Design of LED Collimating Optical System

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Abstract. This paper presents a design method of collimating optical system. LED has the characteristics of small size and long life. The performance of the optical system can be improved. A design of regular arrays is put forward in this paper. And this design can decrease the divergence angle through to the LED light source for the secondary light distribution. Besides the construction will be miniaturized and High-effectived.

Keywords: LED · Free-form surface · Optical system

1 Introduction

Collimating optics as the foundation of optical design has wide application prospect.

The design of this optical system consults the standard specifications and investigates the current optical system structure. When making secondary optics design for LED, the light is adjusted by optimization algorithm. The 8 baseplates are arranged with equal interval. The light source meets color requirements of light source for pharos.

2 Standard of Design

According to GB12708-91-The Colours of Light Signals on Aids to Navigation, light source has white, red, green and yellow four colors. The limit equation for the chromaticity range is shown in Table 1.

Table 1. The color range

Light color	White	Red	Green	Yellow
Limit	Purple color Blue limit Green limit yellow limit	Extremely red limit White limit Red limit	Yellow limit White limit Blue limit	Red limit White limit Green limit
Boundary equation	y = 0.047 + 0.762z x = 2.85 y = 0.150 + 0,640x x = 0.440	y = 0.290 y = 0.990 y = 0.320	y = 0.800 − x y = 0660 + 1.600z y = 0.5 − 0.500z	y = z − 0.170 y = 0.950 − 0.930z y = z − 0.120

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According to the Installation Specification of Pharos, it can be known that the pharos which were arranged at different heights can be seen from the every direction of object contours.The flicker frequency floats within the range of 20 times/min to 70 times/min.

3 Optical System Design

The optical system of pharos in this design is adopted by LED as the light source, the design use 8 baseplates toward 360°. Each baseplate has one yellow, green, red and white four light source respectively. Only one of four lights shining for each time on each baseplate, As shown in Fig. 1.

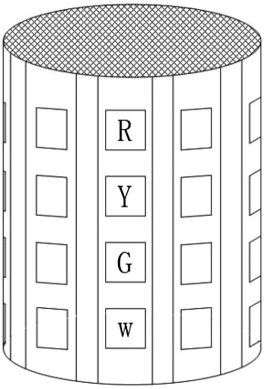


Fig. 1. Structure of pharo

The technical index of LED pharos are shown in Table 2:

Table 2. The technical index of LED pharos

Power	Light intensity	Frequency	Divergence angle	Light source	Color of light	Protection grade
20 W	4000 cd	30 times/min	10°	LED	R, G, Y, W	IP65

According to Snell and total reflection theory, the optical path graph of the lens is analyzed as shown in Fig. 2.

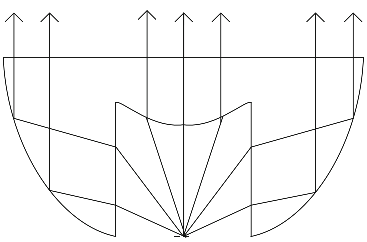


Fig. 2. Profile map

When the internal light exit in the way of collineation, the mathematical relationship between incident ray and emergent ray is shown in Fig. 3

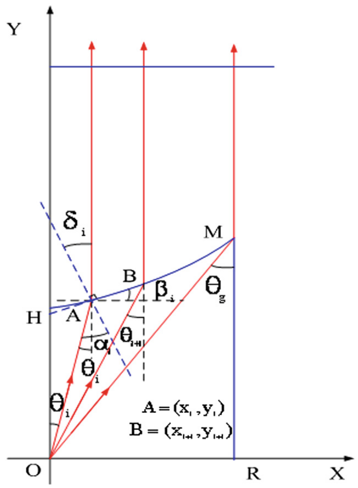


Fig. 3. Internal light rout

In Fig. 3, the light from LED chip O point via A point is refracted and then collimated exit. According to the geometric relationship and Snell theory, it can be got the following trigonometric function relationship:

$$y_{i+1} = y_i * \frac{\tan\theta_i \sin\theta_i + \cos\theta_i - n}{\tan\theta_{i+1}\sin\theta_i + \cos\theta_i - n}$$
$$x_{i+1} = \tan\theta_{i+1} * y_{i+1}$$

When the sides light exit in the way of collineation, the mathematical relationship of light is shown in Fig. 4.

