Design of White LED Light Source for Noble LCD Backlight Module

L. S. Chou [a] & I-Hsin Lin [a]

[a] Department of Electrical Engineering, Yuan Ze University, Chungli, Taiwan, Republic of China

Version of record first published: 30 Jan 2009

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Department of Electrical Engineering, Yuan Ze University, Chungli, Taiwan, Republic of China

A brand new design concept is proposed in this paper. In order to increase the efficiency of light emission, we develop a new scheme in modulating the light rays with white LED light sources emitting from the angle side and in improving design of light guide plate in the backlight module. Results of simulation are shown. The new scheme does not require the usual tedious procedures in adjusting the dot patterns on conventional backlight module design processes. As compared with the current method, the novel design provides much better performance in brightness, increasing emission efficiency from 53% up to 74%.

Keywords: backlight; concave; corner; led; lightguide

1. INTRODUCTION

Liquid crystal display (LCD) needs external light source to illuminate. For transmissive type LCD, the light source is in the backside of the display and the whole set-up is named Back Light Unit (BLU) shown in Figure 1 for monitor. The BLU composed cold cathode Fluorescent Lamp (CCFL), Reflector Sheet, Light Guide Plate (LGP), Diffuser Sheet and Prism Sheet.

Because CCFL contains mercury (Hg), that is prohibited under environmental protection code, for example, in European Union (EU) starts form 2010. It becomes necessary to find the replaced light source for CCFL. Light Emitting Diode (LED) has long life time, low heat emission and less power consumption, is a good replacement for CCFL.

Address correspondence to L. S. Chou, Department of Electrical Engineering, Yuan Ze University, Chungli, Taiwan 320, Republic of China. E-mail: ls_chou@saturn.yzu.edu.tw
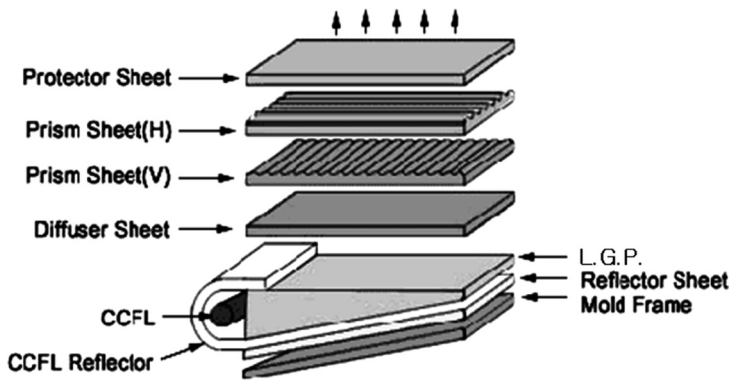
FIGURE 1 BLU for LCD monitor.
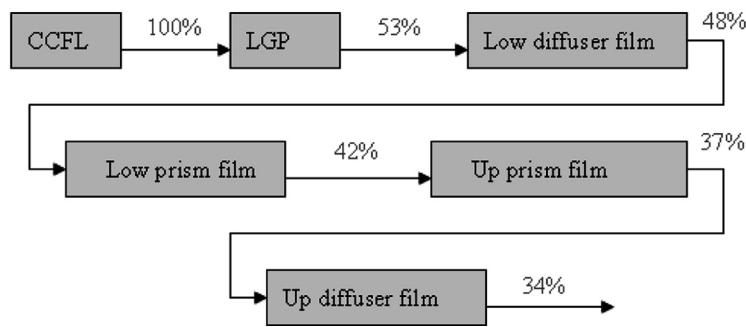
emission efficiency

FIGURE 2 Light emission efficiency for BLU.

TABLE 1 The optical data for different d

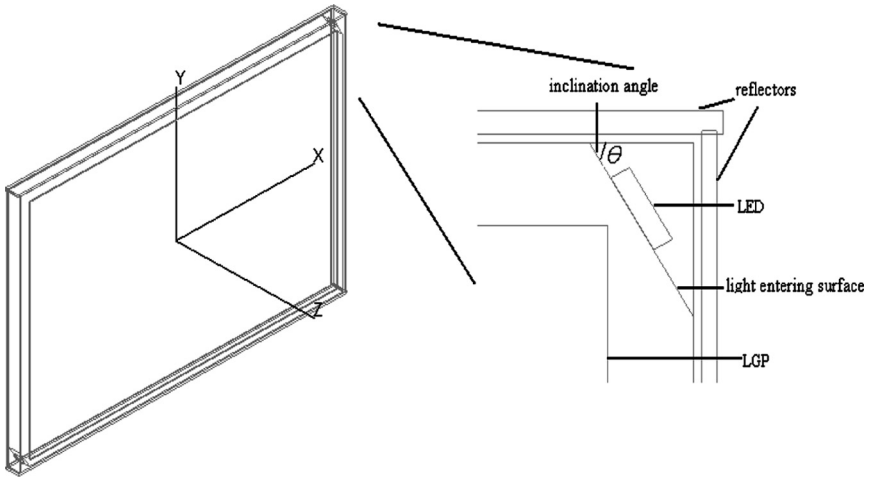| d (mm)	Avg. luminous incidence (lux)	r.m.s.	Luminous flux (lm)
0.25	2697.3	1627	70.78
0.5	2734.6	1657.7	71.7
0.75	2748.2	1678.4	72.1
1	2785.6	1743	73.1
1.25	2775.5	1722.9	72.8
1.5	2832	1756.3	74.3
1.75	2823.5	1790.6	74.1
2	2857.1	1821.4	74.98

