Proceedings of Engineering and Technology Innovation, vol. 2, 2016, pp. 01 - 03

Optical Design of Direct Projection Bicycle Light

Hsuan-Jung Tsai*, Tsang-Yen Hsieh, Jyh-Liang Wang

Department of Electronic Engineering, Ming Chi University of Technology, New Taipei City, Taiwan.

Received 01 February 2016; received in revised form 15 March 2016; accepted 03 April 2016

Abstract

Optical lighting systems usually demand specific illuminance distributions to comply with regulatory requirements for various applications. This study demonstrates an optical design of bicycle light integrated with a special Fresnel lens and a reflector. To enhance the light intensity, the proposed bicycle light adopts direct projection rather than reflection. The Fresnel lens is used to concentrate light and achieve the specific distribution of illuminance. The reflector provides a parabola reflective surface and reduces the divergence of light to greatly cast out parallel light, which improves the illuminance. For optimum case, the simulation is based on the total LED power of 180 lm, and the optical power is analyzed as 85 lm with a distance of 10 m away from the bicycle light. The illuminance distribution of bicycle light and cut-off line can meet the requirements of German StVZO regulations.

Keywords: Fresnel lens, bicycle light, Reflector, direct projection, StVZO

1. Introduction

Bicycle light provide people with safe riding at night. It requests enough brightness on the road and should avoid the light radiation to the people's eye. Therefore, the optical design with cut-off line is important and indeed necessary. German road traffic licensing regulations (Germany StVZO regulations) clearly define the use of bicycle safe and bicycle lighting requirements as following [1]

(1) At least 20 lux in HV, the maximum illuminance Emax shall be found at this point. If Emax is found lateral to HV, its value shall not exceed 1.2 times the value of HV.

(2) Within the range delimited by an angle of 4° to both sides starting from HV up to and including point L1 respectively R1 as well as 1.5° below HV up to and including point 2: at least half of the maximum illuminance Emax.

(3) Up to 5° below HV and between point 2 and point 3 including the latter: at least 2.5 lux and from there 4° to the left and to the right up to and including the points L5 respectively R5: at least 2.0 lux.

(4) In the horizontal plane 3.4° above HV and beyond (zone 1): not more than 2.0 lux.

Optical design of bicycle light can usually classified as reflective mode and direct mode. Reflective mode requires a reflective apparatus. Direct mode uses the convex lens and forms optical imaging or non-imaging depending on the application. In this study, a direct projection bicycle light integrated with a reflector is considered and investigated due to the better light efficiency.

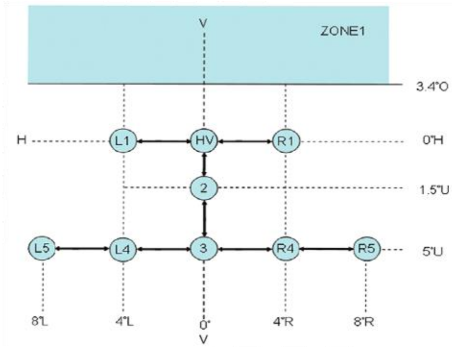

Fig. 1 The illustration of Germany StVZO regulations [1]

2. Method

The requirements and constraints of optical design are based on the Germany StVZO regulations. The regulations require power consumption of 6.2W at 12V. The luminous flux of light source embedded in headlights should exceed a value of 42 lm at test voltage. The required illuminance must correspond to the guideline shown in Fig. 1.

*Corresponding author. Email: pot.martian@gmail.com

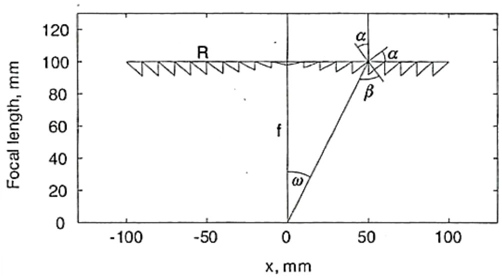

Fig. 2 The Fresnel lens designed with inward grooves facing [3]

A typical imaging Fresnel lens with inward grooves facing has an analytical solution indicated by Tver'yanovich [2]. The structure of Fresnel lens will be performed and based on the creative design methodology process. In accordance with Fig. 2, three equations can be set up to describe the lens. The prism angle α is the goal of a simulation written as [2-3], where n is a material medium, ω is divergence angle of light, α is light emission angle, β is the sum of α and ω, R is lens radius, and f is lens focal length.

$$n \sin \alpha = \sin \beta \quad (1)$$

$$\tan \omega = \frac{R}{f} \quad (2)$$

$$\beta = \alpha + \omega \quad (3)$$

3. Simulation and Result

The optical characteristics of bicycle light are designed to fit German StVZO regulations. 3D modeling and components of the proposed bicycle light, which is equipped a commercial LED lamp (Cree Xlamp XP-G2) as the light source. A specific Fresnel lens is adopted in the optical design of bicycle light. The Fresnel lens combines two focal points together to concentrate light and presents a rectangle distribution of illuminance, shown in Fig. 3.

