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Uniformity Enhancement of LED Backlight Module Using Hollowed Triangular Prism Structure

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A brand new design concept is proposed in this paper. In order to increase the efficiency of light emission, a series of diffusion plates with different hollowed triangular prism structure is designed to guide the light toward to dark region. Tracepro software is used and the results of simulation show that the uniformity of such diffusion plate can be improved as high as 91%. Moreover, the efficiency and the brightness of the backlight module could also be obtained to be about 80% and 255 nits, respectively.

Keywords: backlight; LED; lightguide

INTRODUCTION

In the backlight module (BLM) of liquid crystal display (LCD), the use of cold cathode fluorescent lamp (CCFL) as light source is reducing because of its mercury environmental protection issue. In stead, the use of light emitted diode (LED) as light source for BLM is increasing. Most of medium to large size LCD using direct-viewed light source in bottom arrangement (Fig. 1), the high light uniformity becomes a problem. Because of LED is a point light source, governed by Lambert's cosine law $I(\theta) = I(0)\cos\theta$. The light uniformity becomes a serious and interesting studied topics in recent years. The wedge shape and curved shape of LGP had been studied to obtain the better light uniformity [1]. Chou and Lin [2], had studied that a concave surface of LGP and used two LEDs for light source.

A 74% emission efficiency had been obtained.The use of dot scattering center on the bottom of LGP with different dot size and density are

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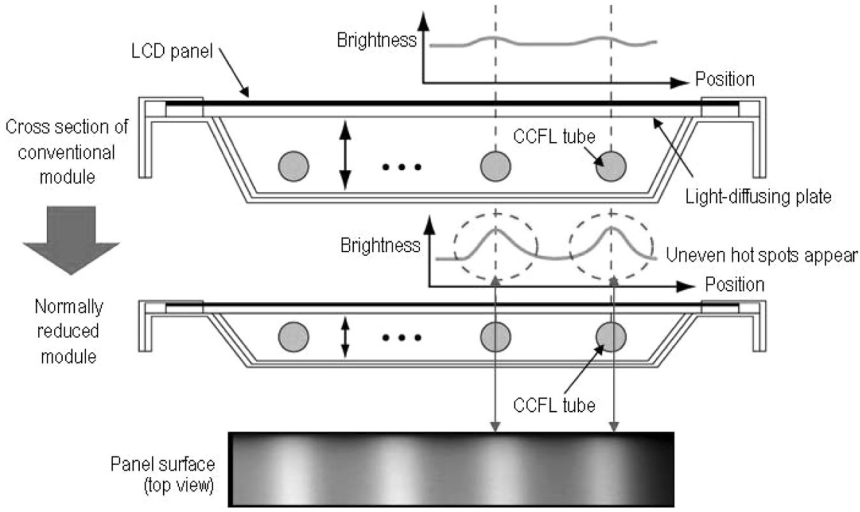

FIGURE 1 Cross section of direct-viewed light sources set-up for BLM.

also patterned [3,4], Ide'Mizuta *et al*. had used molecular dynamics redistribution method to improve the distribution of dot and effectively improves luminance uniformity [5]. Tagaya *et al*. [6,7] had used Monte Carlo method to simulation the dot scattering based on Mie scattering to obtain higher illuminance and uniformity. The use of a backlight with a polarzing light pipe making the black matrix on the TFT glass and color filter both reflective can also reduced the absorption of light by LCD was proposed by Tanase *et al*. [8].

There are side-viewed and direct-viewed LED backlights. In this paper, direct-viewed LED backlight used for large-size displays with high brightness is investigated. By utilizing the optical simulation software Tracepro, we develop a series of diffusion plate with different hollowed triangular prism structure. Such design has several advantages including reducing absorption, guiding light toward dark region and decreasing the thickness of diffusion plate, etc.

