Comparison of Two Methods for Total Luminous Flux Measurement of White LEDs

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Total luminous flux of commercial white LEDs measured with sphere-spectroradiometer method in 2π geometry and goniophotometer method were compared. The measured values in sphere-spectroradiometer method were smaller than that of goniophotometer method by 1% to 5%. Near field absorption and spatial response distribution function of an integrating sphere were estimated as main uncertainty factors of this difference.

INTRODUCTION

For total luminous flux evaluation of LED products, total spectral radiant flux (TSRF) measurement is necessary. A sphere-spectroradiometer constructed with an integrating sphere and a spectroradiometer is commonly used for total luminous flux evaluation of LED products. The sphere-spectroradiometer is calibrated against TSRF standard. In the sphere-spectroradiometer method, test sources that emit light only forward direction are recommended mounted on a port of the integrating sphere wall (2π geometry) [1]. A reference standard source should be mounted at same geometry of the test sources, however, there was no suitable reference standard source for TSRF measurement in 2π geometry until recently. Thus, very few studies had done about total luminous flux measurement of LED products in 2π geometry.

Recently, we developed a new LED-based standard source (2π standard LED) that is suitable for spectral measurement in 2π geometry [2] and TSRF scale for 2π geometry was realized in NMIJ (National Metrology Institute of Japan). Thereby, it has become possible to evaluate total luminous flux of commercial LED products with sphere-spectroradiometer method in 2π geometry. In this study, TSRF and total luminous flux values of commercial white LEDs were measured with two method, sphere-spectroradiometer method using the 2π standard LED as a reference standard source and goniophotometer method. By comparison of the measurement, the uncertainty factors of commercial white LEDs measurement were examined.

EXPERIMENT

In the measurement, 10 types of commercial white LEDs were used as a test white LED. Figure 1 shows spectra of the test white LEDs. Total luminous flux values of the white LEDs were 100 lm to 320 lm and corrected color temperature (CCT) of the white LEDs were from 3000 K to 8000 K. Each white LED was operated at a constant current and mounted on the socket with a built-in thermo-module. The stabilities of total luminous flux of each white LED were ±0.2% by the temperature control.

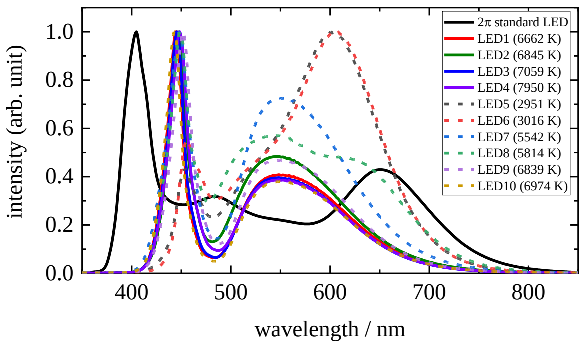

Figure 1. Spectra of 10 types of the test white LEDs and 2π standard LED.

Figure 2 shows angular intensity distributions of 4 types of the white LEDs. The white LEDs emitting light only in the forward direction was selected for a test source, however, LED5–LED10 have radiant intensity even over $\theta = 90°$ direction when measured (e.g., LED6 and LED9 as shown in Fig. 2). In addition, the spatial uniformity of some white LEDs such as LED2 and LED6 were greatly different from that of the 2π standard LED. The angular intensity distribution of the 2π standard LED is almost equal to the Lambertian beam pattern.

In sphere-spectroradiometer method, TSRF of the white LEDs were measured in 2π geometry that calibrated against the 2π standard LED as a reference standard source. Total luminous flux of the white LED was calculated from TSRF. The diameter of the integrating sphere in the sphere-spectroradiometer was 1.65 m. In the measurement, self-absorption correction was performed using a halogen lamp.

In goniophotometer method, total luminous flux of the white LEDs were measured using a $V(\lambda)$-matched detector. An array spectroradiometer was used for measuring a spatially averaged spectrum of the white LED for calculation of spectral mismatch correction factor and TSRF. The illuminance responsivity of the $V(\lambda)$-matched detector was calibrated against luminous intensity standard and the relative spectral responsivity of the array spectroradiometer was calibrated against spectral irradiance standard. The measurement distance was 1.15 m.

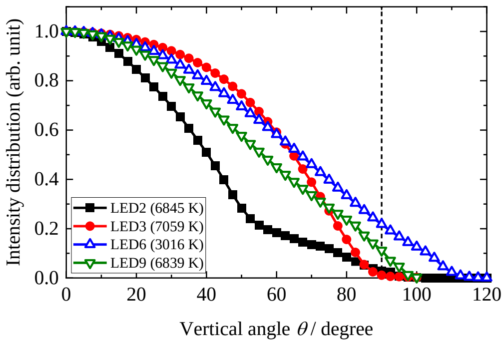

Figure 2. Angular intensity distributions of the white LEDs.

RESULT AND DISCUSSION

Figure 3 shows the differences between total luminous flux measured with two method. As shown in Fig. 3, almost all the results with sphere-spectroradiometer method were smaller than that measured with goniophotometer method by 1% to 5%. For the differences between TSRF measured with two method, similar tendency was also obtained. There was no clear relation between the differences of total luminous flux value and characteristics of the white LEDs, such as spectrum shape and CCT.

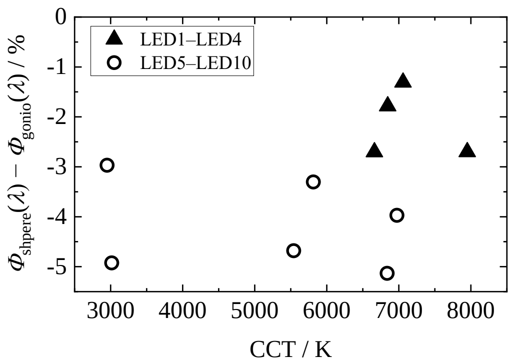

Figure 3. Difference of measured total luminous flux between sphere-spectroradiometer method $\Phi_{\mathrm{sphere}}(\lambda)$ and goniophotometer $\Phi_{\mathrm{gonio}}(\lambda)$.

The uncertainty of the total luminous flux measurement with each two method was about 1% respectively, then these differences between two method were considered to come from other factors mainly. As shown in Fig. 2, some of the white LEDs have backward radiation over $\theta = 90°$ direction. In Fig. 3, these white LEDs has the difference of about 3%–5% (open circles in Fig. 3). In contrast, the white LEDs that emit light only forward direction has the difference of about 1%–3% (closed triangles in Fig. 3).

From this result, two uncertainty factors were considered as the reason of the difference. One important uncertainty factor related to an angular intensity distribution is near field absorption that cannot be corrected by self-absorption correction. This factor was expected to become larger in 2π geometry when the white LED emits light over $\theta = 90°$ direction. In 2π geometry, printed circuit boards and mount jigs cut off the light emitted in the backward direction over $\theta = 90°$. Other uncertainty factor is nonuniformity of spatial response distribution function (SRDF) of the integrating sphere that causes error when a test source has different spatial radiant intensity distribution from that of a standard source.

A quantitative analysis for relation between intensity distributions of white LEDs and measured total luminous flux value is needed as future work.

CONCLUSION

Total luminous flux of commercial white LEDs were compared with two method. As a result, total luminous flux values measured with sphere-spectroradiometer method in 2π geometry using the 2π standard LED as a reference standard source were smaller than that measured with gonio-measurement by 1% to 5%. This difference come from uncertainties related to characteristics of the commercial white LEDs, such as near field absorption effect and SRDF of the integrating sphere.

ACKNOWLEDGEMENT

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