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FIGURE 3 The structure of LGP with two corner LED light sources and four reflectors.

The light emission efficiency through LGP is only 53% shown in Figure 2. Therefore, a new design for BLU using LED is proposed and the light emission efficiency is able to increase from 53 to 74%.

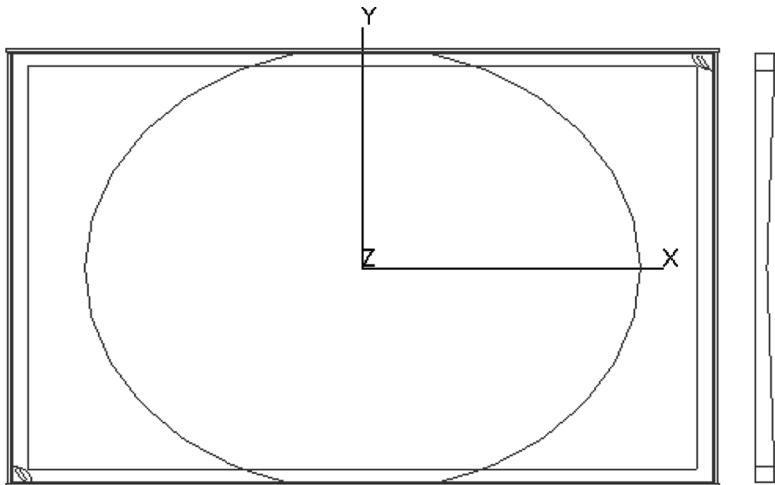The LGP had been extensive studied for CCFL light source [1–12].
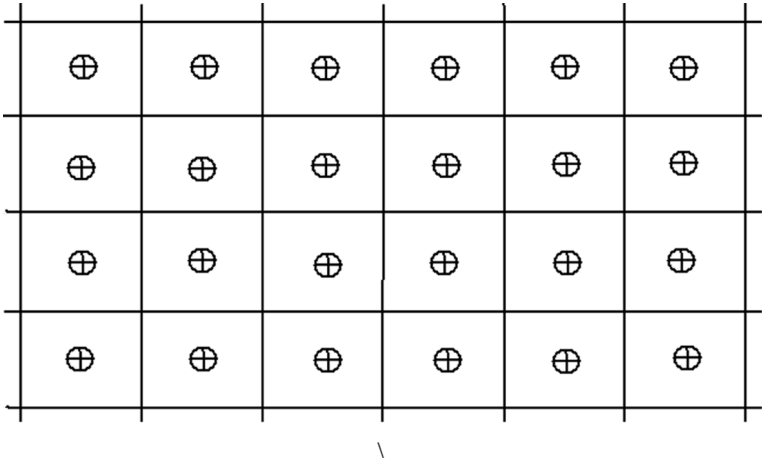

FIGURE 4 LGP with concave surface.
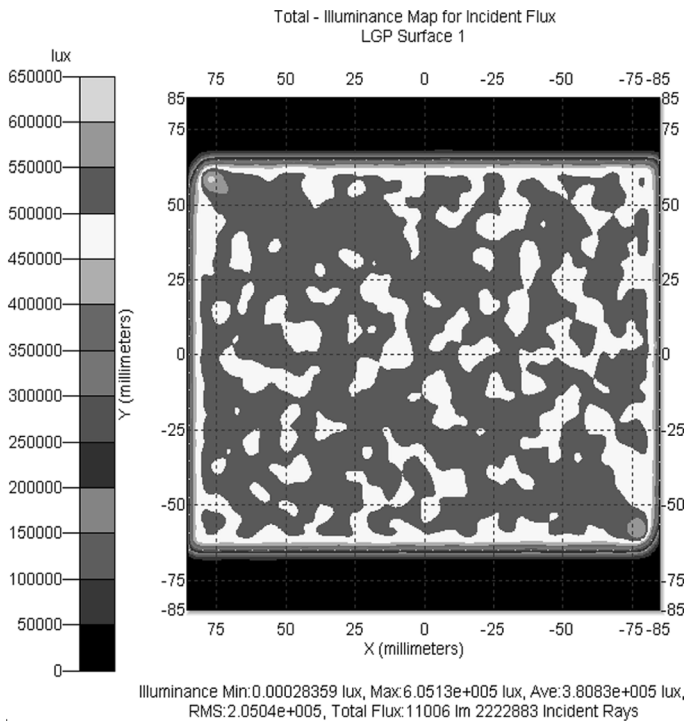
FIGURE 5 Dot pattern.

