Design of portable calibration light device with tunable color temperature

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Abstract. Studied on multiples color temperature LEDs as calibration light based on array, and designed a portable calibration light device with tunable color temperature which could simulate various luminous environment to test the performance of camera and sensor. The experimental carried on the light device. The results showed that the calibration light source could accurately reappear the color temperature light source in the range of 2500K to 6500K under the condition of multi channels constant power supply, and the precision of color temperature is within ±30K and the light is stable, the uniformity is within ±2.5%.

1. Introduction

In traditional calibration devices, the illumination sources are usually incandescent lamp or halogen tungsten lamp built in integrating sphere. With the applying of enlargement on the calibration device and the limitation of the relationship between the light and the volume of the integrating sphere, these traditional light sources have been difficultly to meet the application requirements: on the one hand, increasing the number of incandescent lamps will reduce the effective area of the guiding sphere, which can,t achieve the purpose of increasing the light flux; The use of integrating sphere as containers limits the scope of using that can,t be carried with you. In addition, the poor color of incandescent lamp limits its application in standard source. The emergence of high power LED light source provides a new way for calibration devices, especially applies on smaller calibration devices. In order to produce a calibration light source with tunable color temperature and brightness with high stability and uniformity, which can arrange and combine multiples LED light sources in some form by using multi-channel constant current source to control the light intensity of different color temperature LEDs light sources, that bring the adjusted of brightness and color temperature, and finally the calibration requirements can be achieved. Because the working state and stability of LED are affected by many factors such as heat dissipation, structure and so on. When multi-group LED is used as calibration light source, it is necessary to consider the driving power supply of LED, the arrangement mode of LED array and heat dissipation as a whole [1].In this paper, the experimental study of LED calibration light source has a certain reference value for the design of LED calibration light source.

2. Theoretical analysis of tunable light

According to the principle of chromaticity and center of gravity, When multiples color LED light sources are mixed, the color coordinates of the new color produced by the mixing of two colors that are always on the straight line which connected by the color coordinates of the original two colors and the color
coordinates of the new color depends on the mixing ratio of the tristimulus values of the two colors. The color coordinates of the new colors which is made up of three colors should be in the triangle connected by the color coordinates of the three colors. To adjust the color temperature and illumination of the target light source is actually to adjust the duty cycle of all kinds of mixed lights to achieve adjustable brightness and color temperature.

At present, multiples technical schemes to achieve tunable color temperature are proposed, mainly as follows: 1. White light is generated by mixing red, green and blue LED, which is called RGB technology [2]; 2. Using multi-chip integrated white LED, color temperature can be adjusted by chip combination and current regulation; 3. The brightness of white LED, blue LED and red LED can be adjusted to achieve tunable color temperature; 4. The combination of white LED and yellow LED achieves tunable color temperature ; 5. Low color temperature white LED and high color temperature white LED mixes to adjust brightness and color temperature, that is the so-called cold and warm white LED mixing technology [3]. In terms of technical feasibility and performance stability, the first and fifth schemes are more convenient and practical [4]. In order to adjust the color temperature, the combination of fixed color temperature white LED, warm white LED, green LED and pink LED is designed.

3. Design of calibration light device
Because the radiation power of a single LED is difficult to meet the requirements of practical use, in order to meet the brightness requirements, it is necessary to arrange as many LED light sources as possible, and it also can improve the stability and uniformity of the light outlet. In order to realize the convenience of calibration of testing equipment, a small calibration light device with an output aperture of 50X50 (mm) is developed. Staggered fixed color temperature white LED, warm white LED, green LED and pink LED on the circuit board. and Fixed the board on the outer edges of the square leveling respectively, keep the same distance, equipped with filters and affixed with reflective paper on the inner wall. The layout of the LED lights is shown in Figure 1.

![Figure 1. LED light layout.](image1)

The device is carried on constant current source to ensure the stability of light output. By controlling the intensity of different color temperature LED light source to adjust the brightness and color temperature. the light effect shown in Figure 2.

![Figure 2. Lighting effect of an assembling sample.](image2)
The test of light source is carried on in an Aluminum testing device for opacity. The experimental instruments include: chroma meter, darkroom guide rail, fixing bracket and light source device. In order to measure the performance of the light source of the LED array unit, the stability and uniformity of the single channel LED light source are measured firstly. the equal spacing detection points of the light surface are marked. There are 25 detection points, as shown in Table 1.

