LED Floodlight Optical System Design

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Abstract. According to the requirements of this design, a new type of lens was designed. The uniformity of illumination on the two walls was 0.83 and 0.64 respectively, which solved the problem that one wall surface was basically no light when the traditional wall washer illuminates the two walls. The light source is selected from the CREE XM-L2 type lamp bead with a power of 10 W. In this paper, the cutting method is used as the design idea of the free-form optical system, and the secondary optical design of the LED floodlight optical system is carried out.

Keywords: Uniformity of illumination · Cutting method · LED flood light

1 Introduction

With the development of science and technology, LED lighting fixtures are increasingly used by people. In order to get better lighting effects, it is indispensable for the optical components to re-adjust the light. In order to get better lighting effects, the researchers immediately proposed the concept of free-form surface illumination, in order to solve the problems that traditional lighting optical systems can't solve. The free-form surfaces themselves do not have specific mathematical expressions, each of which is derived independently, so it can be considered that many surface patches are constructed under conditions that satisfy a certain continuity. Thanks to its good local operability, it is easy to optimize the design of the system later. As a result, the design freedom of the free-form surface is extremely high, and the distribution of light energy can be flexibly controlled to meet different lighting requirements. Replacing conventional surfaces with free-form surfaces as optical systems can accelerate the development of new lighting applications. At present, the mainstream methods for optical system design include cutting method, partial differential equation solving method, synchronous multi-surface solving method and mesh dividing method. This paper designs and analyzes the lens design process for the cutting method [1].

2 Design Principle

The lens busbars designed in this paper are designed for one plane and become a lens model through multiple iterations. Therefore, the design of the three-dimensional angle problem of the lens can be simplified to the two-dimensional angle problem of the lens.

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The initial coordinate point (x0, y0) of the curve and the normal vector N0 and the tangent (unit) vector T0 are obtained from the actually required lens aperture size. The angle between the light emitted by the light source and the coordinate axis y axis is θ1, and the light is considered to intersect the tangent vector T0 at (x1, y1) as the second discrete point on the free curve bus. The normal vector N1 and the tangent vector T1 of the intersection are determined by Huygens' theorem. Considering the light from the light source and the angle θ2 of the coordinate axis y2, the third discrete point coordinate (x2, y2) and the normal vector N2 and the tangent vector T2 can be obtained by the above principle. The analogy can obtain the discrete point data set {(xi, yi)} of the optical system, the set of normal and tangent vectors {Ni, Ti}, and the obtained discrete points are successively connected to obtain the target lens bus [2] (Fig. 1).

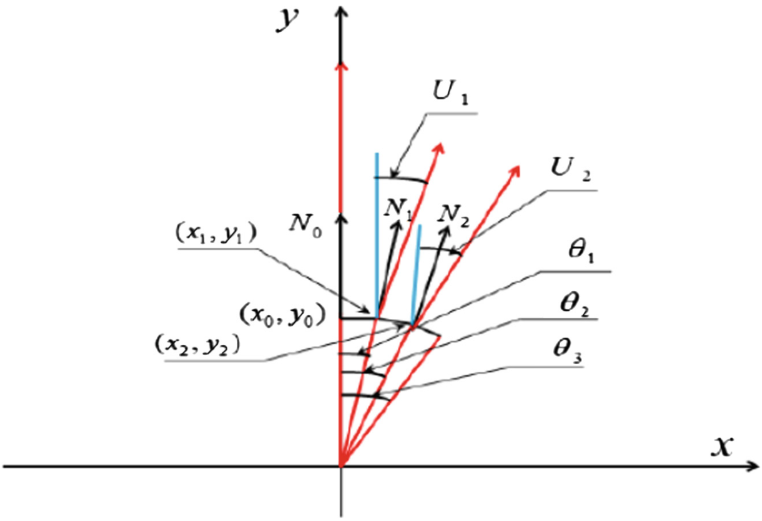
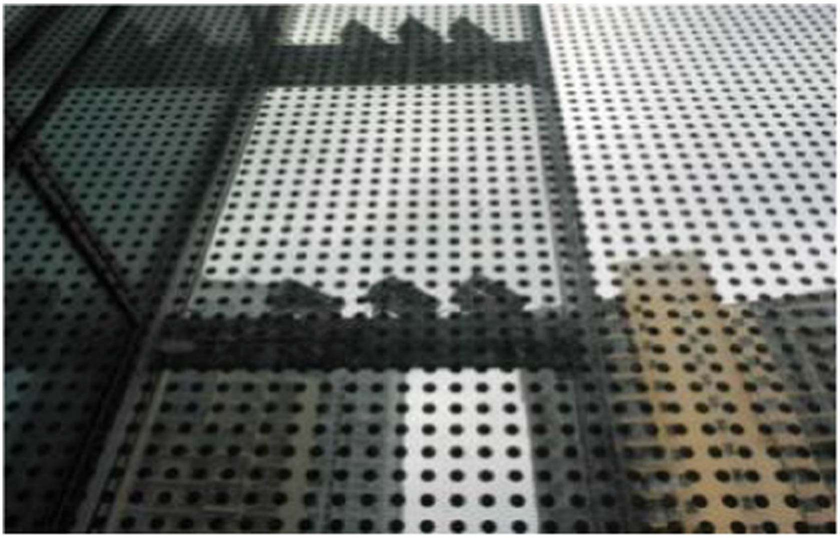