FIGURE 6 The illuminance map in x-y plane with $\theta = 60°$ and no dot pattern.

2. DESIGN AND SIMULATION

The structure of LED light source, LGP and reflectors is shown in Figure 3. A two high power white LEDs is used and placed at opposite corner of LGP. The corner surface of LGP is cut at different shapes; inclination angle ($\theta = 60°$, $45°$) and V-cut or R-cut, for light entering LGP. The LGP is also shaped as concave shown in Figure 3. Four light reflectors is placed on the edges of LGP to prevent the light leakage. The simulation software – Trace Pro is used.
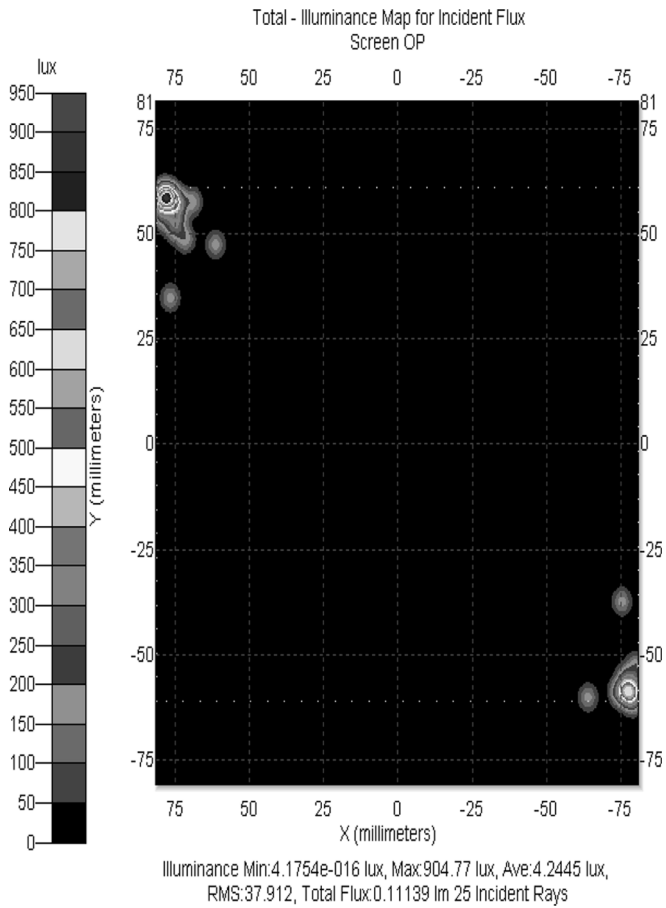

FIGURE 7 The illuminance map in z-direction with $\theta = 60°$ and no dot pattern.

2.1. Parameters Set Up

LGP has the dimension with long 170 mm, width 130 mm and thickness 6 mm, and its material is PMMA (Polymethyl Methacrylate) has index of reflection = 1.49. Each LED has luminous flux $\Phi = 50$ lm and wavelength $\lambda = 546.1$ nm. A 20,000 rays is used for light tracing in simulation. The direction of light is traveling in x-y direction and the output of light is in z-direction, a concave surface with a radius of curvature 200 mm and 2 mm high in on the top of LGP shown in Figure 4.
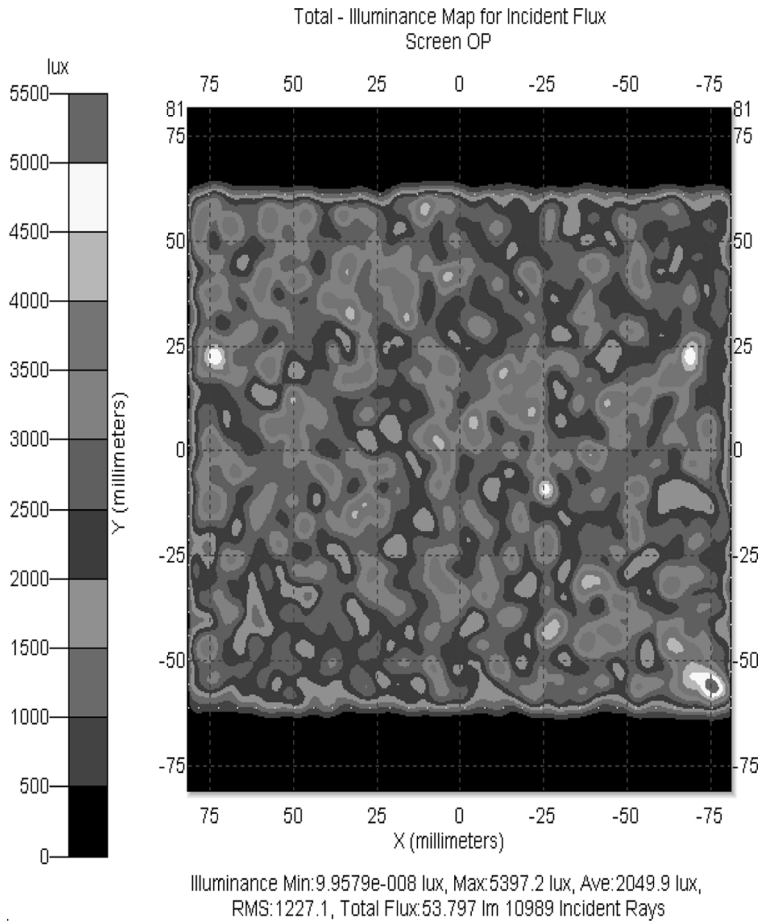

