PHOTOBIOLOGICAL RADIANCE MEASUREMENT IN LEDS' RADIATION SAFETY ASSESSMENT

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ABSTRACT

Recent years, LED technology as well as its applications grow very fast, which deserve more attention to the hazard of LED radiation. The spectral integrated radiances are important parameters in hazard analysis of LED radiation. However, traditional spectral luminance meters are really not suitable to be used to determine spectral integrated radiances in accordance with IEC 62471. Therefore, new solutions for photobiological radiance measurement shall be studied. In this paper, we present a practical measuring method and the principle scheme of the measurement system. Meanwhile, the blue light weighted radiance of LED samples are determined in accordance with IEC62471-1(CIE S009). Moreover, the results based on the measurement in far-field and the average LED intensity are compared with above photobiological radiance. Besides, we discuss the luminance/radiance conservation law in optical system will be not suitable for the photobiological radiance in LEDs' radiation safety assessment, and then propose how to evaluate the safety class of LEDs' application products from the assessment of independent LED devices.

Keywords: Photobiological measurement, optical radiation hazard, weighted radiance.

1. INTRODUCTION

LED technology as well as its applications is growing very fast, powerful and high brightness products are continued to be brought to the marketplace, which deserve more attention to the hazard of LED radiation now. Primarily, the enlargement of the induced current and the multi-chips integration technologies, bring high power lighting LED products. Again, novel technologies, e.g. using of photonic crystals on the surface of LED chips, make LED device more efficiency. Furthermore, beam-forming optics which is widely used in some LED application products collimates the light emission of LED devices and enlarges the exposure on the human retina. Besides, applications of deep blue or UV LED chips, increase the possibility of radiation ocular hazard, especially for children, whose lens are more transparent over shorter wavelength in visible range.

In 2007, LEDs' safety addressing taken out from the scope of IEC 60825 standard, and recently has been determined to bring into IEC 62741. In accordance with IEC 62471, general lighting LEDs shall be measured at a distance which produces the illuminance of 500 lx, but no less than 200 mm, and all other LEDs shall be measured at a distance of 200mm, and the weighted radiance shall be determined over specified field of view (FOV), which bring new challenges to practical measurements.

2. REQUIREMENTS OF PHOTOBIOLOGICAL RADIANCE MEASUREMENT

For present LED products, retinal blue-light weighted radiance and thermal hazard weighted radiance shall be tested, and following procedures have to be considered:

1. The determinant of worst situation

For LED products, the spatial distribution of the radiation is much more complicated, especially for the lighting LED luminaires, it is needed to identify which direction, which part of the apparent source will cause the greatest potential hazard to retina.

2. The size and location measurement of the apparent source

For LED products with secondary optic systems, the location of the apparent source is mostly different to that of the chip, and should be searched for by image focusing to find most serious hazard. Especially for the LED projector, whose apparent source location is much more difficult to determine. Furthermore, the dimension of the apparent source shall be determined.

3. The determining of exposure duration of pulsed light and wave of the pulse train for the measured lamp.

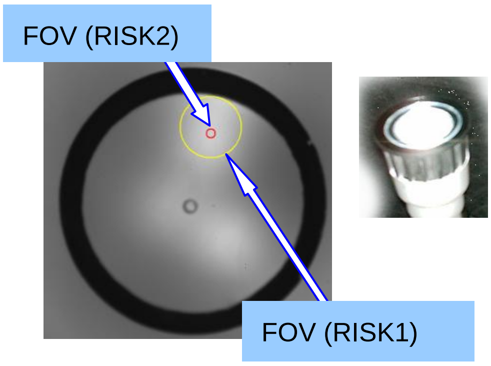

Figure 1. the maximum values of spectral integrated radiances over relative FOV.

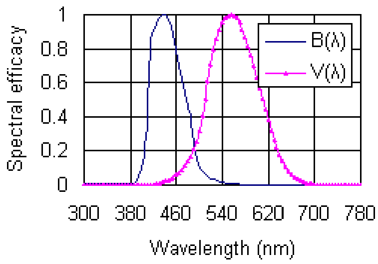

Figure 2. The spectral response V(λ) of photopic vision and the blue-light hazard function B(λ).