Fig. 1. Schematic diagram of the cutting method

The above design ideas exist in the recursive relationship of the optical system discrete point data set {(xi, yi)}, the normal and the tangent vector set {Ni, Ti}; the refraction surface recursive relationship of the lens optical system can be derived from the Huygens theorem vector form inferred.

3 Design Goals

With the increasing progress of LEDs, traditional optical systems can not meet the lighting effects of LED lamps, so the design of free-form optical systems is increasingly needed. LED floodlights are widely used in exterior lighting of buildings. Because the light distribution design of ordinary light-transmitting lamps can not meet the requirements of uniformity of illumination of special walls, this design combines



(a) Lamp placement position bottom view

(b) Lamp placement position top view

Fig. 2. Luminaire placed real scene

specific examples to analyze multiple floodlights simultaneously. In the process of use, the influence of illumination is optimized to obtain a half-cut LED floodlight optical system [3] (Fig. 2).

Among them, the technical requirements are shown in Table 1.

Table 1. Technical requirements

Request detail	Parameter value
Type of lamp	LED flood light
Lighting fixtures for each floor	2
Lamp manufacturer	CREE
Rated voltage	AC220V
Protection level	IP67
Average illumination	90lx
Illumination uniformity	≥ 0.6
Single light flux	3000l m
Floodlight mounting bracket length	1 m
Irradiation range	4.5 m * 2.4 m
Lamp and wall distance	1.5 m
Power	10 W

The lighting area of the luminaire is shown in Fig. 3. Figure 3(a) is a plan view of the building, and the B side of the A side is an area requiring illumination. Figure 3(b) shows the area that the DIAlux software simulates that the building needs to be illuminated. At the same time, the wall of the n layer will not only be affected by the wall washer, but also by the wall washers of the n − 1 layer and the n + 1 layer. So this analysis simulates 3 floors and takes the middle floor as the test area [4].

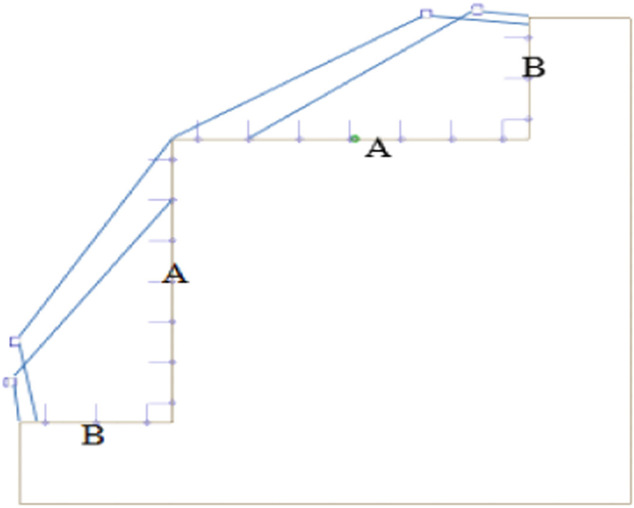
According to the illumination area division of Fig. 3, it can be understood that the luminaire needs to uniformly illuminate the wall of 4.5 m * 2.4 m at a distance of 1.5 m from the wall of the B wall. Therefore, the light emitted by the LED chip needs to be re-adjusted by the lens [5].