Illuminance Min:9.9579e-008 lux, Max:5397.2 lux, Ave:2049.9 lux, RMS:1227.1, Total Flux:53.797 lm 10989 Incident Rays

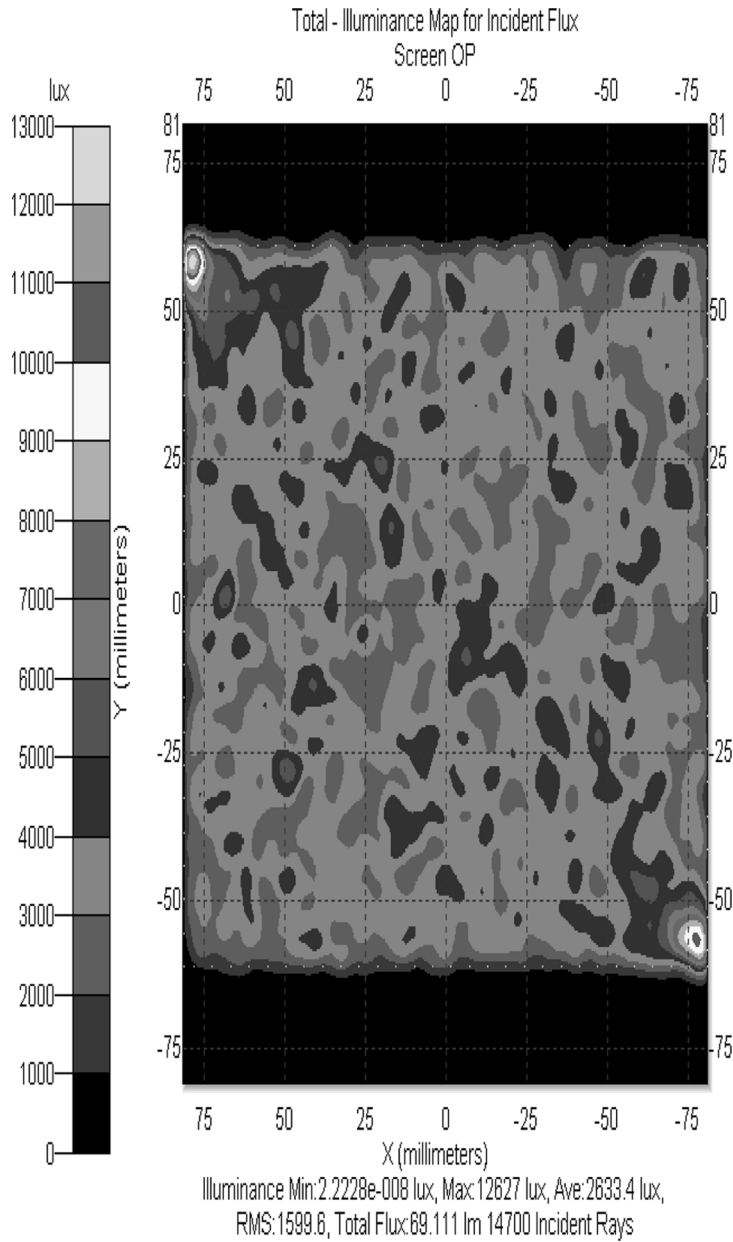**FIGURE 8** The illuminance map in z-direction with $\theta = 60°$ and dot pattern.