In Fig. 4, the light exit from light source O is refracted through the interior concaved lens and then collimatly exit after producing total reflection on the side. According to the geometric relationship and Snell law, it can be got the following trigonometric function relationship.

$$[\tan\theta'_{i+1} - \tan(\frac{\theta'_i}{2} + \frac{\pi}{4})]x_{i+1} = [\tan\theta'_i - \tan(\frac{\theta'_i}{2} + \frac{\pi}{4})]x_i$$
$$- (\tan\theta_{i+1} - \tan'_{i+1} - \tan\theta_i + \tan\theta'_i)x_0$$

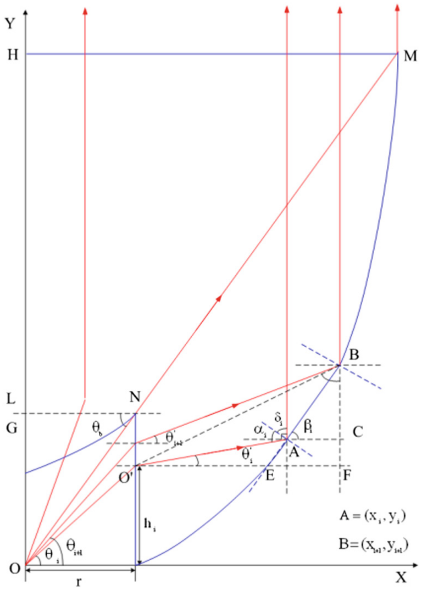


Fig. 4. Side light route

Figure 5 is a solid model:

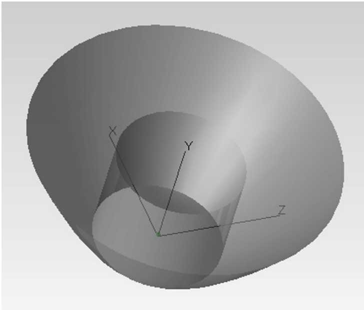


Fig. 5. Solid model of freeform lens

4 Result Analysis

The color of the identification signal plays an important role. Because signal with different colors conveys different meanings.

The optical signal color chroma range is shown as Fig. 6.

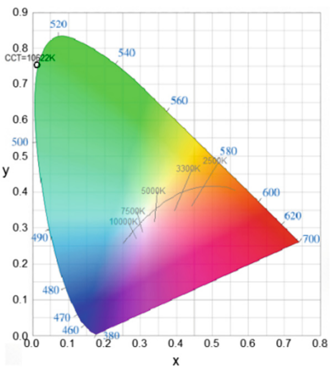
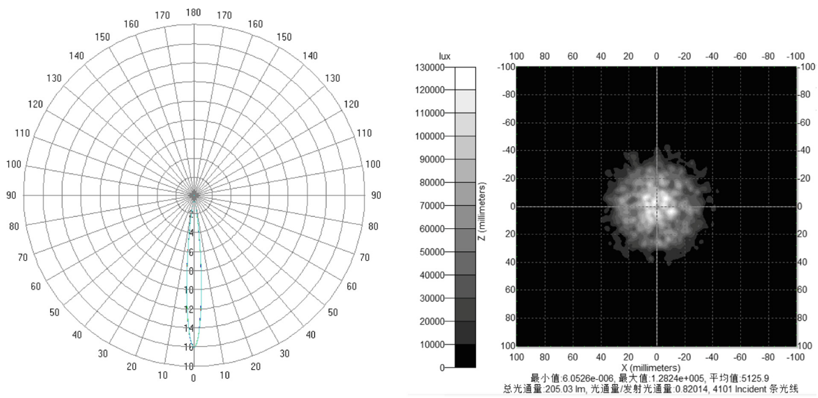


Fig. 6. Chromaticity coordinates of green

When the wave length is 510 nm, the chromaticity coordinate (0.027, 0.730) meets the specification 《GB12708-91》. Besides, the other three colors also meet the requirements.

The collimate light distribution can improve the utilization rate of light, reduce energy loss and enhance the transmission distance.

The simulation result is shown as below, The distribution angle is 10° and the spot diameter is 40 mm. From the light distribution curve, it can be seen that the light is collimated very well in space (Fig. 7).



a Light Distribution Curve **b** Illuminance Maps

Fig. 7. Light distribution curve and illuminance maps

5 Conclusion

In this paper, the optical module of LED pharos is designed in the way of optimization algorithm. Combined with the standard specifications, a method of array is put forward. The luminous flux of single LED light source is 250 lm and the luminous efficiency is

100 lm/w. A way of iterative analysis is put forword in distribution design. It can be known that the divergence angle of light distribution curve is 10°, which achieves better simulation result.

References

1. Yuncui, Z.: Research of three color lighting-emitting diode illumination system for digital micro-mirror device. J. Lighting Eng. **21**(3), 56–58 (2010)
2. Xiaohua, D.: Application and prospects of LED in navigation mark. Mar. Traffic Eng. **12**, 89–95 (2000)
3. Chen, F., Wang, K., Qin, Z.: Design method of high-efficient LED headlamp lens. Opt. Express **18**(20), 20926–20938 (2010)
4. Zhao, S., Wang, K., Chen, F.: Lens design of LED Searchlight of high brightness and distant spot. J. Opt. Soc. Am. A **28**(5), 815–820 (2011)
5. Chen, J., Wang, T.: Freeform lens design for LED collimating illumination. Opt. Express **20** (10), 10984–10995 (2010)
6. Ries, H., Muschaweck, J.: Tailored Freeform Optical Surfaces. J. Opt. Soc. Am. A **19**(3), 590–595 (2002)