4 Designing Process

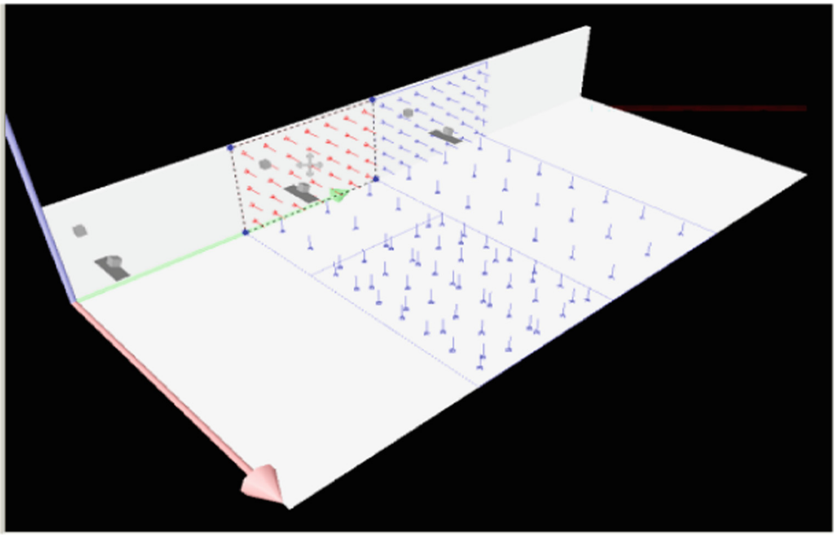
For the wall lighting requirements, find the appropriate light source XM-L2 on CREE's official website. The light source can output a luminous flux of 1052 lm. The following is a suitable light distribution curve for the luminaire found on the market [6]. The size chart of the lamp is shown in Fig. 4.

In summary, the luminaire needs to uniformly illuminate a wall of 4.5 m * 2.4 m at a distance of 1.5 m from the wall of the B wall, and the luminaire is on one side of the wall. The target light distribution curve is shown in Fig. 7. It is necessary to reduce the illumination by the corner of the wall and increase the illumination angle not by the corner of the wall so that it can illuminate farther [7].

The XYZ coordinate axis is established with the LED as the origin of the coordinate axis. As shown in Fig. 5, the hemisphere in the figure is a lens to be designed. The illumination angles in the x-axis direction are not the same, and the illumination angles in the y-axis direction are the same but are small [8].