FIGURE 9 The illuminance map with $\theta = 60°$, edge reflectors and dot pattern, in z-direction.

The LGP has a dot pattern on the bottom, the dot has a diameter 0.04 mm and separated from dot center to dot center with 0.2 mm distance shown in Figure 5.

2.2. Simulations

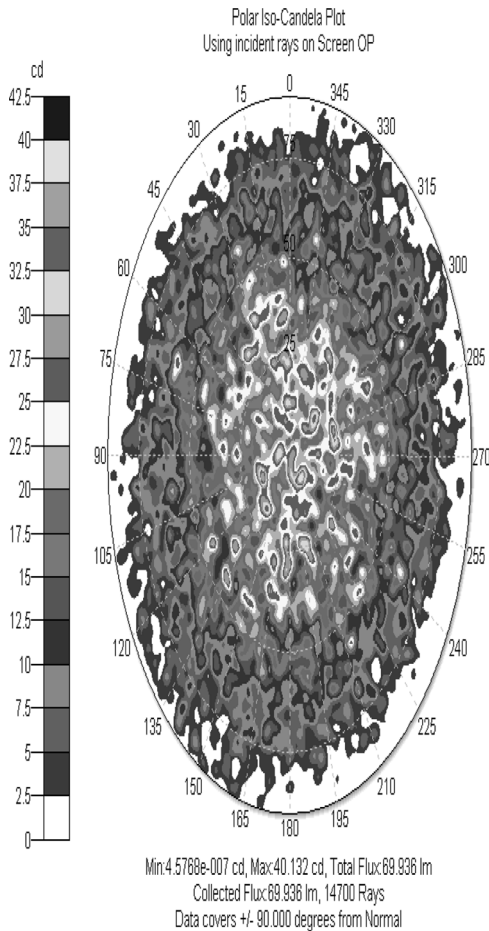*Case 1. LED light entering opposite corner with a surface at inclination angle (θ = 60°, 45°).*

FIGURE 10 Polar Iso-Candela plot with $\theta = 60°$, edge reflectors and dot pattern.

In $\theta = 60°$, the Figure 6 shows the illuminance map on x-y plane and Figure 7 also shows that there is almost no light emitting from z-direction.

When LGP with dot pattern, the dot is acting as a scattering center and destroying the total reflection condition and the light emitting from z-direction with emission efficiency 53.79% shown in Figure 8.
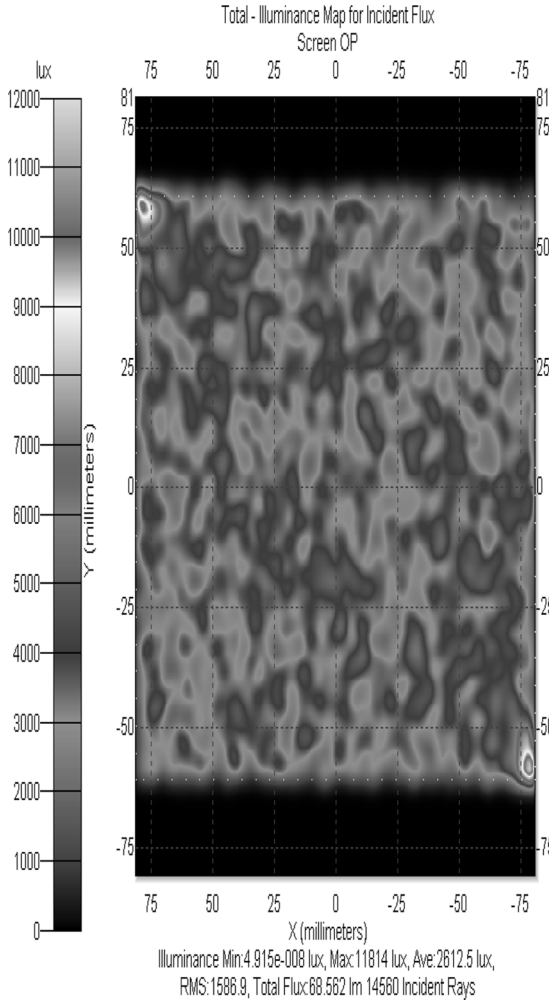