4. The maximum weighted radiance over the specified FOV as figure 1 shows.

The FOV is related to the exposure duration of measured LED products. The weighted radiances should be weighted by hazard weighting functions, e.g. the blue-light hazard function B(λ) (figure 2). Consequently, traditional commercial luminance meters are not able to evaluate the optical safety. As figure 3 and table 1 shows, although the average intensity of the white LED is largely exceeded the blue LED, however the blue light weighted radiance of the white LED is smaller than the blue LED. And figure 4 and table 2 show the test results tested by a traditional luminance meter, a spectroradiometer and the retinal radiance meter, obviously, the traditional measurement may underestimate the LED's optical hazard.

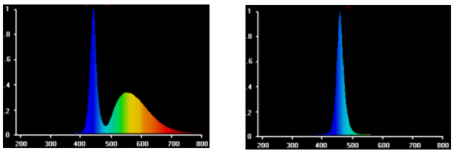

Figure 3. White and blue LEDs

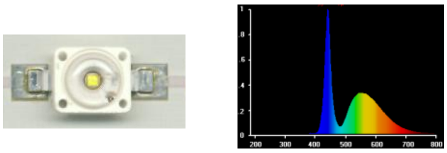

Figure 4. white LED device

Table 1. Test result of white and blue LED

	White LED	Blue LED
Luminous Intensity	23.3 [cd]	2.42 [cd]
Blue light hazard radiance	114 [W/m^{2}sr]	262 [W/m^{2}sr]

Table 2. Test result of white LED

	Traditional luminance	Retinal radiance meter
Luminance	63970 [cd/m^2]	107085 [cd/m^2]
Blue light hazard radiance	81.8 [W/m^{2}sr]	137 [W/m^{2}sr]

Consequently, it is much more complicated to estimate the radiation safety of final LED products based on measurements of LED devices. More bothersome, multi-LED modules or arrays are widely used in SSL products, and the beam-forming optics may also be assembled together, which induce the beam configuration and the location of apparent source to be more complex, and bring great confusion in photobiological radiance measurement for LEDs' radiation safety assessment. Although the radiance cannot be increased by application of optical collimators, projection lenses, however they will concentrate light beam and then increase the exposure irradiance on the retina over the specified FOV (figure 5). Besides, multi-LEDs assembling will also increase retinal hazard.

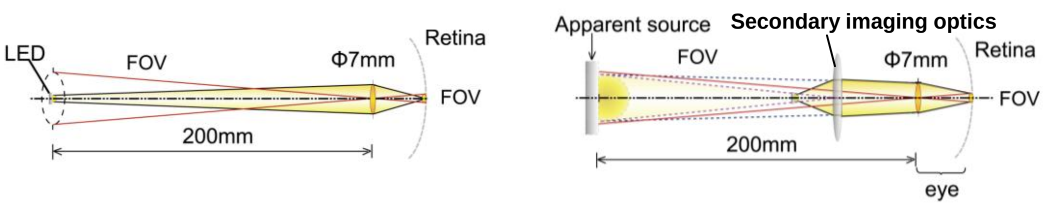

Figure 5. Effect of secondary imaging optics

3. PHYSICAL MEASUREMENTS

Nowadays, there are two physical measurements for LEDs' radiance. One is calculated based on the radiant intensity in far-field and the emission area of the LED. The other one is a physical radiance based on averaged LED intensity at a specified condition in CIE 127. However, what we have to determine in LEDs' radiation safety assessment is the weighted radiance based on the photobiological effects, which is related to hazard action spectral function, physiological status of human eye, viewing condition, and the radiance distribution and location of the apparent source. Therefore, there is great difference between the photobiological radiance and the above physical radiance, which greatly challenge traditional measurements.

However, existing commercial radiance meters and spectral radiance meters are the physical instruments, whose measurements are generally different from that for the photobiological measurement, including the field of view, aperture diameter, spectral weighting function, and temporal response. Using traditional spectral luminance meter, we can only measure luminance and spectral integrated radiance over constant field angle as shown in figure 6, which isn't consist with radiation safety assessment of LEDs. The field angle of the luminance meter are mostly 0.1deg, 0.2deg, 1deg, 2deg, which are different from FOVs specified in IEC 62471, accordingly it is impossible to determine optical hazard weighted radiance. Furthermore, the aperture diameter of a traditional luminance meter will be changing with focusing, and commonly it is very large (about 50mm), which will often underestimate the optical hazard of narrow beam angle light source.

