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EFFECTS OF NON-UNIFORM SPATIAL RESPONSE DISTRIBUTION FUNCTIONS OF INTEGRATING SPHERE ON THE TOTAL LUMINOUS FLUX MEASUREMENT OF PANEL LIGHT SOURCE

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Abstract

Integrating sphere (IS) is commonly used to measure the total luminous flux emitted from a light source. Although the spatial response inside IS should be theoretically uniform regardless of the location of the IS, due to the dusts and some other causes, the spatial response distribution function (SRDF) of IS is not uniform. This nonuniformity mediates non-uniform distribution of the illuminance. For the light source has a planar configuration such as Organic LED (OLED) panel, this nonuniform SRDF might be affected to the total luminous flux depending on the size of the light source. Moreover, the larger the difference of SRDF inside IS, the larger the measurement errors. In this research, we assume the reflectance of the hemisphere walls to be uniform, and that the difference between two hemispheres were changed. Our simulation results show that the larger the size of the light source, the larger the effects on the total luminous flux. When the reflectance of the lower hemisphere is lower than 90%, the effects of the size are evident.

Keywords: Photometry, Integrating Sphere, Total luminous flux, Spatial Response Distibution Functions, Panel Light source

1 Introduction

For total luminous flux measurement of light sources, an integrating sphere (IS) photometry is widely used. Theoretically as the spatial response inside IS should be uniform regardless of the location of the IS, entire illuminance within IS is assumed to be uniform. However, in reality, spatial response is lower in the southern hemisphere than that in the northern hemisphere as a sort of contamination which is caused by the dust and other sources. This nonuniformity mediates non-uniform distribution of the illuminance. In IS photometry, a test light source is measured in comparison with a standard light source. In case the luminous intensity distribution of test lamp is different from that of luminous flux standard lamp, SRDF of IS causes errors in the measurement value of total luminous flux of the test lamp. Several studies (e.g. Ohno and Daubach, 2001). Wasapinyokul et al. studied the effects for the line-shaped light source (Wasapinyokul et al., 2017). However, few studies have explored the non-uniform spatial attributes of IS for a planar light source. When a light source to be measured has a planar configuration, such as OLED panel, the light source emits light into half hemisphere. As a result, the illuminance distribution inside IS is not uniform. Moreover, reflected light is not uniformly distributed within IS as some portion of the light is absorbed or secondly reflected at the surface of the light source. Thus, it will be serious affected by both the characteristics of the SRDF of IS and the configuration of the measurement such as the position and the directions of the settings. When the reflectance of hemispheres have larger difference, the effects would be more serious. In several international standards, CIE S 025/E:2015 and IES LM-79, the reflectance of the inner sphere wall is defined to be higher than 90%. However, in reality, the reflectance of the inner sphere wall of the south hemisphere can be lower in the long run.

In this study, we aim to quantitatively estimate the amount of the errors caused by the nonuniformity of SRDF in measurement of a panel light source. We focus on the difference in the reflectance on the north and south hemisphere. We will also explore the effects of the orientation of the light emitting side of the panel light source.

2 Methods

For the simulation of the total luminous flux measurement by the IS, we used hybrid light simulation software using bidirectional Monte Carlo ray tracing method (Lumicept, Integra Inc.). The total luminous flux value of the test light source is estimated by the ratio of the illuminance value of the standard lamp whose total luminous flux is known, then its value was compensated with the self-absorption value. This is the same principle as general measurement with IS. In this study, the calculations were continued until the difference between total luminous flux obtained from two successive rays became smaller than 0.1%. About 3 billion light rays are emitted depending on the conditions.

The IS model used in this simulation is shown in Figure 1. The geometry and the polar coordinate system of this model based on the general one whose diameter was 1 m. The light detector was located on the equator. In order to block light beams entering the light detector directly from the panel source, the baffle plate was placed inside the detector. The auxiliary lamp to calculate self-adsorption was also set at the same level as the light detector. The baffle plate was placed in front of them in order to block direct light beam from the auxiliary lamp. The panel source was placed at the centre of IS by a cylindrical pole whose diameter was 3 cm. The reflectance of the surface of pole and baffle plates were 95% in the other side. In order to simplify the nonuniformity of the spatial response distribution functions, we first assumed the reflectance of the northern hemisphere to be higher than that of the southern hemisphere, whose hemisphere had uniform spatial response, i.e., uniform reflectance.