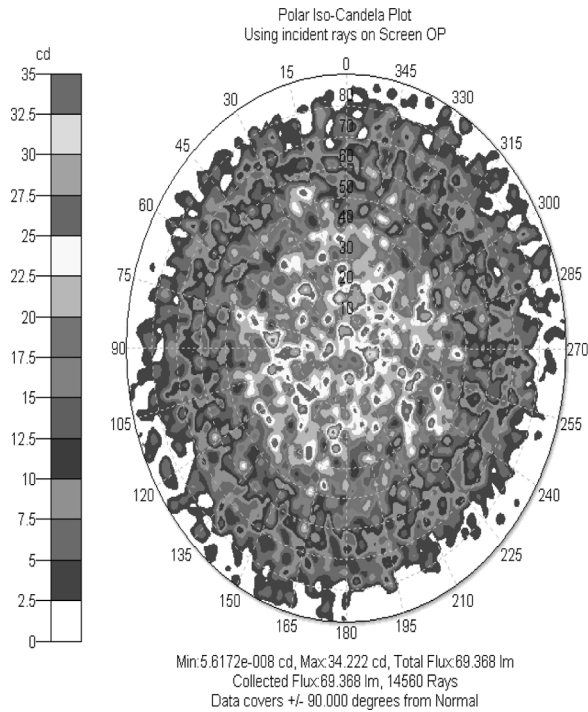**FIGURE 11** The illuminance map with $\theta = 45°$, edge reflectors and dot pattern, in z-direction.

FIGURE 12 Polar Iso-Candela plot with $\theta = 45°$, edge reflectors and dot pattern.
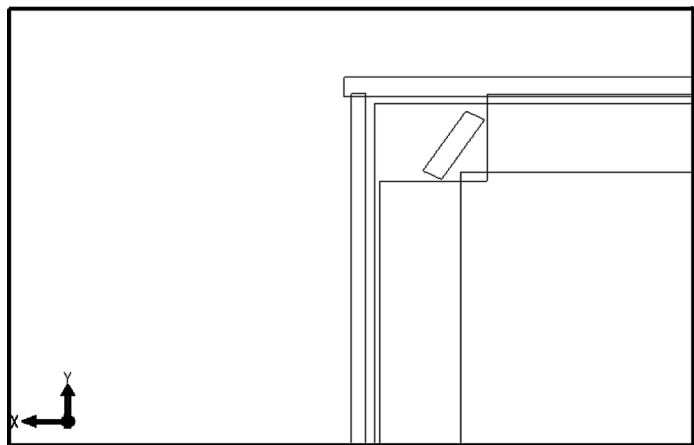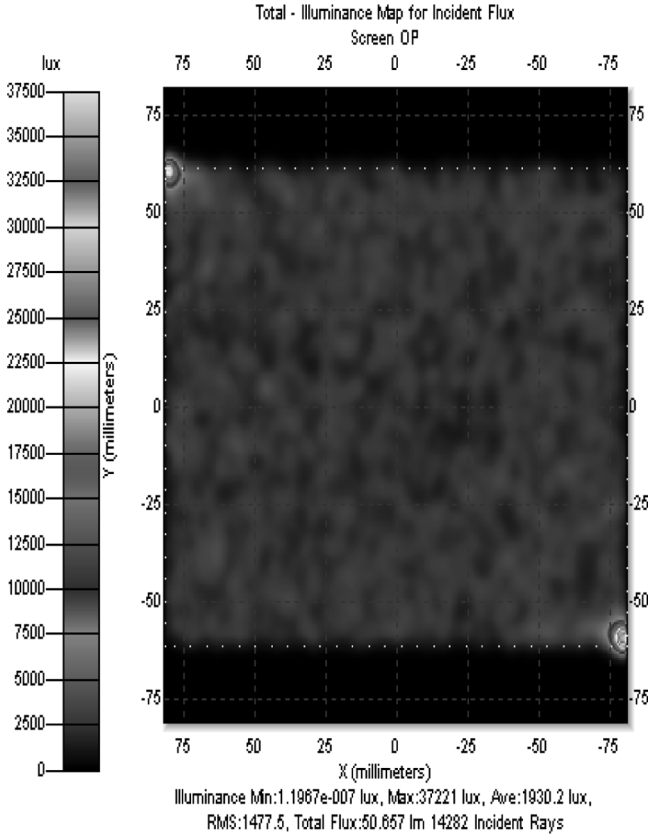

FIGURE 13 V-cut set-up.

FIGURE 14 The illuminance map for V-cut structure in z-direction.

After adding reflectors, the light emission efficiency increases to 69.11%. By Figures 9 and 10, the average luminous incidence is 2633.4 lux and its r.m.s value is 1599.6, total luminous flux is 69.11 lm.

If $\theta = 45°$, the results shown in Figures 11 and 12. The average luminous incidence is 2612.5 lux and its r.m.s value 1586.9, total luminous flux is 68.56 lm. The emission efficiency is 68.56%, lower than $\theta = 60°$.

Case 2: R-cut and V-cut

The v-cut structure is shown in Figure 13. The LED is located closed to the cutting edges. In V-cut, the cutting edge is $5 \, mm \times 5 \, mm$, the emission efficiency is 50.65%. Shown in Figures 14 and 15.