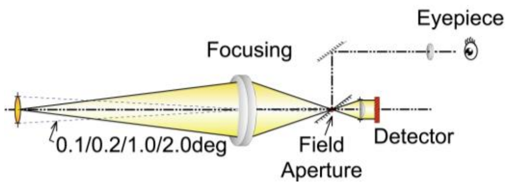

Figure 6 Traditional luminance meter

Besides, the luminance/radiance conservation law in optical system will be not suitable for the photobiological radiance in LEDs' radiation safety assessment. As figure 7 shows,inverse distance square law is not always right for narrow beam, and hazard distance calculation can be applied only under far-field condition.

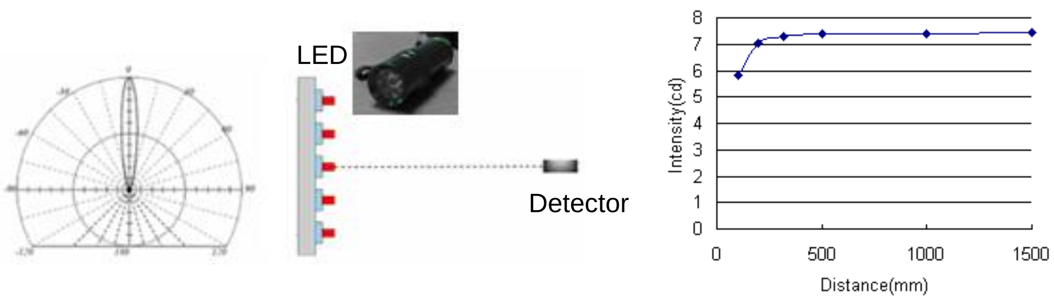

Figure 7. Intensity of LED array

4. PHOTOBIOLOGICAL MEASUREMENTS

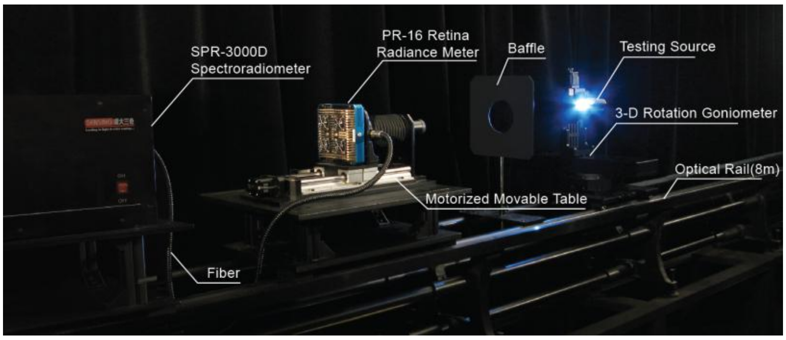

Figure 8. photobiological safety measurement system

Figure 8 shows a novel photobiological safety measurement system for the measuring of spectral integrated irradiance and radiance, which is including a temporal spectroradiometer and a retinal ridiance meter, both the spectroradiometer and retinal ridiance meter can be mounted on the optical rail (8m). Accordingly, the spectral radiance (L'_{λ} (λ)) of the tested LEDs over the FOV (range from 1.5mrad to 110mrad) can be determined at the applicable measurement distance (200 mm or the 500lx distance) in accordance with IEC 62471. Besides, a rotating mechanism with motor-drivable horizontal axis and the vertical axis, is used to search the most hazardous orientation as in figure 9 and the location of the apparent source as in figure 10 for test LEDs installed on the rotation table by the CCD imaging meter.

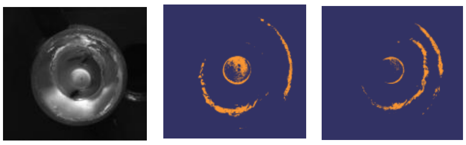

Figure 9. The apparent source of a white LED at different viewing orientation.