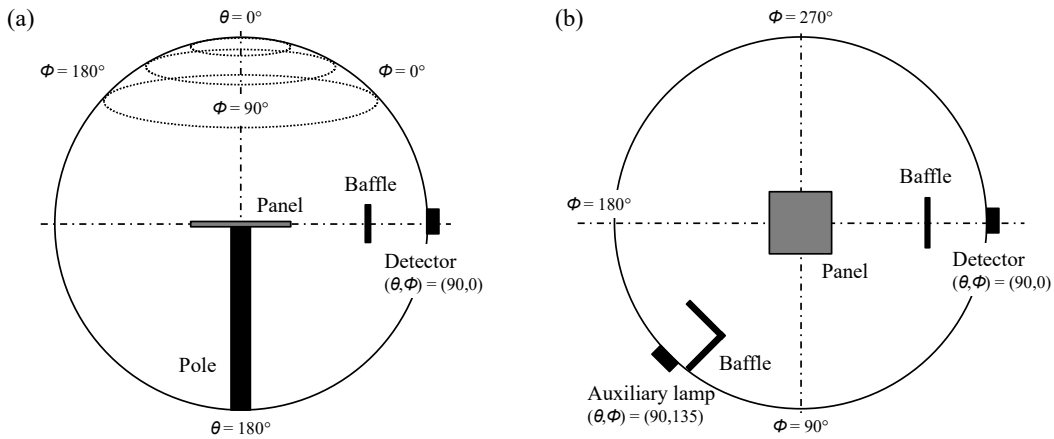

Figure 1 – The geometry of IS model (a: front view, b: top view)

In the simulation, the combination of the reflectance of the inner wall of the northern hemisphere and southern hemisphere had 95%-95%, 95%-90%, 95%-80%, 95%-70%, respectively. We set the luminous distributions of three types of the reference standard lamps as shown in Figure 2. One was 2π sr Lambertian, and others were 4π sr. The sizes of the panel source were: 10, 20, and 30 cm, or in other words, 10%, 20% and 30% relative to the diameter of the IS. In order to verify the direction of the light emitting surface of the light source, we adopted two directions: upwards and downwards direction. In former case, the direct light emitted from the light source first hit the northern hemisphere which had higher reflectance value, while in the latter case, the direct light hit the southern hemisphere with lower reflectance value.

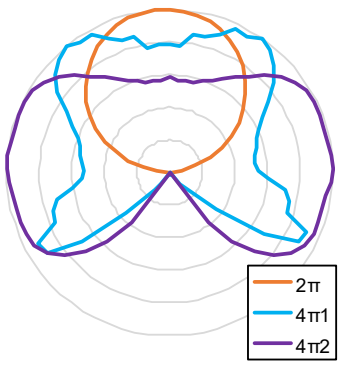

Figure 2 – The luminous distributions of three types of reference standard lamps

3 Results and Discussion

Figure 3 shows the results of the simulation in which the luminous distribution of 2π sr Lambertian were used. Panel (a) and (b) indicate the orientation of the light emitting side: upwards and downwards, respectively. Each color bar indicates different size: red, green and blue bars indicate the size of 10, 20, and 30 cm, respectively. Four different combinations of the reflectance are shown in the figure. Panels (a) and (b) show different trends depending on the reflectance. Although the reflectance changed drastically, the estimated total luminous flux remained almost the same, with an error of a few percent. This indicates the effectiveness of the measurement of the total luminous flux with an IS. The nonuniformity of in reflectance within the inner wall is well compensated with the measurement of the standard lamp, as far as the light distributions of the standard lamp and the test light source are similar. The difference is

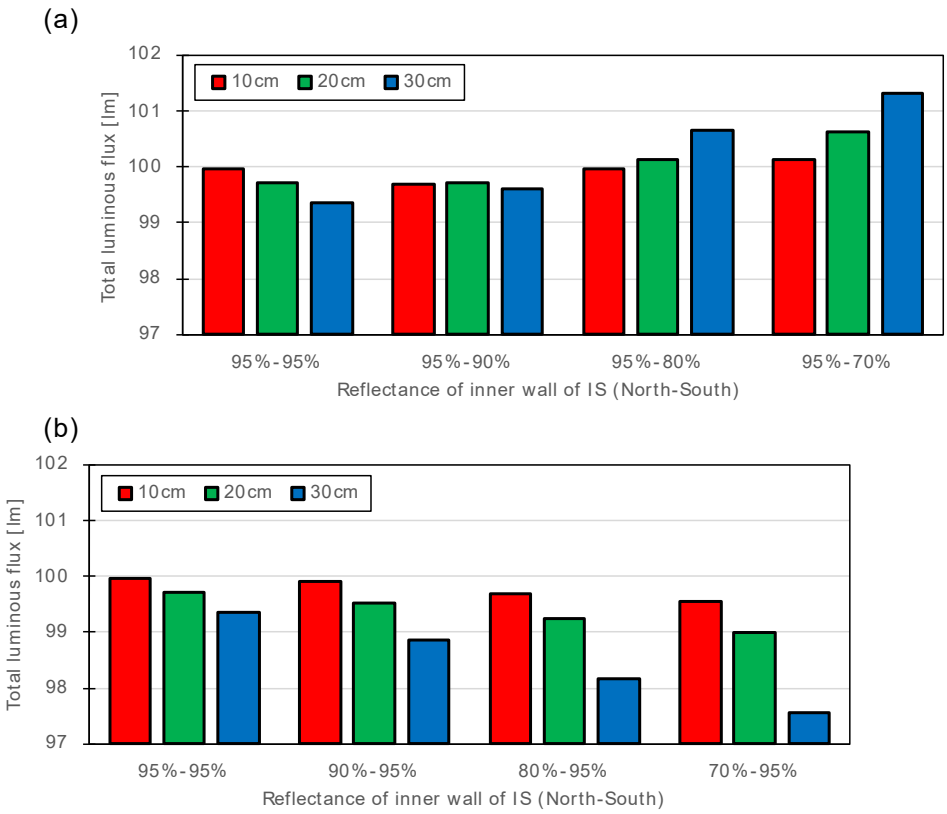

Figure 3 – The results of the simulation
Panels (a) and (b) indicate upwards and downwards conditions, respectively.