SIMULATION AND RESULTS

1. Set-Up

A 171×250 mm LCD is used and LEDs are in array set-up (Fig. 2) in bottom of BLM with 18 mm thickness. Reflectors are equipped around four sides and bottom of BLM for prevention of the leaking of light. We design 5 rows of LED array with space of 50 mm on the bottom surface

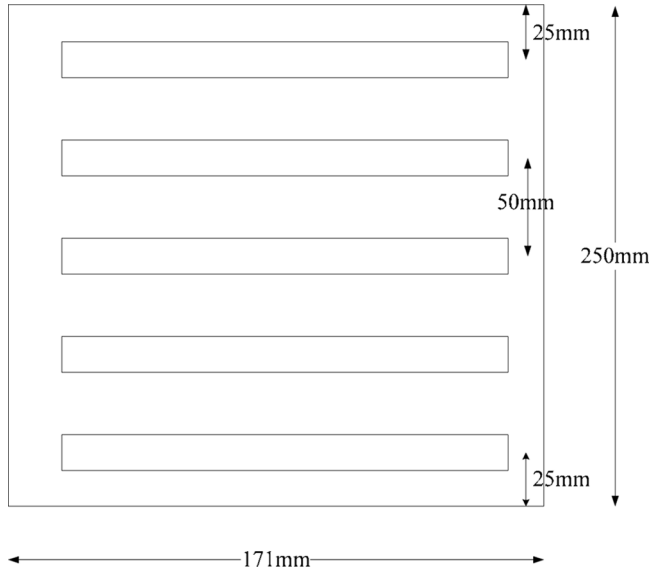

FIGURE 2 The 5 array LED set-up with dimension.

of backlight module. The distance between the first row of LED array and the backlight module is 25 mm. Moreover, the diameter and height of LED are set to be 2 mm and 4 mm, respectively. The distance between two neighboring LED is 15 mm in array and each array has 12 LEDs.

Each LED has luminous flux $\Phi = 30$ lm and 30,000 rays are used for each LED light tracing. A total 1800,000 light rays are used in simulation. The diffusion plate is made of Polymethyl Methacrylate (PMMA) with index of refraction = 1.49 and its thickness is 6 mm

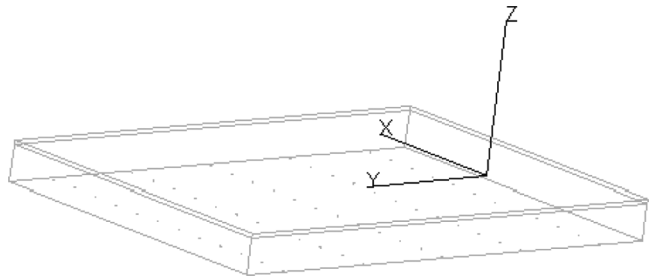

FIGURE 3 Diffusion plate without microstructure, the thickness of the diffusion plate and the BLM are 2 mm and 18 mm, respectively.

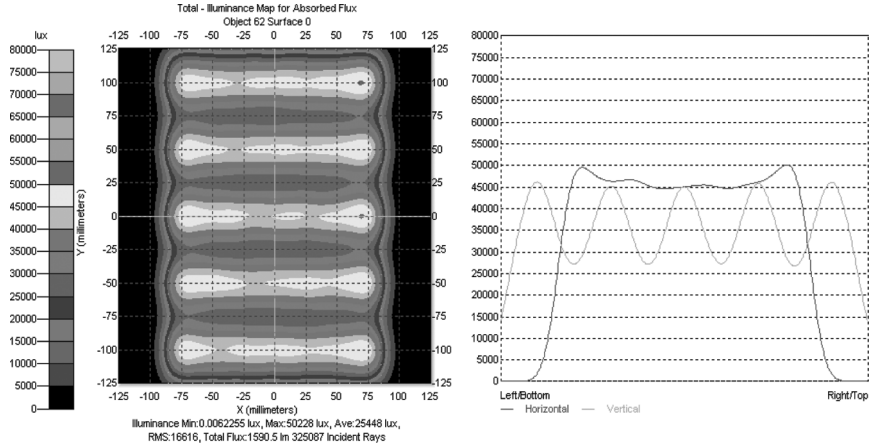

FIGURE 4 Illuminance map for diffusion plate without microstructure.

placing on the top of BLM. An optical simulation software Tracepro is employed. Finally, we set a detection surface by utilizing total absorption material on the top of diffusion plate. When the diffusion plate without any microstructure (Fig. 3), the illuminance map (Fig. 4) is clearly shown 5 rows of LED array on x-y plane of the backlight module. The uniformity and the emission efficiency of the backlight module are 53% and 88% respectively.

2. RESULTS

Case 1: Diffusion Plate with V-Shape Structure

In order to improve the uniformity of the backlight module, the diffusion plate should be designed to guide light toward dark region. First, we design V-shape structure on the bottom of diffusion plate. The schematic diagram and the parameter of the diffusion plate are shown in Figure 5. The illumination map (Fig. 6) shows the uniformity and the emission efficiency of the backlight module are 83% and 80%, respectively.

