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# Design and optimization of a partial integrated backlight module

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A B S T R A C T

On account of the limitation of the fabrication technique for the total integrated light guide plate (LGP) we developed earlier with a reflective film coated on the bottom surface of LGP, is not compatible with the mature technique of coating reflective film in industry currently, in this paper, we propose a partial integrated backlight module (BLM) that the reflective film is separated from the LGP. Firstly, we optimize the unit structures on the top surface and the bottom one of the key component partial integrated LGP (ILGP), which are the aspheric semi-cylindrical micro-concentrator structure and the micro-prism respectively. Secondly, we establish the expressions that connect micro-prism distribution with the size of the partial ILGP. By using this set of expressions, a micro-prism distribution to make the luminance uniformity of the partial integrated BLM higher can be obtained. Finally, we apply the optimized micro-structures and the expressions to design a 5.0 inch partial integrated BLM. Simulation results show that the luminance uniformity reaches 91.14%, the energy efficiency, average illuminance and average luminance are 1.62, 1.63 and 1.29 times of those in the typical one respectively. The performance of the partial integrated BLM is greater than that of the typical one, which indicates that the partial integrated BLM proposed in this paper is feasible, and the micro-prism distribution expressions have important application value.

## 1. Introduction

A typical backlight module (BLM) is comprised of light sources, a reflective film (RF), a light guide plate (LGP), a diffusion film (DF) and double crossed brightness enhancement films (BEFs) [1]. Because of some disadvantages in the typical BLM, such as complexity of the device structure and excessive manufacturing processes [2], many research institutions have done lots of researches on integrated BLMs in order to reduce the thickness, simplify the structure and improve the performance. In 2003, Okumura et al. proposed an integrated LGP with a polymer containing spherical particles in micro-size [3]. In 2004, Feng et al. presented an integrated LGP with crossed micro-prism structures fused on the top and bottom surfaces [4]. In 2006, Chien et al. proposed an integrated LGP with micro-pyramids on the top surface of the LGP and micro-prisms on the bottom surface of the LGP [5]. In 2007, Lee et al. developed a single-sheet polydimethylsiloxane LGP having micropatterns with an inverse-trapezoidal cross section [6]. And in 2015, Wang et al. proposed a BLM that comprised a collimated light source and an integrated LGP with microstructures fused on the bottom and one of sections surfaces [7]. All of integrated LGPs mentioned above might be used less optical sheets or even got rid of optical sheets. However, the important performance parameters were not reported [4,5], the uncommon material [3,6], or light sources were used [7]. Currently, the common material of LGPs is polycarbonate (PC) or polymethyl methacrylate (PMMA), and the common light sources are light emitting diodes (LEDs). In 2013, Xu et al. reported an integrated LGP [8], into which the five sheets of the typical BLM were totally integrated, including of the RF. While, the concept of integration here includes that the RF was integrated into the integrated LGP, is not helpful in extending the design to the industry. In the current backlight industry, the RF can be massively produced and the fabrication technique is mature. Whereas, each piece of total integrated LGP needs to be coated with the RF individually on the bottom surface of the LGP, which is not in accordance with the massive replication process of LGP and might increase the cost.

Based on our early researches on the total integrated LGP and micro-nano optics [8–14], in this paper we propose a partial integrated BLM, which is suitable to the mature replication technology in the industry. The partial integrated BLM consists of light sources LEDs, a partial integrated LGP (ILGP) and a RF. The partial ILGP is integrated with other key optical sheets and the RF is separated. Because of the air space between the RF and the partial ILGP, it can be concluded from the perspective of optical waveguide that the propagation of the light in the partial BLM will be changed substantially. Compared with the total

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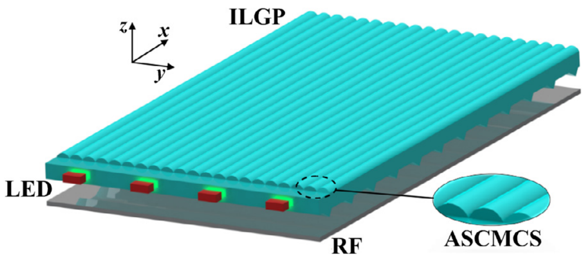


Fig. 1. Diagram of the partial integrated BLM.

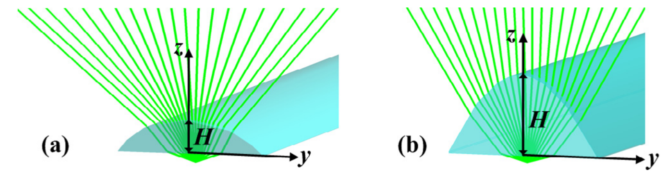


Fig. 2. Diagram of ASCMCS unit on the top surface of ILGP. (a) Before optimization. (b) After optimization.

ILGP proposed before, the partial ILGP is not only different in structure, but also the relevant micro-structures fused on the surfaces of the partial ILGP need to be redesigned and optimized to satisfy the performance requirements. It is of great significance to develop a partial ILGP that it not only can perform well, but also can be produced by current fabrication technology. In this paper, we optimize and design the micro-structure unit fused on the top surface of the partial ILGP, the base-angles of the micro-prisms fused on the bottom surface of the partial ILGP. The relationship expressions between micro-prism distribution and the size of partial ILGP are also proposed, which has not been reported at home and abroad yet. By using this set of expressions above, the micro-prism distribution that makes the luminance uniformity of the partial integrated BLM higher is attained directly. Afterwards, by adjusting above distribution slightly, the luminance uniformity can reach higher than 90%. The partial integrated BLM is set up by the software Lighttools after we obtain the optimized design parameters. The simulation results show that the performance parameters in the partial integrated BLM we designed are greater than those in the typical one.