mediated by the difference in the reflectance of the wall to which the direct emitted light from a light source hit. In 95-95 condition, which mimicked the uniform reflectance of the inner wall, the total luminous flux decreased as the size of the panel increased. One of the reasons for this decrease is shadowing effect, which is derived by the absorption of the light by a light source. Compared with this ideal case, the results of the simulation show that when the difference in reflectance is rather small (5%), the size effect is small in the upwards case, where the direct light emit from the light source first hit the higher reflectance area. However, as the difference in reflectance becomes larger, the estimated luminous flux also increased by about 1% (95%-70% condition). When the light source was set downwards, the total luminous flux decreases as the size of the panel increases. This trend can be observed for all the reflectance conditions. In summary, the non-uniformity affects the estimated value of total luminous flux, e.g. the error in the total luminous flux increases, as the size of the light source increases

In order to quantitatively evaluate the effects of the panel size, we re-plotted the results of the simulation. Figure 4 indicate how the total luminous flux changed as the size of the light source. Different symbols indicate the different reflectance setup. Red, green and blue symbols indicate the 95-90, 95-80, 95-70% combinations, respectively. Uniform condition (95-95%) is shown with a dot line. We simulated the light source to be 100 lm for all the conditions, so the estimated total luminous flux directly indicates the amount of the error.

When the panel size is 10cm, the error of the total luminous flux is about 0.3 % for both upwards and downwards conditions regardless of the reflectance conditions. As the size of the panel gets larger, the effects of the difference in reflectance becomes notable. For the size of 20cm, the error is as much as 1 % for 95-70% condition. The error is about 2% for the 30cm panel. As is clearly shown in the panels, the effects of the nonuniformity in reflectance show completely opposite behavior. In the upwards condition, the estimated total luminous flux increases as the difference in reflectance, while in the downwards condition, the total luminous flux decreases.

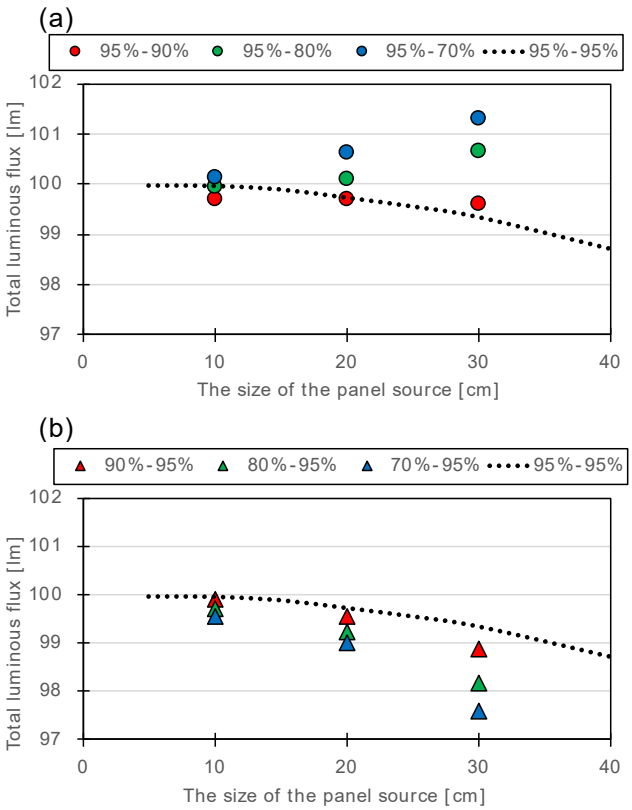

Figure 4 – The relationship between total luminous flux and the size of the panel source Panels (a) and (b) indicate upwards and downwards conditions, respectively.

Our results indicate that total luminous flux is affected by SRDF for the panel light source. In this research, we considered only a simple and extreme case: two different reflectance in north- and south- hemisphere. Especially for the panel light source, the condition for the setting is very important. At least, the direction of the light emitting side showed different size dependent effects. When the rather realistic SRDF of the IS would be adopted, we would have more complicated effects of SRDF. For the panel light source, further studies would be essential for evaluating uncertainty including the orientation of the light source.

Finally, our simulations clearly show that it is important to maintain the condition of IS properly in order to minimize the error factors, or uncertainties, mediated by the experimental setup.

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