For R-cut structure shown in Figure 16, and the round edge length is 10 mm. Its illuminance map is shown in Figure 17. The emission
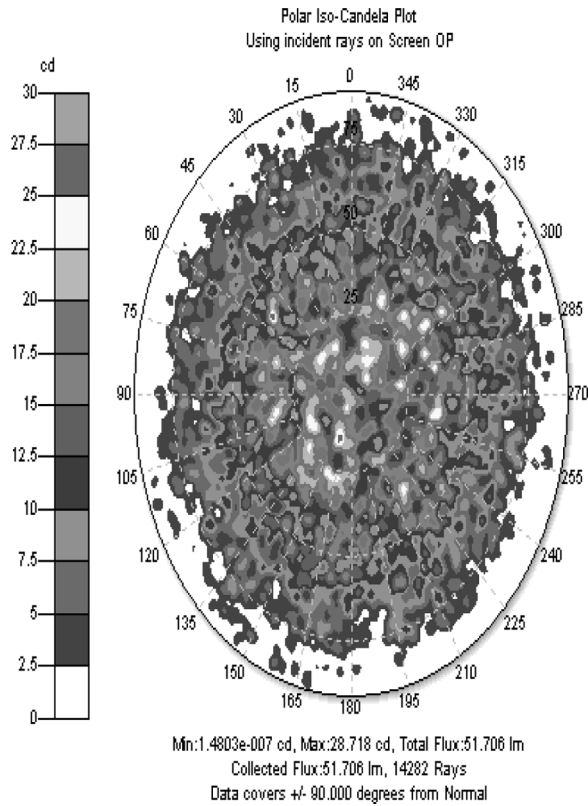
Polar Iso-Candela Plot
Using incident rays on Screen OP

Min:1.4803e-007 cd, Max:28.718 cd, Total Flux:51.706 lm
Collected Flux:51.706 lm, 14282 Rays
Data covers +/- 90.000 degrees from Normal

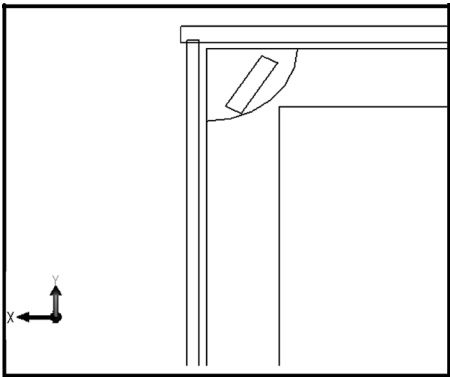**FIGURE 15** Polar Iso-Candela plot for V-cut structure.
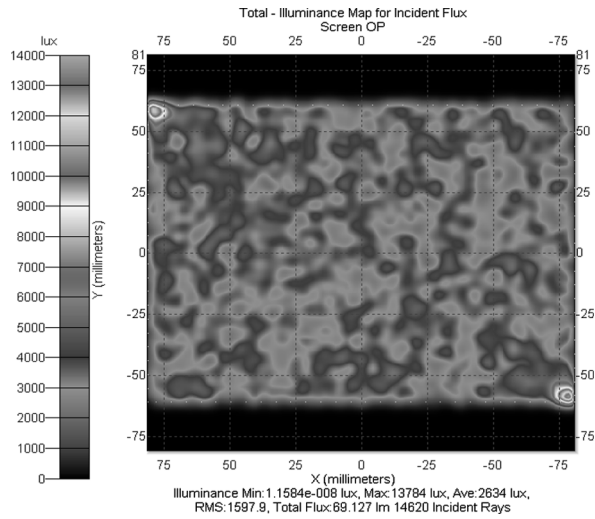

FIGURE 16 R-cut set-up.

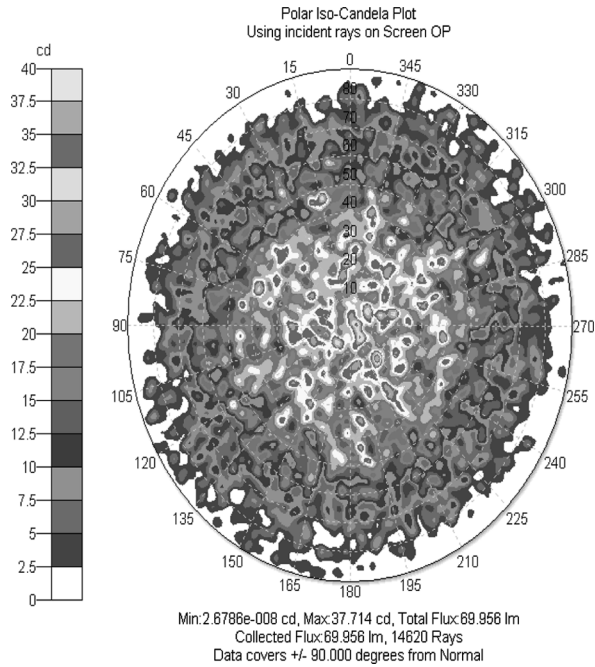**FIGURE 17** The illuminance map for R-cut structure in z-direction.