Case 2: Diffusion Plate with Hollowed Triangular Prism Structure

The improvement of uniformity from 53% to 83% proves the utilization of V-shape structure could guide light toward dark region. However, the 5 rows of LED array could be still observed since the

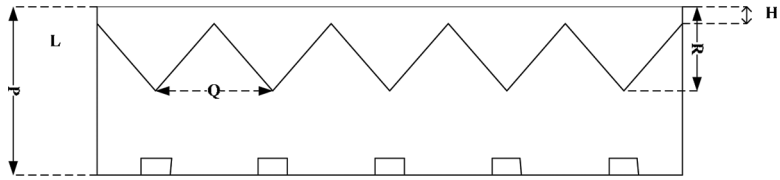

FIGURE 5 Cross section diagram of BLM with V-shape pattern diffusion plate and dimension (Q = 50 mm; R = 6 mm; H = 1 mm; P = 20 mm).

normal intensity of LED is relatively higher. In order to solve this problem, we propose further a hollowed triangular prism structure embedded in the diffusion plate to reflect the normally incident light to the dark region. The schematic diagram and parameter of the diffusion plate are shown in Figure 7. The illumination map (Fig. 8) shows the uniformity and the emission efficiency of the backlight module are about 79.3% and 83.6% respectively. Such result shows the utilization of hollowed triangular prism structure not only enhance the uniformity of backlight module, but also increase the emission efficiency due to the reduced absorption.

Case 3: Diffuser with Hollowed Triangular Prism and V Shape Pattern (Fig. 9)

The simulation result is shown in Figure 10 in which the light uniformity is raised to 91.5% and light efficiency is 79.5%.

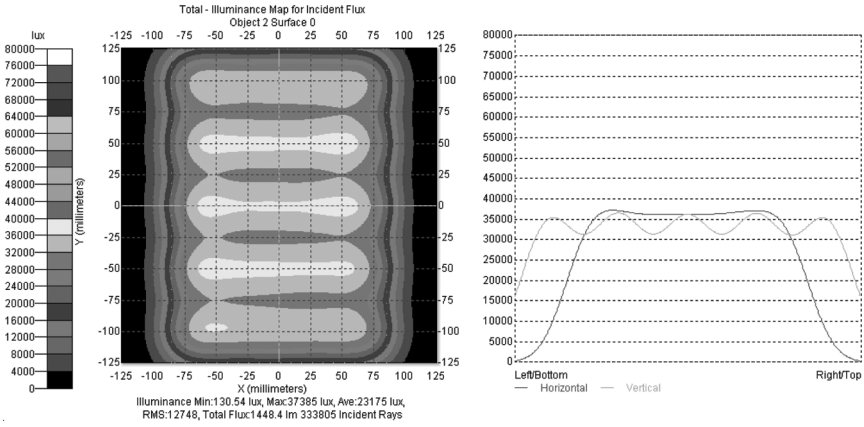

FIGURE 6 Illuminance map for diffusion plate with V-shape pattern.

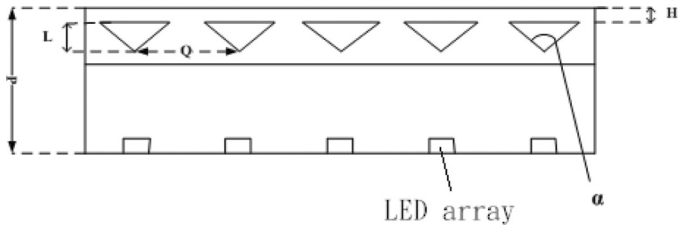

FIGURE 7 Cross section diagram of BLM with hollowed triangular prism structure diffusion plate dimension (L = 1.6 mm, H = 0.2 mm, Q = 50 mm, $\alpha = 120°$, R = 2 mm, P = 20 mm).