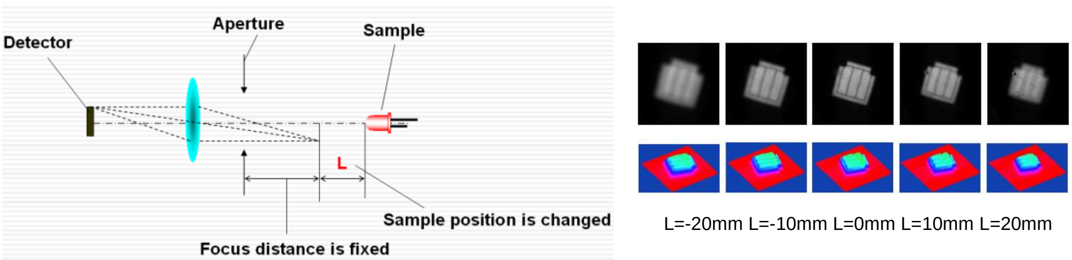

Figure 10. The image of the CCD accommodated to search the location of the apparent source

5. TEST RESULTS

A LED lamp with collimated LED light source is tested at 200mm distance, and both the bare LED chip and the LED with collimating optics is tested.

1. Bare LED chip

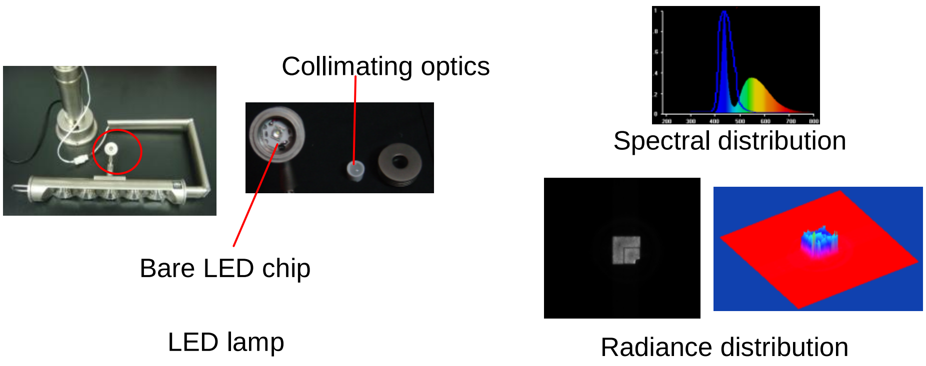

Figure 11. Test of the LED chip.

Table 3. Blue light hazard radiance of the LED chip

Blue Hazard	L_B[W/m^{2}sr]	EL[W/m^{2}sr]
RG0	131	100
RG1	6750	10000
RG2	24599	4000000

Accordingly, this LED chip mounted in this lamp system is *Low-Risk*.

2. Collimated LED light source

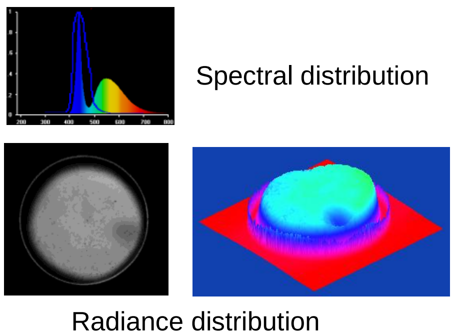

Figure 12. Test of the collimated LED.

Table 4. Blue light hazard radiance of the collimated LED light source

Blue Hazard	L_B[W/m^{2}sr]	EL[W/m^{2}sr]
RG0	7580	100
RG1	28600	10000
RG2	29600	4000000

Accordingly, the LED with collimating optics is *Moderate-Risk*. Obviously, although additional optics will not enlarge the physical radiance of LED, it is able to enlarge the optical hazard level.

6. CONCLUSIONS

LED devices and products can be hazardous to human eye, some LED products with beam shaping optics is able to be the *Moderate-Risk* group. Traditional measurements are really not suitable to be used to determine spectral integrated radiances in accordance with IEC 62471. A retinal radiance meter combined a temporal spectroradiometer can determine the weighted radiances over specified FOV for assessment of radiation safety.

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