Low Light Level Realization at Near Correlated Color Temperature

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Integrating sphere lamp is usually used as the normal spectral radiance calibration source. The spectral radiance can be adjusted by using a variable aperture between the integrating sphere and the lamp. However, the relative spectral in the red region increases rapidly when the luminance is decreased from 30000 cd/m^2 to 0.01 cd/m^2. The variation of correlated color temperature is as high as 255 K. By using another integrating sphere, low light level radiation source at nearly constant spectral distribution is obtained. The variation of correlated color temperature is 60 K with the luminance decreased to 0.0033 cd/m^2.

INTRODUCTION

Integrating sphere and tungsten lamp are the most popular spectral radiance light sources, covering from 250 nm to 2500 nm. However, the spectral radiance is hard to cover a large range using the tungsten lamp and diffuse plate. If the distance between the tungsten lamp and diffuse plate is varied from 50 cm to 500 cm, the spectral radiance changes 100 times. If the current of the tungsten lamp is changed, the correlated color temperature (CCT) will be different. With the new needs in remote sensing such as weather forecast, the early-morning orbit satellite is required to fill the gaps on the global scale every 6 hours. The spectral radiance changes more than six orders of magnitude from day to night. The spectral radiance can be as low as 10^{-5} W/(m^2·sr·nm). In order to calibrate spectral radiance responsivity at low light level, integrating sphere lamp must be used to establish a low light level facility.

EXPERIMENT AND RESULT

Variable aperture is usually mounted between the lamp and integrating sphere to change the luminance at the exit port. In our experiment, OL 455 integrating sphere lamp is used. By continuous adjusting the aperture, the sphere luminance can be decreased at least 10^6 times. Figure 1 shows the relative spectral distribution at different luminance.

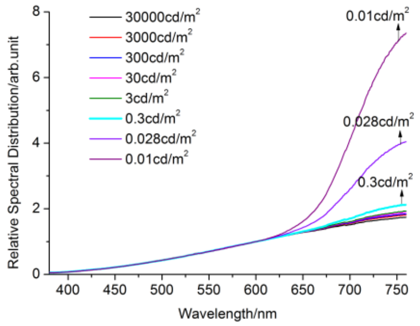

Figure 1. The spectral distribution of OL455

The spectra are all normalized by the spectral radiance at 600 nm. When the luminance is decreased from 30000 cd/m^2 to 3 cd/m^2, the difference is less than 10% at 760 nm. The corresponding CCT decreased from 2808 K to 2770 K. However, the difference increases to 20% when the luminance is decreased to 0.3 cd/m^2. Further, the spectral difference exceeds 300% when the luminance is decreased to 0.01cd/m^2. And the corresponding spectral irradiance at 380 nm is still higher than 10^{-4} W/(m^2·sr·nm). The corresponding CCT is only 2553 K, 255K lower than that of 30000 cd/m^2.

For the obvious increase in the infrared region, it may be due to the fact that the variation of the aperture influences the structure of the integrating sphere. The integrating sphere is made of PTFE or $BaSO_4$, while the aperture is not. The reflectivity of the aperture in the red region may be higher. Also, radiation from different part of the lamp enters the

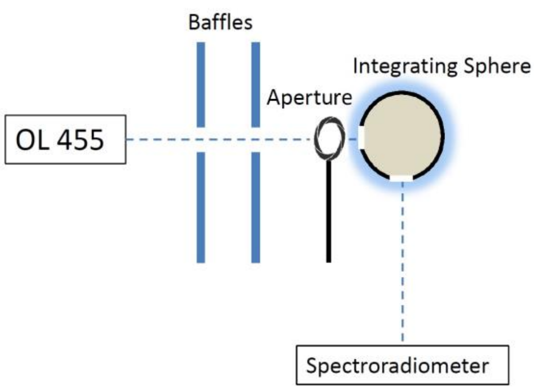

Figure 2. Low light integrating sphere facility

integrating sphere when the aperture is changed.