## 2. Design and optimization of partial integrated BLM

As shown in Fig. 1, the partial integrated BLM consists of light sources LEDs, a partial ILGP (hereinafter ILGP) and a RF. The top surface of the ILGP is fused with the aspheric semi-cylindrical micro-concentrator structure (ASCMCS) arrays, the bottom surface of the ILGP is fused with the micro-prism arrays which are matched with the ASCMCS arrays on the top surface [8,12], and the RF is placed under the ILGP.

### 2.1. Optimization of micro-structure unit on top surface of ILGP

There are no structures on the top surface of the LGP in the typical BLM, thus the BEFs are necessary to concentrate rays effectively. In the partial integrated BLM proposed in this paper, the top surface of the ILGP is fused with the micro-concentrator structures to concentrate the output rays. So, it is able to be less dependent on the BEFs. Compared with the total ILGP we reported in 2013 [8], the RF in the partial integrated BLM is placed beneath the bottom surface of the ILGP instead of being coated on the bottom surface, which makes the micro-prisms on bottom surface less effective in converging rays. Therefore, the converging function is more dependent on the micro-structures of the top surface. In order to enhance the partial integrated BLM's capacity for converging rays, we need to further optimize the micro-structure unit on the top surface of the ILGP.

According to our previous researches about the micro-structures on the top surface of the total ILGP [8], the ASCMCS unit is an effective structure on ray concentration, as shown in Fig. 2(a). The bottom width of the ASCMCS unit is 180 μm, and the profile function is shown in Eq. (1).

$$z(y) = H - \left[\frac{cy^2}{1+\sqrt{1-(1+k)c^2y^2}} + \alpha_1 y^2 + \alpha_2 y^4 + \alpha_3 y^6 + \alpha_4 y^8 + \alpha_5 y^{10} + \alpha_6 y^{12}\right] \quad (1)$$

where, $y$ denotes the coordinate of the width which is the horizontal axis. $z$ denotes the coordinate of the high which is the vertical axis. $H$ denotes the central highness of the micro-structure unit, as shown in Fig. 2. $c$ is the curvature, $k$ is the conic and $\alpha_1 \sim \alpha_6$ are the coefficients in Eq. (1). The initial coefficients in Eq. (1) are shown in Table 1 [8].

As the ASCMCS has decent converging function, we choose it as the initial model to be optimized in this paper. We set the optimization goals as follows. Firstly, the rays should be mostly guided towards the normal direction [15,16]. Secondly, the energy on the receiver surface should be distributed evenly. By the method of iterative algorithm, the diagram of the optimized micro-structure unit is shown in Fig. 2(b), and the optimized coefficients in Eq. (1) are shown in Table 2. When rays traced through the optimized ASCMCS, the total energy received by receiver is 1.38 times of that in the initial model, which indicates that the optimized ASCMCS has better capacity for converging rays than the initial model. The green lines in Fig. 2 display the ray tracing result of a point light source with a divergent angle of 150 degrees in the y–z plane. It shows that the divergent angle in the optimized ASCMCS is smaller than that in the initial model after tracing.

### 2.2. Relationship between average luminance and the base-angles of micro-prism on bottom surface of ILGP

The two base-angles of the micro-prisms fused on the bottom surface of the ILGP have considerable influence on the luminance of the integrated BLM [17,18]. In order to achieve a better outcome, the relationship between the micro-prism's base-angles and the average luminance is discussed.

The top surface of the ILGP in the partial integrated BLM is fused with the optimized ASCMCS arrays discussed above. The micro-prism arrays are fused on the bottom surface of the ILGP, and the bottom width of the micro-prism unit is 49 μm. There are two types of micro-prisms on the bottom surface including the concave micro-prism and the convex one, as shown in Fig. 3 [8]. Where, $\alpha$ is the micro-prism base-angle closer to LEDs, and $\beta$ is the one farther to LEDs. According to the distribution law of the micro-structures on the bottom surface of LGP, the micro-prism arrays are arranged from sparse to dense along the direction far away from the light sources. When the relationship between the micro-prism base-angles and the average luminance of the output light is analyzed in this section, the micro-prism distribution is fixed based on above distribution law.

PMMA is used as the material of the ILGP, which is commonly used in the industry. The size of the ILGP model is 116.3 mm × 68.7 mm × 0.5 mm. 10 LEDs with Lambertian intensity distribution are equally spaced at the shorter edge of the ILGP as light sources. The size of each LED is 3.8 mm × 0.6 mm × 1.2 mm, where the emitting area is 2.5 mm × 0.4 mm and the distance between the adjacent LEDs is 6.56 mm. The luminous flux and the maximum emitting angle of each LED are 6.6646 lm and 110°, respectively. The reflectivity of the RF is 95%. The configurations mentioned above are selected from the practical cases in industrial applications.

On the basis of the previous researches [17], firstly $\beta$ is set as 50°, and the relationship between average luminance and $\alpha$ is analyzed when $\alpha$ is changed from 10° to 90°. The simulation results from Lighttools are shown in Fig. 4(a). Fig. 4(a) shows that the average luminance