(a) Lighting range of lamps



(b) Lighting simulation of building

Fig. 3. Simulated building

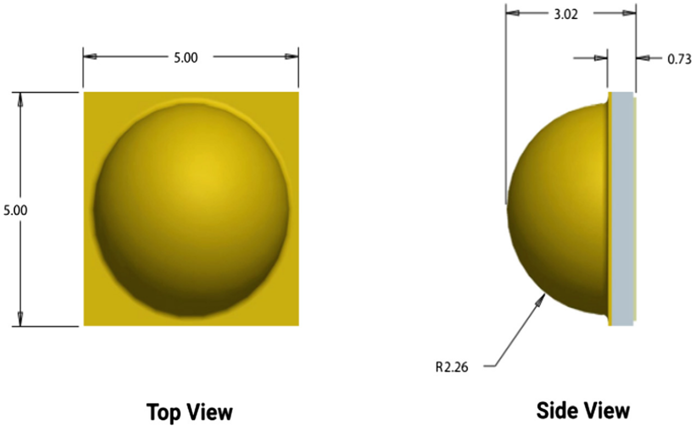


Fig. 4. XM-L2 size chart

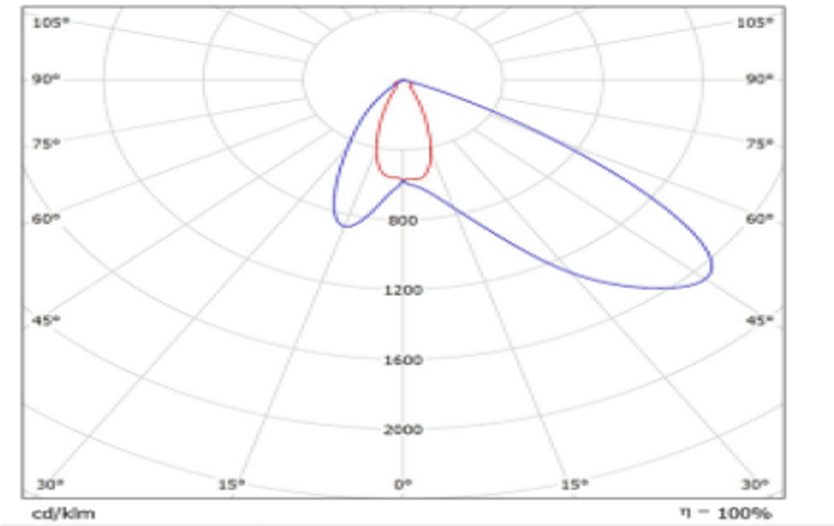


Fig. 5. Target light distribution curve

Finally, the maximum illumination angles in the four directions are ranked 60°, 23°, 30°, and 23° in a clockwise direction. The lens model is shown in Fig. 6 [9].

After the use, the simulated scene situation in DIAlux.

Among them, the yellow line in Fig. 7 represents the light distribution curve of the luminaire, and the blue area represents the test area.

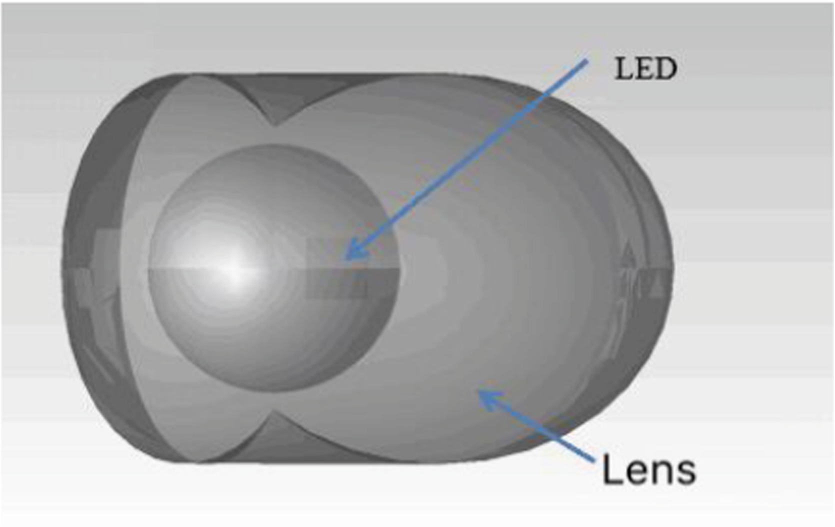


Fig. 6. Positional relationship between lens and COB

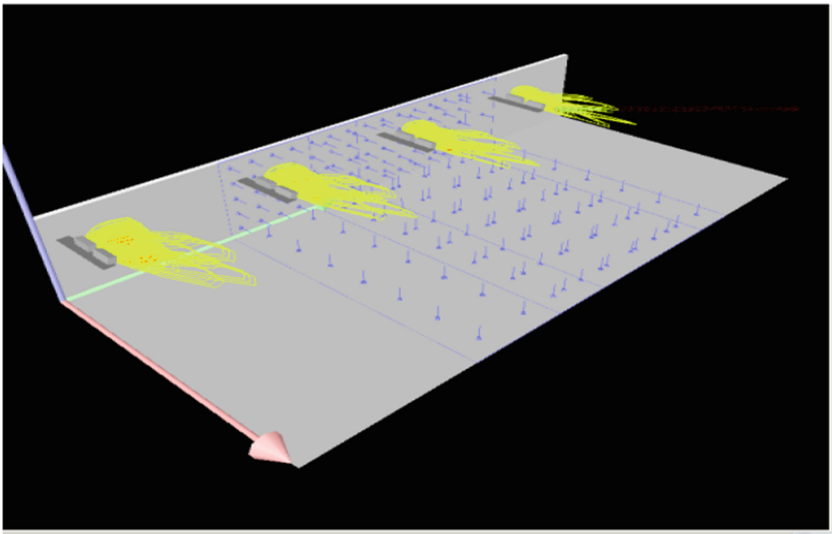


Fig. 7. Graphic design after simulation

5 Design Effect and Analysis

The luminaire with the added lens eliminates the need for the worker to adjust the angle in the horizontal direction during installation. The angle between the outer lamp and the horizontal line is 70°, and the angle between the inner lamp and the horizontal line