Table 1. Distribution of test points.

|   | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 6 | 7 | 8 | 9 | 10 |
| 11| 12| 13| 14| 15 |
| 16| 17| 18| 19| 20 |
| 21| 22| 23| 24| 25 |

The measurement results are transformed which the color temperature and the uniformity of the luminous surface are shown in Table 2.

Table 2. Accuracy of color temperature and uniformity of luminance of single channel of output surface.

| No | Warm white LED(2700K) | White LED(4995K) | Pink LED | Green LED |
|----|------------------------|------------------|---------|----------|
|    | accuracy of Color T(K) | Uniformity of LM(%) | accuracy of Color T(K) | Uniformity of LM(%) | Uniformity of LM(%) | Uniformity of LM(%) |
| 1  | +10                    | 4.89             | -1.28   | -2.56    | -2.85    | -3.57    |
| 2  | +10                    | -1.28            | +25     | -0.25    | +1.60    | +0.02    |
| 3  | +10                    | 1.22             | +5      | 2.37     | 3.06     | +4.37    |
| 4  | +10                    | 1.67             | -5      | 3.29     | 3.76     | +4.02    |
| 5  | +10                    | 2.67             | +25     | 4.45     | 4.87     | +4.33    |
| 6  | +10                    | -3.69            | +25     | -1.94    | -2.52    | -3.09    |
| 7  | +10                    | -3.67            | +5      | -2.71    | -2.00    | -1.74    |
| 8  | +10                    | -0.75            | -15     | +0.06    | +0.73    | +1.88    |
| 9  | +10                    | 0.15             | -15     | 1.45     | 2.24     | +3.54    |
| 10 | +10                    | 3.53             | +5      | 4.68     | 4.08     | +4.33    |
| 11 | +10                    | -4.13            | +25     | -4.64    | -4.04    | -3.71    |
| 12 | 0                      | -4.05            | +5      | 4.41     | 3.97     | -2.68    |
| 13 | 0                      | 1.56             | -15     | -1.79    | 1.65     | +0.02    |
| 14 | 0                      | -0.64            | -35     | -0.25    | -0.76    | +1.78    |
| 15 | 0                      | -3.75            | -15     | 3.99     | 3.86     | +3.47    |
| 16 | -10                    | -2.75            | +15     | 4.72     | 5.22     | -3.50    |
| 17 | 0                      | -1.88            | -15     | 3.95     | 3.77     | -3.09    |
| 18 | 0                      | 0.20             | -25     | 1.79     | 2.27     | -1.74    |
| 19 | 0                      | 0.49             | -35     | 0.25     | 0.58     | -0.12    |
| 20 | 0                      | -1.53            | -15     | 4.37     | 2.18     | +3.85    |
| 21 | 0                      | -0.45            | +45     | -4.02    | 4.49     | -3.96    |
| 22 | -10                    | 2.70             | +15     | -0.02    | 1.23     | -3.09    |
| 23 | -20                    | 4.16             | -5      | 0.37     | 0.11     | -4.44    |
| 24 | -20                    | 4.42             | -15     | 1.21     | 1.64     | -2.36    |
| 25 | -20                    | 2.93             | -15     | 4.06     | 1.76     | +0.33    |

According to the test results, under the condition of monochrome temperature illumination after a long time, the accuracy of color temperature of the whole luminous surface is less than ±0.5K, the uniformity of luminance is less than ±5% and the luminous effect of the whole luminous surface is good.
The color temperature of 3000K, 3500K, 4000K, 4500K and 5000K were set respectively. The date of accuracy of color temperature and uniformity of luminance of the surface under the condition of long-time lighting were measured by the instrument as follows.

Table 3. Accuracy of color temperature and uniformity of luminance of mixing light of output surface.

|       | accuracy of Color T(K) | Uniformity of LM(%) |
|-------|------------------------|---------------------|
| 3000K | -20~+30                | -2.31~+2.45         |
| 3500K | -20~+20                | -1.98~+2.45         |
| 4000K | -20~+15                | -2.10~+2.22         |
| 4500K | -15~+30                | -1.39~+2.45         |
| 5000K | -25~+30                | -2.33~+2.44         |

According to the data in the table, the accuracy of color temperature and uniformity of luminance of the luminous surface are further improved, basically controlled within ±30K and ±2.5% and the effect is better.

4. Conclusion
In this paper, according to the principle of mixing light, the basic unit of LED array is proposed and a portable calibration light device is designed. Experiments show that the stability of luminance is within ±2.5%, the accuracy of color temperature is within ±30K, and the color temperature is continuously adjustable, which can meet the requirements of the light source for calibration. Through the study on the distribution of LED arrays in this paper, it has reference significance for the design of other LED light products.

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