

Spatial-angular luminance distribution measurement of phosphor-based LEDs

M. López*, A. Ferrero**, J. Campos**, and A. Sperling*

*Physikalisch-Technische Bundesanstalt, Bundesallee 100, Braunschweig, 38116, Germany

**Consejo Superior de Investigaciones Científicas (CSIC), Instituto de Óptica, Serrano 144, Madrid

28006, Spain

<mailto:marco.lopez@ptb.de>

The investigation of the angular luminance distribution of the high-power phosphor-based white LED is presented. The luminance distribution is measured with a near-field goniophotometer established at PTB which uses an Imaging Luminance Measurement Device (ILMD) as a detector. Moreover, the investigation of the wavelength dependence of the angular luminance distribution, measured by separating the “blue” and “yellow” spectral components of the light emission of the LED by means of a band-pass and a long-pass filter, is also presented.

1 Introduction

The measurement of the spatial-angular luminance distribution $L_S(x_S, y_S, z_S, \vartheta_S, \varphi_S)$ ¹ of a light source is absolutely required to fully describe the emission characteristic of a light source. Today, these measurements are used for generating ray data (“ray files”), which are commonly used for optical simulation tools (ASAP, Zemax, etc.) for the design of SSL-lamps which use white phosphor-based light-emitting diodes (LEDs) as light sources [1,2]. The radiation emitted by such LEDs is composed of two spectral components, a “blue” component which is generated by the blue LED chip and a “yellow” component generated by the fluorescence emission of the phosphor layer, deposited on the blue LED chip. Thus, in order to optimize the optical design of the SSL-sources, the luminance distribution as a function of the wavelength of the LED is also required.

2 Measurement principle

The luminance distribution measurement is carried out with a near-field goniphotometer which uses an imaging luminance measurement device ILMD to capture the luminance distribution of the light source in all directions in which the light is emitted (see Fig. 1). The measurements are carried out by moving the measuring camera with the goniophotometer’s mechanical system along traces spanning an imaginary spherical surface around the light source. From the measurement of the

luminance images the ray-data are generated. For each camera pixel (i, j) with the area $\Delta A_p(i, j)$ the geometry of the optical path defines a geometric solid angle element $d\Omega_{\text{Pixel}}(i, j, \vartheta_p)$ and an associated elementary area $dA_p(i, j)$. The fraction of luminous flux $\Phi_S(x_S, y_S, z_S, \vartheta_S, \Omega_S)$ emitted from the light source and collected by a corresponding pixel of the CCD matrix is defined by the entrance pupil of the camera and its distance from the object in focus. It is equal to the luminous flux portions $\Phi_{\text{Pixel}}(i, j, \vartheta_p, \Omega_{\text{Pixel}})$ and can be regarded as a ray.

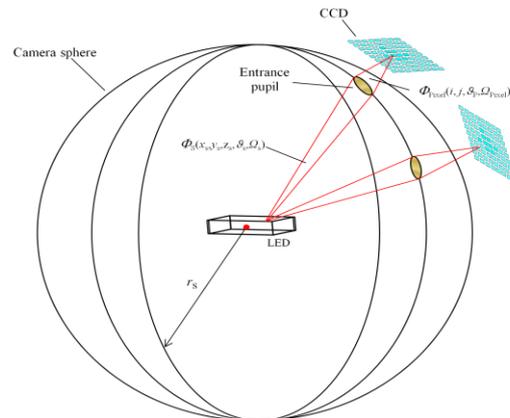


Fig. 1 Principle of a near-field goniophotometer.

Knowing the camera position $\{\vartheta_k, \varphi_k\}$, the image coordinates $\{x_p, y_p\}$ in the CCD-matrix can be also determined. With this information, the image data can be converted into rays with respect to the goniometer coordinate system (device coordinates) by means of a coordinate transformation.

