Backlight unit. Considering the results of each BLU, brightness of the three-band white LED BLU is lower than that of the conventional white LED BLU result. We think that this is because light extraction efficiency is lower for the mixed phosphor than for the conventional yellow phosphor.



(a)



(b)

FIG. 5. LGP serration effect simulation: (a) Without Serration LGP (b) With Serration LGP.

TABLE 2. Backlight results for Conventional white LED type and three-band white LED type.

	Brightness	CIE x	CIE y	Color Gamut
Conventional LED BLU	2100 Cd/m^2	0.321	0.334	59%
Three-band LED BLU	1700 Cd/m^2	0.337	0.346	75%

Fig. 6 and Fig. 7 show the color filter spectrum and emission spectra simulation results for Color Gamut. Compare two types of BLU color gamut spectra; the three-band white BLU of blue, green and red peak was shifted more than the conventional white BLU of blue, green and red peak. Calculated peak wavelength of three-band white LED was 445 nm, 540 nm and 635 nm. For conventional type of white LED, peak wavelength was 460 nm, 555 nm and 605 nm. So, blue was shifted 15 nm, green 15 nm and red 30 nm. These shifted wavelengths made for wide color gamut results. For those results, we found that the three-band white LED BLU color gamut was enhanced 16% compare the

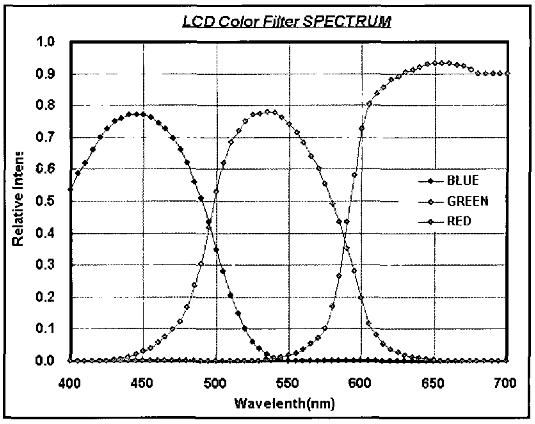
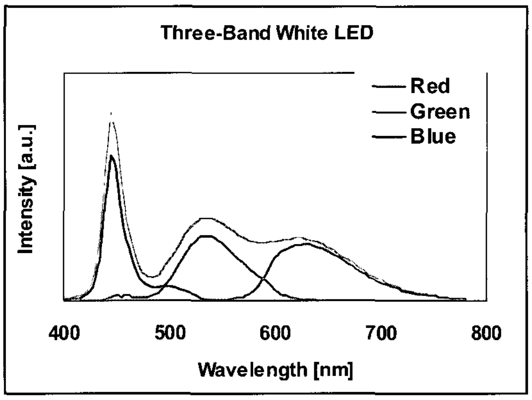
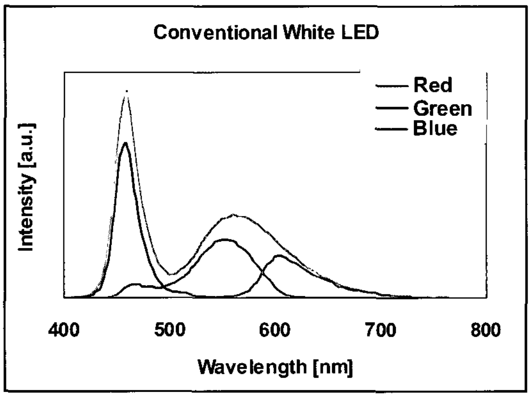


FIG. 6. Spectrum of Color Filter.



(a)



(b)

FIG. 7. Color Gamut Simulation Results for a two type of BLU. (a) Three-band white LED type and (b) Conventional white LED type.

conventional type white LED BLU.

The chromaticity coordinate of three-band white LED BLU and conventional white LED BLU is shown in Fig. 8. And Table 3 shows chromaticity coordinate of after matching simulation results. Obviously, triangle area of three-band white LED BLU is larger than conventional white LED BLU triangle area. This result

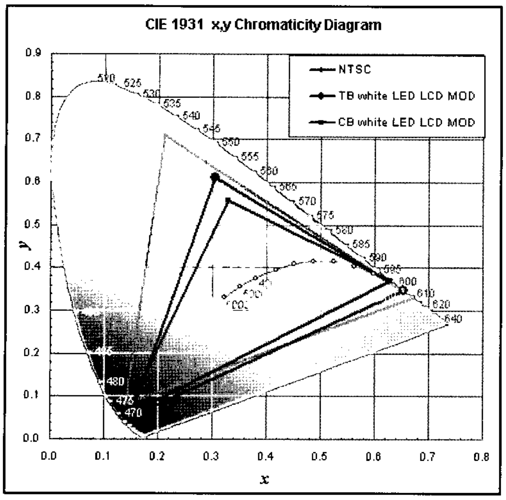


FIG. 8. Chromaticity coordinates for three-band white LED BLU and conventional white LED BLU.

TABLE 3. Chromaticity coordinate of each BLU matching results.

	BLUE	GREEN	RED
Conventional LED BLU	x: 0.1399 y: 0.0519	x: 0.3293 y: 0.5585	x: 0.6283 y: 0.3712
Three-band LED BLU	x: 0.1490 y: 0.0506	x: 0.3040 y: 0.6105	x: 0.6525 y: 0.3470

means three-band white LED BLU has more good qualities of color gamut compared with the conventional white LED BLU.

IV. CONCLUSION

We have developed Wide Color Gamut Backlight Unit (BLU) by means of three-band white Light-Emitting Diode. For conventional type, emission spectrum of LED is blue and yellow peaked. But this three-band type, emission spectrum peak has blue, green, and red. Furthermore, we do not have to use red, green, and blue chips. So, we can get low cost and high color gamut BLU. Also, it was found that the three-band white LED BLU color gamut was enhanced 16% compare to the conventional white LED BLU. But three-band white LED BLU of lower brightness requires more investigation.

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