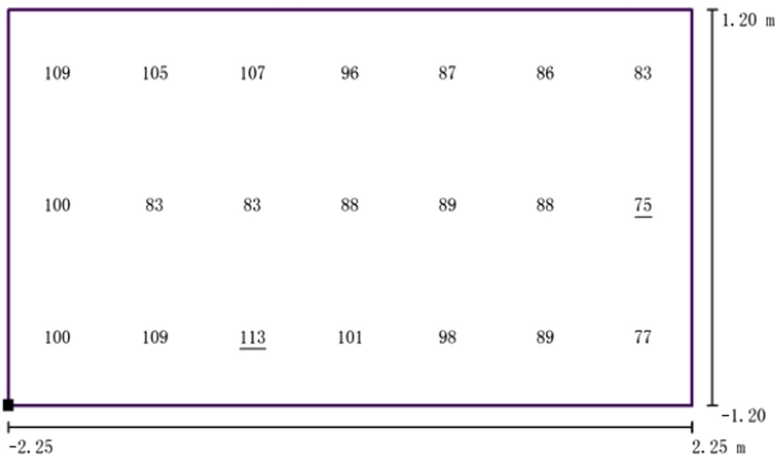


Fig. 8. A wall illumination distribution after simulation

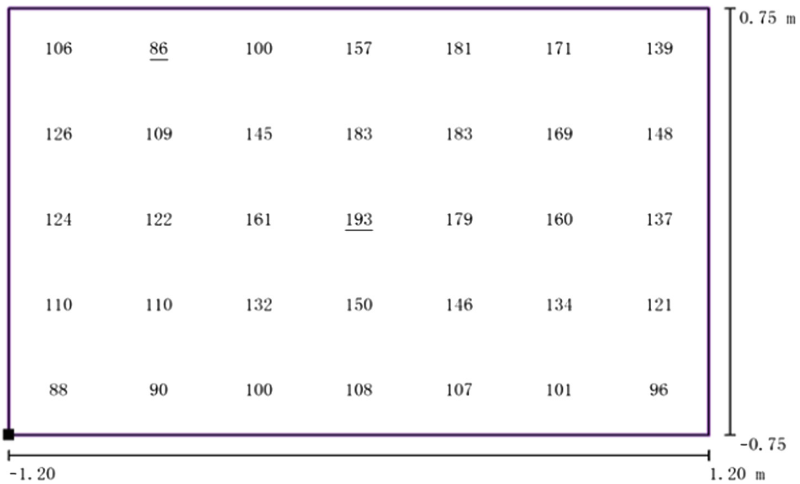


Fig. 9. B wall illumination distribution after simulation

is 80° [10]. The illuminance uniformity of the A wall and the B wall are 0.83 and 0.64, respectively, and the average illuminance is 94 lx and 133 lx, respectively, and the difference is 39 lx (Figs. 8 and 9).

The comparison shows that the illuminance uniformity of the new lens on the A wall surface and the B wall surface is 0.83 and 0.64, which are in line with the project requirements. Generally, the wall washer optical system can only uniformly level the A wall illumination to 0.7, and the B wall surface is basically dull [10]. When the AB wall is illuminated by the street light optical system, the illumination uniformity is 0.5 or less, and the B wall surface is extremely bright. Therefore, the comprehensive comparison shows that the new lens is more suitable for use in this project [11].

6 Conclusion

In this paper, the secondary optical design of the optical system of the LED floodlight is carried out by using the cutting method as the design idea of the free-form optical system. Taking the half-cut lens as the design object, the required lens light distribution curve is analyzed, and the free-form optical system is designed to make the optical system finally achieve the required lighting effect.

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