THE MEASUREMENT OF WEIGHTED LED RADIANCE RELATED TO PHOTOBIOLOGICAL SAFETY BASED ON THE SPECTRORADIOMETRY AND IMAGING METHODS

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ABSTRACT

Optical radiation safety of LED products is currently being addressed in IEC 62471-2006. The measurement of weighted radiance for maximal exposure related to photobiological safety assessment of LED optical radiation is very different from the measurement of traditional luminance/radiance, and is not tractable yet to any national laboratories. A measurement system based on the spectroradiometry and imaging methods is a suitable solution in order to obtain the weighted radiance of an extended LED source.

Key words: Photobiological safety-related measurement, Blue light hazard weighted radiance

1. INTRODUCTION

Optical radiation with biological significance covers the wavelength generally from 180nm to 3000. Most important tissues of photobiological effect to human are the skin and the eyes. Over exposure from 300nm to 1400nm may cause photochemical and thermal injury to eye's retina. Optical radiation safety of LEDs was addressed firstly in the laser safety standard IEC 60825-1 in 1993. However, in 2007, LED was taken out from the scope of the laser safety standard IEC 60825-1(Ed.2)[1], and now put into the scope of lamps and lamp systems CIE S009 standard, which then was adopted by the IEC as an international industrial standard IEC 62471/ Ed.1 in 2006[2], and also EN 62471-2008 in Europe, and GB/T 20145-2006 in China.

High-power LEDs with attached optics generally have complex beam profiles. The retinal hazards are dominant for white LED products generally. However, the measurement of weighted radiance for maximal exposure related to retinal safety assessment of LED optical radiation is very different from the measurement of traditional luminance/radiance, and is not tractable yet to any national laboratories.

2. PHOTOBIOLOGICAL RADIANCE RELATED TO EYE'S SAFETY

What's photobiological radiance related to eye's safety? The main features include,

a. Photobiological response weighted, e. g. BLH spectral function
b. Field of view related to the exposure duration
c. Incidence aperture as eye's pupil
d. Accessible maximal exposure
e. Focusing on the apparent source, not true source

The retinal hazard caused by optical radiation includes thermal burn and photochemically induced retinal injury. For white LEDs based on blue LED chips and yellow phosphor, the main hazard is the photochemical retinal injury caused by high color temperature, high luminance area of the LED. The hazard functions for both thermal and photochemical hazard assessment and the spectral response V(λ) of photopic vision are entirely different. Thus it is necessary to determine the spectral radiance of LED from 300nm to 1400nm, whose spectral range is wider than that of normal commercial instruments, and the measurement shall be in accordance with the optical hazard principle to human eyes.

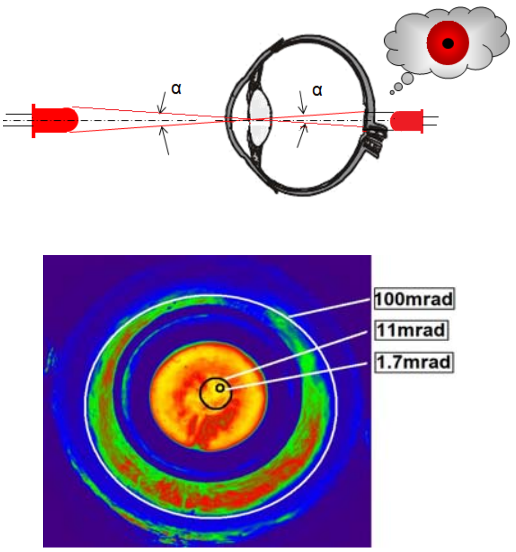


Figure1 Eye's imaging related to the photobiological safety

The field of view (FOV) is mainly dependent on the eye movement. It is possible for a small spot to be formed on the retina, which is equivalent to a normal minimum value of 1.7 mrad due to the limit of an eye's resolving power. A normal eye, when focused on an object, moves slightly and randomly, resulting in a spread of the image of the point source over an area at the retina. The spread covers an angular subtense from 1.7 mrad to 100 mrad depending on exposure duration. As shown in figure 1, the difference of radiance over the FOVs related to various exposure times is significant, thus it is very difficult to determine the maximum radiance by using the commercial luminance meters.

The luminance/radiance of LED products is generally dependent on the acceptance aperture of measuring meter, especially for narrow beam LEDs[3]. The aperture of 7mm diameter as maximum eye pupil is specified in the safety classification, and measuring distance of the acceptance plane from the apparent source is also required at producing 500lx position for GLS, otherwise to be 200mm[2].