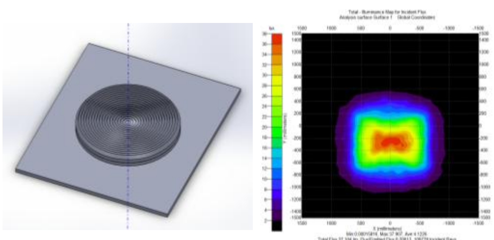
Fig. 3 (a) 3D CAD of Fresnel lens, and (b) the simulated illuminance distribution of the LED lamp with the specific Fresnel lens

The simulated illuminance distribution of the LED lamp with the specific Fresnel lens only provide central illuminance with rectangle shape, and does not extend the illuminance distribution to reach the requirements of L1 and R1. Thus, the optical design of bicycle light combined with Fresnel lens cannot fit German StVZO regulations. Moreover, a reflector is proposed to improve the optical design. The reflector provides a parabola reflective surface and reduces the divergence of light to greatly cast out parallel light, revealed in Fig. 4. It evidently indicates that the simulated illuminance distribution can be coherent with the real illuminance of projection.

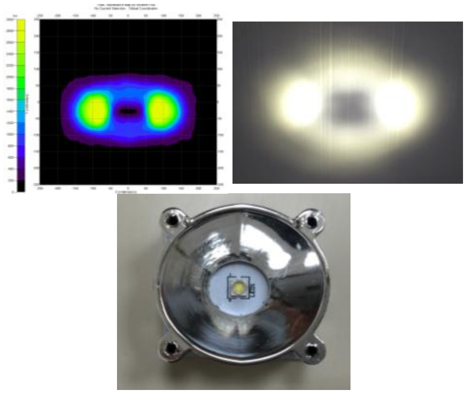
Fig. 4 (a) simulated illuminance distribution of the LED lamp with a reflector, (b) the real illuminance of projection with a distance of 1 meter, and (c) the reflector entity

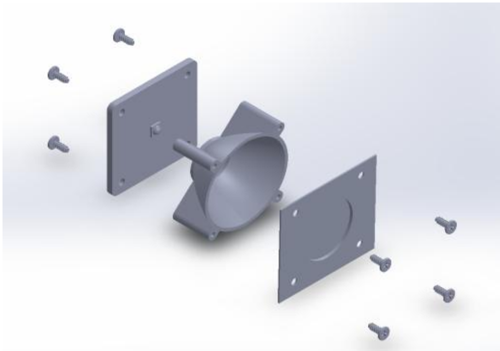
Fig. 5 Schematic mechanisms of direct projection bicycle light

Fig. 5 gives the final design of direct projection bicycle light. The design combines the specific Fresnel lens and reflector. The combination demands some modulations of the physical dimensions to achieve the optimum simulation. By the trial of optical simulation to fine tune the design of bicycle light, an optimum illuminance distribution can be made. Fig. 6 demonstrates the simulation result of the optimum design. The simulated illuminance distribution is similar as an extended rectangle and in compliance with the requirements of Germany StVZO regulations.

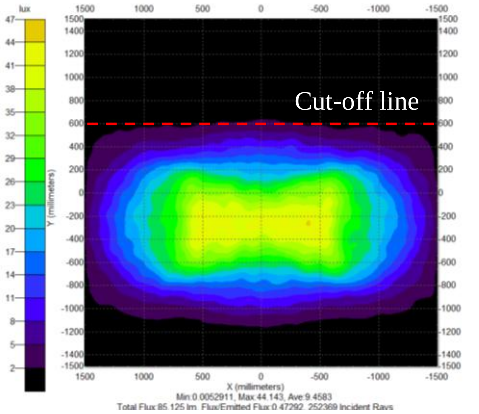

Fig. 6 Simulated illuminance distribution of the proposed direct projection bicycle light

4. Conclusions

A direct projection bicycle light is proposed in this research. The optical design of bicycle light is integrated with a special Fresnel lens and a reflector. The Fresnel lens combines two focal points to concentrate light and achieve the specific distribution of illuminance. The reflector provides a parabola reflective surface and reduces the divergence of light. The simulated illuminance distribution of bicycle light and cut-off line can meet the requirements of German StVZO regulations.

References

[1] Road traffic licensing regulations, Germany: Government Printing Office, 2012.

[2] E. V. Tver'yanovich, "Profiles of solar-engineering Fresnel lenses," Gelioteknika, vol. 19, no. 6, pp. 31-34, 1984. Translated into English in Applied Solar Energy, vol. 19, no. 6, pp. 36-39, 1984.

[3] R. Leutz and N. Suzuki, Nonimaging Fresnel Lenses, Paris: Springer, May 2001.