Collimation and homogenization of light for high Illuminous LED-based system

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Abstract

To replicate the sunlight, some groups have used a mini lens array as an optical element to attain homogenization of light. However, the collimation of the light beam in compact settings is still a challenge. A light collimation and homogenization LED system is proposed using a parabolic mirror and mini lens array. The parabolic mirror ensures the collimation of the light beam, while the mini lens array secures the homogenization. We assembled and tested the results of the 2×2 array and 8×8 array models, which show a small divergence (6.72°) and good uniformity (uniformity coefficient is 67.4% and 45.7% respectively).

Keywords

Collimation Illumination; LED System; Mini Lens Array; Square Spot

1. Instruction

In recent years, more and more LED lights have been applied, including the lighting field and automobile signal field [4-5]. LED lamp has a series of advantages such as energy-saving and long service life. The light distribution of LED has its unique characteristics. When the traditional bulb is a point light source, the light starting point is distributed in the 360 ° space, while when the LED is a point light source, the light is distributed in the 180 ° space, which is half of the traditional light source. To make full use of the light emitted by the LED, the light of the LED must be focused first, which requires the secondary light distribution design. To facilitate the calculation and design of light distribution, the best way is to first gather the light from LED into parallel light, get collimated light, and then distribute light to the whole lamp, and design the corresponding lens or mirror to change the light to the required angle [6]. The design solution can be used to expand the application of compound eye lenses to medical light medical treatment, street lighting, etc. The mini lens array can be used to meet the design requirements of these fields, improving the light energy utilization while significantly improving the uniformity of light. The need for high-power collimated uniform light that simulates sunlight is, therefore, more urgent.

2. Simulation results

According to the above, in this paper we use ZEMAX software to model and simulate the design scheme of a uniform lighting system, then use the existing product design experiments on the market and redesigns the simulation parameters, and finally uses MATLAB to compare and verify the results. The simulation control experiment is divided into units and 2 × 2 arrays. Each unit is composed of parabolic reflector and mini lens arrays, as shown in Figure 1.

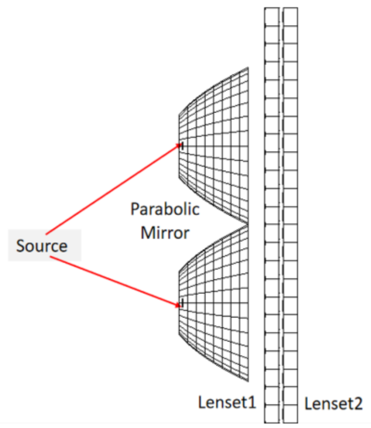

Figure 1. Simulation Modal of a 2×2 Array of a Homogeneous System

In Fig. 1, the height of the parabolic reflector cup is 18.89mm, the LED is set at 0.89mm in the parabolic reflector cup, the two layers of mini lens arrays are parallel to each other, the bottom layer is set at 1mm in the reflector cup mouth, and the top one is directly set at the back of the first group of lenses.

In the whole system, through the optimization design of each parameter, it is found that the relative position parameters of the two mini lens arrays and their radius have a great influence on the overall illumination and flatness. When the distance between two layers of mini lens arrays is 0mm, that is, the distance between mirrors is 8mm, and the radius is 2mm, ZEMAX is used to simulate the optical system with the aforementioned parameters, and the simulation result of 2×2 array is shown in Figure 2.

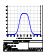

Figure 2. Simulation Result of a 2×2 Array of a Homogeneous System
(a) Results on Detective Plane(b) Cross-Section Row Result

Fig. 2 is the overall illumination distribution diagram of the spot on the target surface of the unit system, and the spot area is mm 2. Fig. 2b is the overall illumination distribution diagram of the spot on the target surface of the 2×2 array system. The uniformity coefficient calculated by Formula 1 and Formula 2 is 68.8%. The two universal international standards (SJ/T11346 and ISO/IEC21108) take 0.8 as the minimum standard of uniformity. Therefore, 0.85 as the uniformity coefficient defined in the design requirements is reliable and effective.

3. Experimental results

To verify the reliability of the simulation results, an experimental device is built. The lighting box is composed of LEDs, parabolic reflecting cups, and mini lens arrays. The LED light source contains a white light chip with a size of 5 × 5mm, and the luminance of a single LED is 1100 lm and the illumination of the whole array reaches 11.3 Klux under proper working conditions. In the 2×2 LED array, the distance between each other is 43mm. Since there was slight light leakage around the spot, we added a black matrix whose aperture is 20×20 mm, matching the position of LEDs. To keep a proper working temperature of the system, we set the working voltage and current as 7.3V and 2.5A respectively, which means the overall power reaches only 40% of maximal power. If the system is combined with a cooling fan, the working power can be higher. Fig.3a is the profile of the lighting box.

As for the mini lens array, the raw material covered PDMS and solidifying initiator (PDMS DC184, Dow Corning Co.). Firstly, they should be mixed with 10:1, and put in a vacuum to remove unwanted bobbles. We designed and made the metal mode to produce a mini lens array in mass. The size of each mini lens is identical to the simulation model. We put the mode on a horizontal stage and filled it in the liquid mixture. In this way, we can control the thickness of the mini lens layer and keep it uniform easily. The mini lens layer solidified after 2 hours at 60°C, which is shown in fig. 3b. It is noticed that the thickness of the top layer is equal to the focal length of the bottom mini lens array.

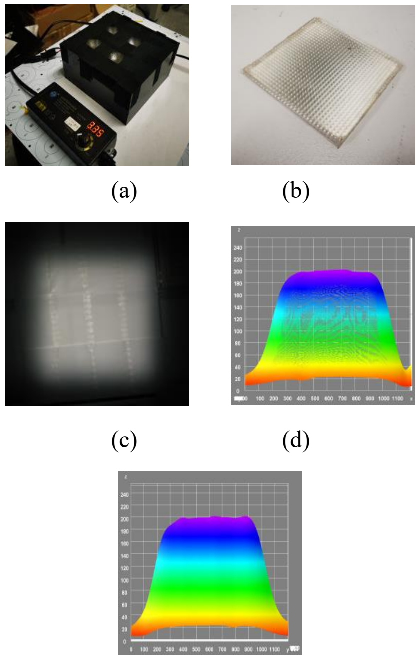

Figure 3. Fabricated Devices and Measured Results of the 2×2 Array Homogeneous System. a) The Device of the 2×2 Array of Lighting Box (b) A layer of the Mini Lens Array (c) The Output of the Lighting Box (d) The Front View of the Light Intensity Distribution (e) The Left View of the Light Intensity Distribution

The performance of the lighting box is shown in Fig. 3c, and a target surface is set 3m away from the rear mini lens array to obtain the spot. The spot is imported into ImageJ, and the front and left view of the light intensity distribution is shown in Fig. 3d and 3e respectively, which are similar to the simulation results. The part with uniformity coefficient H ≥ 0.85 dominates 67.4% of the whole area.

4. Conclusion

In this paper, we proposed a new method to generate a uniform and collimated light beam with simple and easy-to-fabricate components. With the double-layer mini lens array, we can converge the light from the LED array and get the uniform spot at the far-field. The simulation and experimental results are in agreement. The uniformity coefficient can reach 67.4%, and divergence is 6.72°. With the proposed method, it is much easier to fabricate a uniform, collimated, and large-area artificial sunlight system. Besides, the system can also be used as a backlight for LCDs.

5. Acknowledgements:

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