3. SPECTRORADIOMETRY AND IMAGING BASED MEASUREMENT

A measurement system that mimics a human eye was set up (Figure 2), which includes a spectroradiometer, a scientific grade CCD camera, and a beam splitter that splits the measured beam into the spectroradiometer and the CCD camera. An incident aperture with 7 mm diameter was set at the front focal plane of the imaging lens, so that the field of view and the diameter of the incident aperture are constant no matter where the light source is. The measurement areas of the spectroradiometer and the CCD camera are overlapped, thus the measured result from the overlapped area on CCD can be corrected by the spectrum data from the spectroradiometer to determine the weighted radiance of the LED. Furthermore, more accurate results can be obtained even for LED with non-uniform chromaticity by correcting the spectral response of the CCD detector with suitable filters, such as blue light hazard function correction filter.

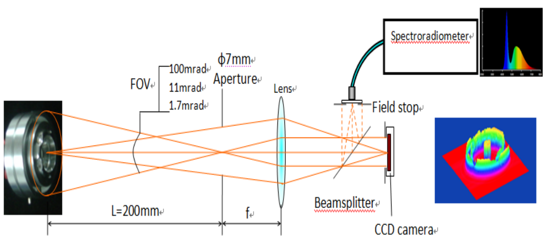


Figure 2 Principle of the measurement system.

The measuring field could be implemented from 1.5mrad to 110mrad regarding CIE S009 / IEC 62471 standard. The maximum weighted radiance (L_B, L_R, L_{IR}) can be determined based on the radiance distribution of the apparent source. The measurement facility in NIST is shown in Figure 3. It should be important for temperature of LED components/modules at host points to be stabilized by TEC cooling set.

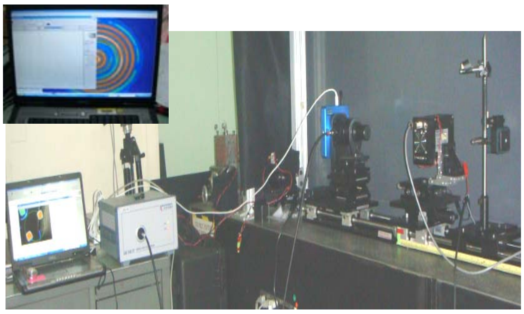


Figure 3 the measurement facility in NIST

Spectral radiance scale is traceable to NIST spectral radiance standard, which consists of 1000W spectral radiance standard lamp and a white reference standard, shown in Figure 4. Wavelength range from 350nm to 900nm is generally sufficient for lighting LEDs.

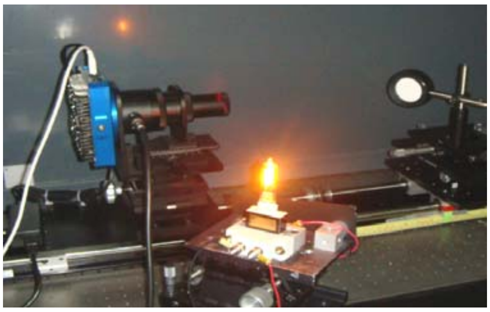
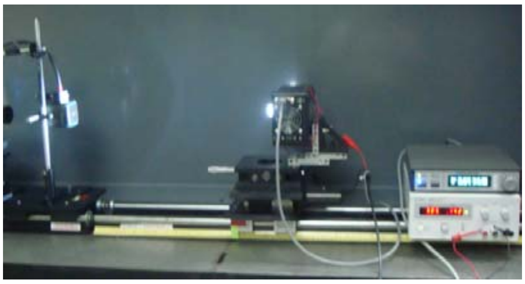


Figure 4 Spectral radiance calibration facility

4. CONCLUSIONS

For angular subtense of the source to be measured not more than the specified field of view, radiance measurements can be performed as an irradiance measurement, alternative method as Figure 5. For compare of the spatially averaged radiance values measured by above system and by alternative method. High-power LEDs with TEC cooling, smaller than the measuring field were used for the task. A diameter 50mm sphere with 7mm input stop was placed at specified plane(200mm or 500lx location) to accept the beam of the LEDs, and subsequently the spectral irradiance was measured by array spectroradiometer to obtain the weighted photobiological radiance.



(a)

(b)

Figure 5 (a) Alternative method of spatially average radiance; (b) LED sample

The measured results were shown in table1, and agree with the results obtained by using an alternative irradiance measurement technique. The measurement method integrated imaging and spectroradiometry is a suitable solution, especially for LED products with complicated beam profile

Table 1 Weighted radiance results of LED samples

Results [W/m²/sr]	Measuring fields	Alternative method [W/m²/sr]
White LED L_B=1.13E+02	γ=100mrad	109.8
White LED L_{IR}=1.25E+00	γ=34.8mrad	1.237
Blue LED L_B=2.62E+02	γ=100mrad	259.8 1

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