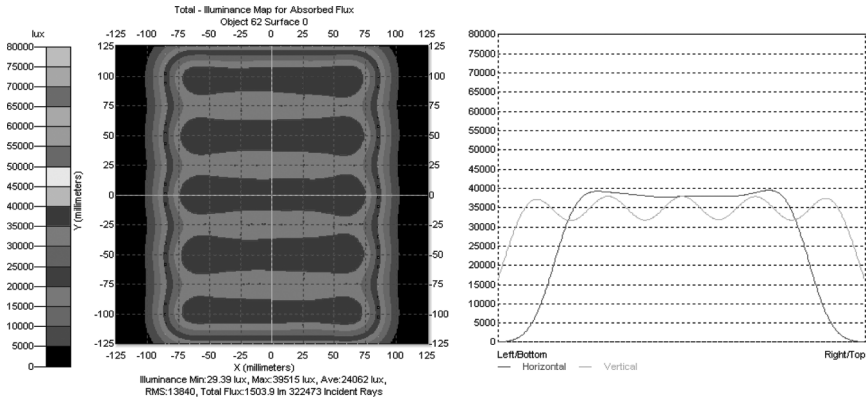

FIGURE 8 Illuminance map for diffusion plate with hollowed triangular prism structure.

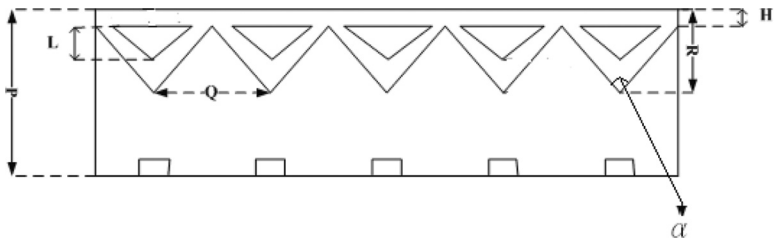

FIGURE 9 Cross section diagram of BLM with hollowed triangular prism structure and V shape pattern diffusion plate and dimension ($\alpha = 120°$; Q = 50 mm; R = 6 mm; L = 4 mm; H = 1 mm; P = 20 mm).

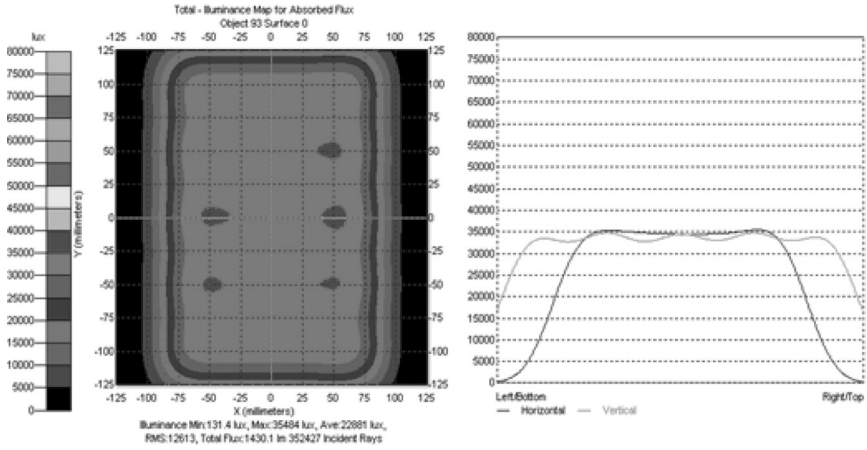

FIGURE 10 Illuminance map for diffuser with hollowed triangular prism structure diffusion plate and V shape pattern.

From the above preliminary simulations, the diffuser with hollowed structure and V shape pattern on the bottom improve the light uniformity. In order to carry out more detail study on different hollowed structure and different shape pattern, a series of different design and simulation have been carried out as following.

Type a. Diffusion plate with hollowed triangular prism and V shape pattern (Fig. 11).
Type b. Diffusion plate with hollowed semi-spherical column and V shape pattern (Fig. 12).
Type c. Diffusion plate with hollowed triangular prism structure and semi-spherical shape pattern (Fig. 13).
Type d. Diffusion plate with hollowed semi-spherical column and semi-spherical shape pattern (Fig. 14).

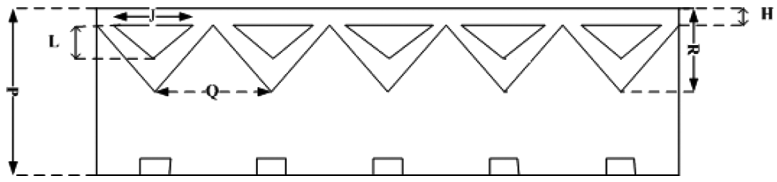

FIGURE 11 Cross section diagram of BLM with hollowed triangular prism structure and V shape pattern diffusion plate and dimension ($P = 20\,mm$; $L = 4\,mm$; $Q = 50\,mm$; $R = 7\,mm$; $H = 1\,mm$; $J = 8\sqrt{3}$).