Figures 2 shows the facility consists of OL 455, baffles and an integrating sphere with an inner diameter of 50 mm. The integrating sphere has two ports which situates at perpendicular directions. The entrance port has a diameter of 25.4 mm, and the exit port has a diameter of 12.7 mm. The baffles are used to screen the stray light. The integrating sphere is mounted on the other side of the baffles. An variable aperture is placed in front of the integrating sphere limiting the spectral flux entering the integrating sphere. The distance between the aperture and the entrance of the integrating sphere is about 6 cm.

First, the luminance of OL 455 is fixed at 30000 cd/m^2. The aperture is at its maximum with a diameter of 10 mm. The luminance at the exit port of the integrating sphere is 12.2 cd/m^2 and CCT is about 2760 K. By decreasing the diameter of the aperture, spectral radiance at three different levels is recorded, as shown in figure 3. The relative spectral distribution differs by more than 70% at 760 nm when the luminance is decreased to 0.07 cd/m^2.

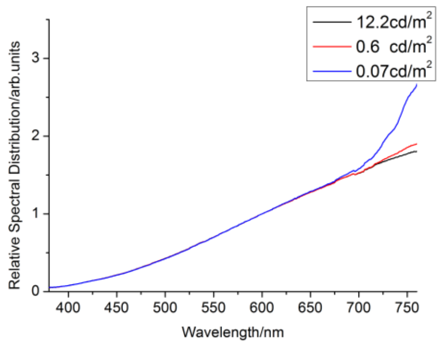

Figure 3. The variation of the relative spectra

Meanwhile the difference is less than 1.5% between 400 nm and 600nm. According to the ratio 12.2 to 0.6, the diameter of the aperture is about 2.2 mm for 0.6 cd/m^2. The difference is less than 6% at 760 nm for 0.6 cd/m^2. It seems that there is a turning point in the role of the diameter. The red region will increases rapidly below the turning point. The aperture has a decisive influence for 0.07 cd/m^2.

Second, the variable aperture in figure 2 is removed. By adjusting the luminance of OL 455, the spectral radiance is recorded at four different levels. When the luminance of OL 455 is about 3 cd/m^2, the luminance at the exit port of the integrating sphere is 0.0033 cd/m^2 and the corresponding CCT is about

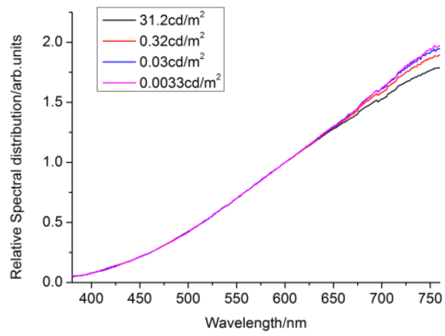

Figure 4. The variation of the relative spectra

2748 K. Comparing to the result in figure 1, CCT is nearly 200 K higher than that of the luminance 0.01 cd/m^2 in figure 1. Therefore, the variation of CCT is reduced significantly using the facility in figure 2.

The spectral radiance from 380 nm to 430 nm is in the range (3-9) × 10^{-5} W/(m^2·sr·nm) when the luminance is 0.0033 cd/m^2. If the spectral radiance less than 10^{-4} W/(m^2·sr·nm) is needed at 760 nm, the luminance should be smaller than 0.00028cd/m^2. By increasing the diameter of the integrating sphere and distance between the integrating sphere and OL 455, the spectral radiance can be realized with CCT near 2748 K.

CONCLUSION

If the relative spectrum is nearly constant throughout a high dynamic range, low light level spectral radiance can be obtained with the help of a photodetector. By measuring the ratio from normal spectral radiance to low light level using a silicon detector, the spectral radiance at low light level can be calculated.

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REFERENCES

1. C-Y Cao, Preliminary study for improving the VIIRS DNB low light calibration accuracy with ground based active light source, in Proceedings of SPIE, 9607, 96070D, 2015.
2. Joe Laveigne, Calibration of a high dynamic range, low light level visible source, Proc. of SPIE, 8014, 801415-10, 2011.