MEASUREMENT OF THE TOTAL LUMINOUS FLUX OF HIGH-POWER LIGHT-EMITTING DIODES BY USING A ROBOT-GONIOPHOTOMETER

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Introduction

High-power Light-Emitting Diodes (LEDs) are replacing many of the traditional light sources (incandescent and fluorescent lamps) in a wide range of applications, e.g. lighting and signaling, because of their high intensity achieved nowadays. However, this also brings new radiometric and photometric measurement challenges due to the wide variety of LEDs with different colors and different characteristics of spatial radiation emission. In general, there are two methods established for measuring the total luminous flux Φ_v of light sources: goniophotometer and integrating sphere [1]. Both methods complement each other and have advantages and disadvantages. Although both can be absolute methods, the greatest advantage of a goniophotometer is its capability to measure the angular luminous intensity or illuminance distribution of a light source, which is not possible with an integrating sphere. The advantages of a modern (robot-based) goniophotometer, compered to a typical one, e.g. of variable radius, a still light source, a high measurement speed and flexibility, among others, have been published by G. Sauter in [2]. Therefore, we have established a "mini" robot goniophotometer at the PTB to measure the total luminous flux of high-power LEDs.

Robot-goniophotometer

Figure 1 shows the robot goniophotometer which basically consists of a four-axis manipulator with a photometer head attached to Axis 4. The Axes 1-3 are used to move the photometer head over an imaginary hemisphere surface. The photometer head is maintained in such away that it "looks" to the hemisphere center over the whole traces by means of Axis 4. This manipulator allows the scanning of the hemispheres with a radius of up to 1 m. The speed motion is optimized for each radius (max. speed 0.2 °/s). The position and the orientation of the head is obtained by solving the kinematics of the manipulator. These may also be measured, e.g., with a laser-tracker in order to obtain the photometer head position up to a few tenths of a millimeter. The acquisition of the photometer signal y as well as of the angles $\{\vartheta,\varphi\}$ is carried out in a dynamic way which reduce the measurement time considerably. Here, the photometer signal is converted into frequency and counted continuously allowing a good synchronization with the robot mechanics and the data store without any loss.

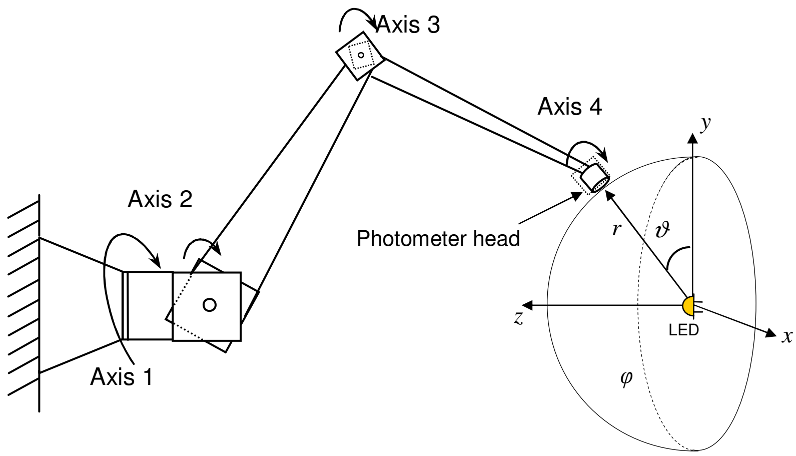

Figure 1. Four-axis robot goniophotometer used for measuring the luminous flux of high-power LEDs.

Results

The determination of the total luminous flux of a high-power LED (white, LUXEON K2) was carried out by measuring the angular illuminance distribution $E_V(\vartheta,\varphi)$,

$$\Phi_v = r^2 \int_{\varphi=0}^{2\pi} \int_{\vartheta=0}^{\pi/2} E_v(\vartheta,\varphi) \sin\vartheta d\vartheta d\varphi, \qquad (1)$$

where r is the radius of the imaginary hemisphere. In this case, errors due to a misalignment of the light source from the center of the rotation of the photometer are negligible. The total luminous flux was measured at three different radii: 0.3 m, 0.5 m and 0.8 m, from where a mean value of 75.35 lm (I_f = 1.002 A and V_f = 3.05 V) was obtained. Corrections of the radius r were carried out by fitting an error model to the measurements. In addition, the stray-light and the spectral mismatch F of the photometer were separately measured and corrected. The values obtained for the stray-light and F were of 3×10^{-4} and 1.002, respectively. The robot goniophotometer was also compared with a well-characterized compact goniophotometer [3] at the PTB by means of a low-power standard LED. Here, a difference of ≤1 % was obtained.

Figure 2 shows a measurement of the relative angular illuminance distribution of the high-power LED under test. It should be noted that its angular emission, $E_V(r,\vartheta) = E_{V0}\cos^{g-1}(\vartheta)$, where g = 1.98, is an almost perfect Lambertian radiator g = 2. In the worst case, the deviation with respect to a perfect Lambertian radiator is ≤3% (see Figure 3).

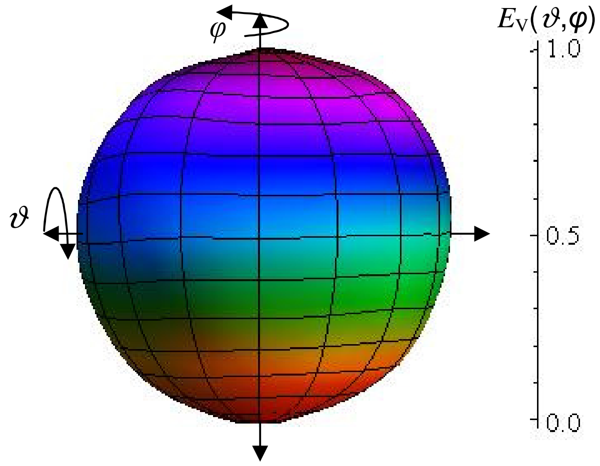

Figure 2. Angular illuminance distribution of a high-power LED (white, LUXEON K2).

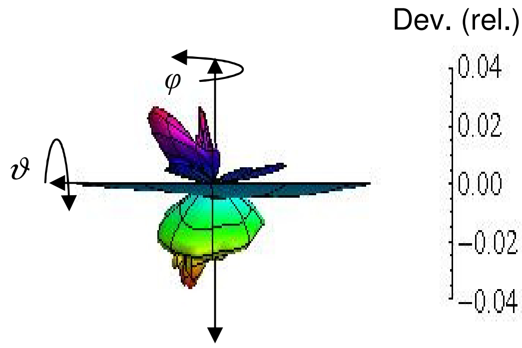

Figure 3. Deviation of the angular illuminance distribution from a perfect Lambertian radiator.

Summary

A robot goniophotometer based on a 4-axis manipulator for measuring the total flux luminance of high-power LEDs has been described. It allows the scanning of hemispheres with a radius of up to 1 m. A comparison with a well-established compact goniophotometer at the PTB showed a deviation of ≤1 %. The robot goniophotometer is still undergoing characterization, which will be completed soon. A relative standard measurement uncertainty of ≤1% is to be expected. The whole characterization of the measurement system and the results including spectroradiometric measurements will be presented at this conference.

References

[1] Measurement of LEDs, Technical Report CIE 127:2007

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[3] G. Sauter, M. Lindemann, A. Sperling und Y. Ohno; Photometrie von Lumineszenzdioden, PTB-Mitteilungen 113, Heft 4, 2003.