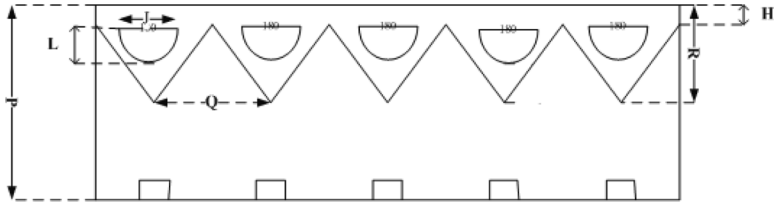

FIGURE 12 Cross section diagram of BLM with hollowed semi-spherical column and V shape pattern diffuser (P = 20 mm; L = 4 mm; Q = 50 mm; R = 7 mm; H = 1 mm; J = $8\sqrt{3}$).

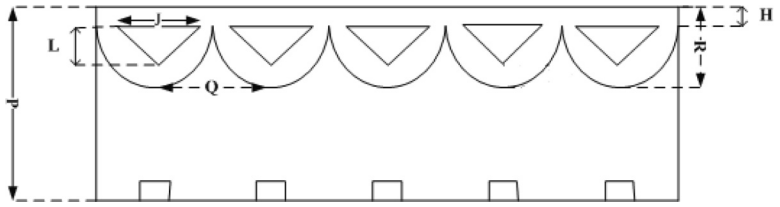

FIGURE 13 Cross section diagram of BLM with hollowed triangular prism structure and semi-spherical pattern diffuser(P = 20 mm; L = 4 mm; Q = 50 mm; R = 7 mm; H = 1 mm; J = $8\sqrt{3}$).

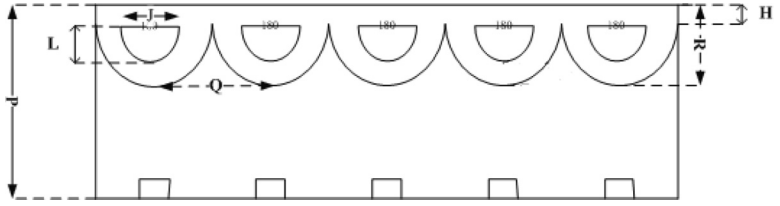

FIGURE 14 Cross section of BLM with hollowed semi-spherical column and semi-spherical pattern diffuser (P = 20 mm; L = 4 mm; Q = 50 mm; R = 7 mm; H = 1 mm; J = $8\sqrt{3}$).

LIST 1 The Light Uniformity and Light Efficiency for Different Structures of Diffuser

Structure	Uniformity %	Light efficiency %
a	88	77
b	84	78.3
c	86.5	77.5
d	85	75

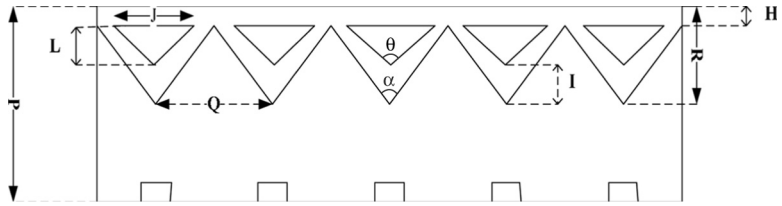

FIGURE 15 Cross section of BLM with hollowed triangular prism and V shape pattern diffusion plate with different dimension; P = 20 mm; L = 4 mm; Q = 50 mm: R = 6 mm, H = 1 mm, I = 1 mm, R = 7 mm, H = 2 mm, I = 1 mm; R = 8 mm, H = 3 mm, I = 1 mm; R = 9 mm, H = 4 mm, I = 1 mm.

The simulation result is shown in List 1, in which the light uniformity is highest (88%) for hollowed triangular prism and V shape pattern (type a structure). In order to reach the best uniformity for diffusion plate with different hollowed triangular prism and V shape patterns, the following designs with different diffusion plate thickness and V shape height is indicated in Figure 15. In which the angle α and θ will change accordingly, the simulation results are shown in List 2. The data in List 2 show the best light uniformity and light efficiency are No. 2 and 5 design with $\theta = 110^\circ$ and R = 6 mm and 7 mm diffuser thickness respectively. Figure 16 shown the illuminance map for No. 2 and Figure 17 shown the illuminance map for No. 5 design.