FIGURE 18 Polar Iso-Candela plot for R-cut structure.

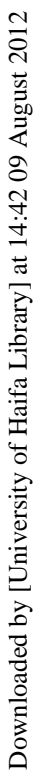**FIGURE 19** The configuration of concave surface in LGP.

efficiency is 69.12% which is better than V-cut structure. From Figures 15 and 18, it is evidence that the uniformity is better in R-cut.
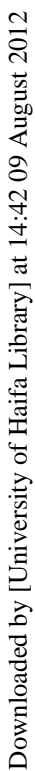
Case.3: Concave Surface.

The R-cut LGP with $d = 0.25$ mm, the definition of d is shown in Figure 19, its illuminance map and Polar Iso-Candela plot are shown in Figures 20 and 21. It is found that the emission efficiency is increasing to 70.78%, which shows the concave surface does have the effect of increasing light emission from LGP.

In order to find the optimal value for d in the design, an increment 0.25 mm for d value and the result is shown in Table 1. It shows the d 2 mm has the optimal value with avg. luminous incidence 2857.1 lux, r.m.s 1821.4 and luminous flux 74.98 lm.

Its illuminance map, and Polar Iso-Candela plot is show in Figures 22 and 23.

FIGURE 20 The illuminance map for R-cut with concave surface.

FIGURE 21 Polar Iso-Candela plot for R-cut structure with concave surface ($d = 0.25$ mm).
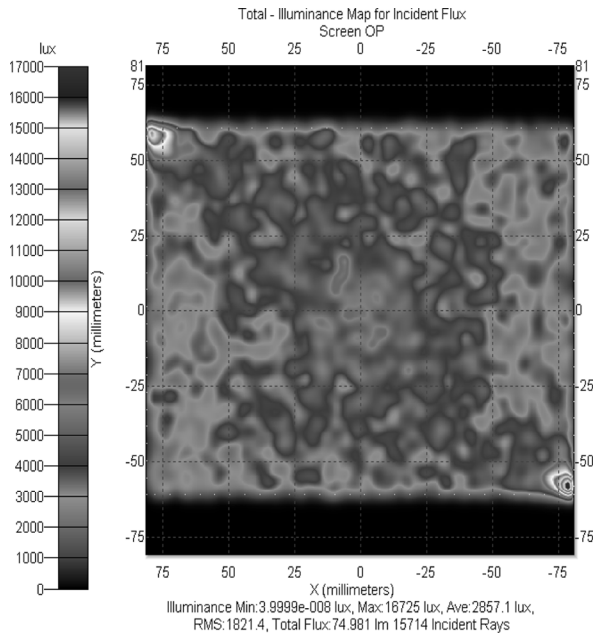
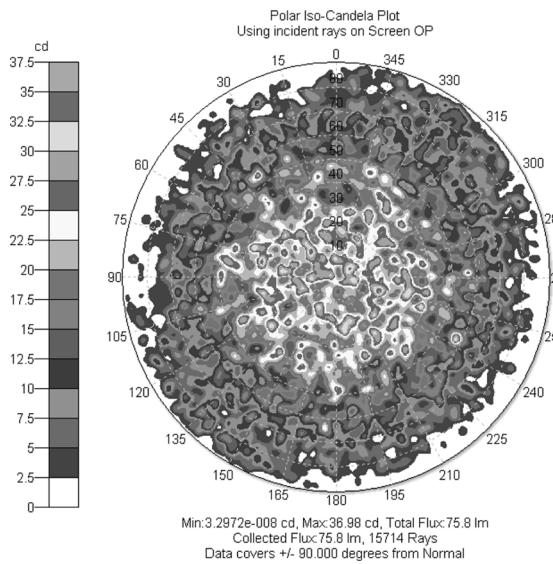**FIGURE 22** The illuminance map with R-cut and d = 2 mm, in z-direction.

FIGURE 23 Polar Iso-Candela plot with d = 2 mm.

CONCLUSION

With two 50 lm LEDs for light source, placed at two opposite corner. A LGP having R-cut (length 10 mm) for light incidence, a concave surface (r = 200 mm, d = 2 mm) on the top, and a dot pattern with dot radius 0.04 mm, dot to dot distance 0.2 mm at bottom, the back-light unit has an luminance 2857.1 lux, r.m.s 1821.4 and luminous flux 74.98 lm is obtained. The emission efficiency has increased from 53% (for CCFL light source) to 74% in this noble design.

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