LIST 2 Light Uniformity and Light Efficiency for Different Diffuser Thickness(R) and θ

R \ θ	100	110	120
6 mm	1. Uniformity 91.5% Light efficiency 79.5%	2. Uniformity 95% Light efficiency 79.5%	3. Uniformity 91.5% Light efficiency 79.5%
7 mm	4. Uniformity 96.2% Light efficiency 75.6%	5. Uniformity 94.6% Light efficiency 79%	6. Uniformity 88% Light efficiency 77%
8 mm	7. Uniformity 95.1% Light efficiency 75.3%	8. Uniformity 88.5% Light efficiency 78.3%	9. Uniformity 85.4% Light efficiency 78.4%
9 mm	Uniformity 89.1% Light efficiency 75.1%	Uniformity 85.7% Light efficiency 76.1%	Uniformity 85.4% Light efficiency 78.3%

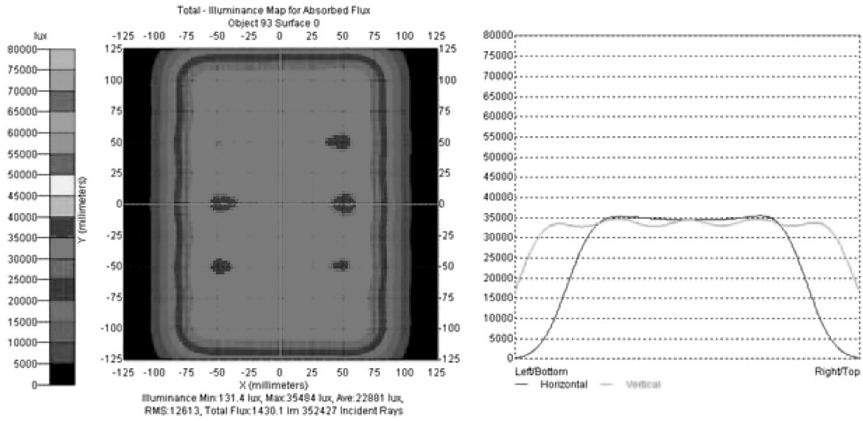

FIGURE 16 Illuminance map for diffusion plate hollowed triangular prism structure and V shape pattern and its dimension are R = 6 mm, $\theta = 110°$, H = 1 mm.

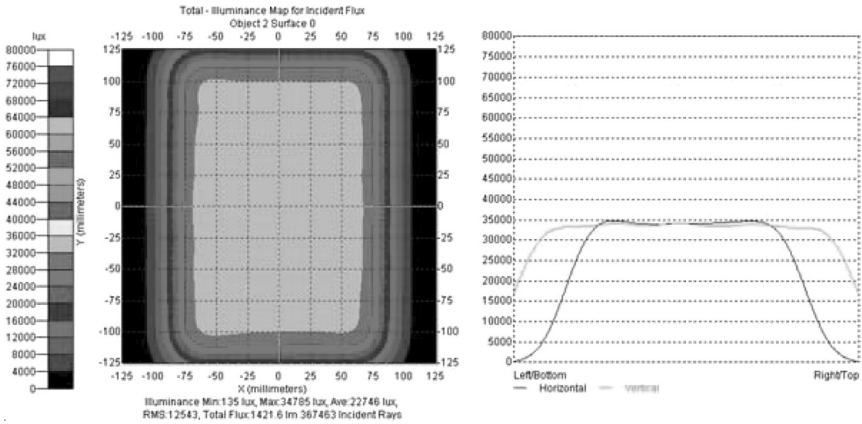

FIGURE 17 Illuminance map for diffusion plate with hollowed triangular prism structure and V shape pattern and its dimension are R = 7 mm, $\theta = 110°$, H = 2 mm.

CONCLUSION

It is found that the uniformity of BLM with hollowed triangular prism structure diffusion plate has raised from 53% to 79%. It is observed that the diffusion plate with hollowed structure can improve the light uniformity of BLM. Using different hollowed structure (triangular

prism and semi-spherical column) and diffusion plate with curved or V-shape bottom, the best light uniformity is obtained for diffusion plate with hollowed triangular prism and V-shape bottom. In order to obtain the highest light uniformity, different diffusion plate thickness and hollowed triangular prism angle have been used for simulation. The best result is thickness equal to 6 mm and 7 mm and hollowed triangular prism angle is 110° in which the light uniformity is 96%.

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