¹
$$L_S(x_S, y_S, z_S, \vartheta_S) = \frac{d\Phi_S(x_S, y_S, z_S, \vartheta_S)}{dA_S(x_S, y_S, z_S) \cdot \cos \vartheta_S \cdot d\Omega_S(\vartheta_S)}$$

3 Measurement set-up

The spatial-angular luminance distribution of LEDs is measured with the near-field goniophotometer established at PTB [1] (see Fig. 2). The near-field goniophotometer employs a commercial luminance camera model: LMK 98-4 equipped with a Sony ICX 285 AL CCD sensor, which provides a resolution of 1380 pixels \times 1030 pixels, a dynamic range of 12 bits and a fix focus macro objective lens with a focal length of 50 mm. A photometer (Photometer 1) is placed adjacent to the luminance camera to measure (if desired) the illuminance distribution of the light source to determine the total luminous flux of the source independently. During the measurement, the luminance camera is maintained at a fixed position while the source (LED) is moved along the angles $\{\vartheta, \phi\}$.

To investigate the spectral variation of the luminance distribution of the white LED, a “blue”-band and “yellow”-long-pass filters were placed in front of the luminance camera. As a result, the “blue” and “yellow” components of the white LED spectrum can be separated as shown in Fig. 3

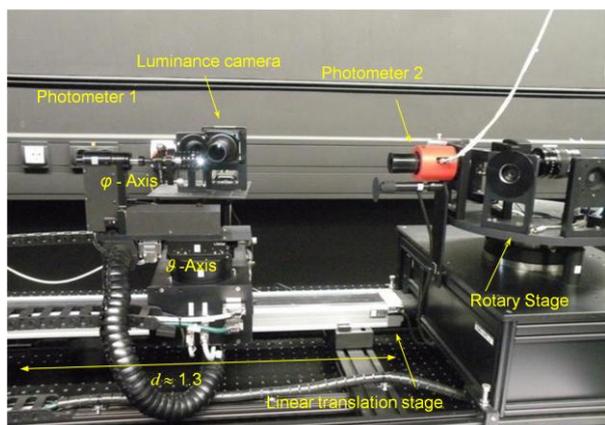


Fig. 2 Joined far- and near-field LED-goniophotometer at PTB.

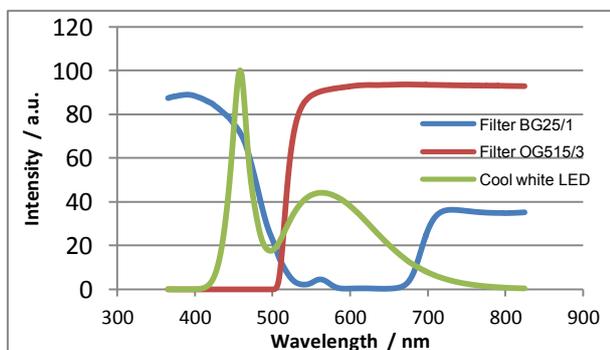


Fig. 3 Spectral transmission of “blue”-band and “yellow” long-pass filters and spectral distribution of cool-white LED Golden Dragon LW W5SM.

4 Results

The measurement of the luminance distribution can be reported in a ray file or as a mathematical model which is composed of coefficients obtained by fitting the model to the luminance measurements. In this work, the model $L(\vartheta_s, \phi_s = k_i) = L_0(x_i, y_i) \cdot \cos^{g(x_i, y_i)}(\vartheta_s)$ was used to fit the angular distribution of the luminance measurements. Here, the matrix coefficients $L_0(x_i, y_i)$ and $g(x_i, y_i)$ characterize the amplitude and lambertianity (directionality), respectively, of the light source. For a perfect lambertian emitter $g(x_i, y_i) = 0$. In Fig. 4 the matrix coefficients for the luminance distribution without and with additional “blue” and “yellow” filters are shown. Here, the luminance images show explicitly the spectral dependence location of the light emission of the LED. For example, Fig. 4 (a) shows a lower emission of the blue component the larger the L-structure is. Moreover, the emission characteristic is more lambertian for the “yellow” than for the “blue” spectral component.

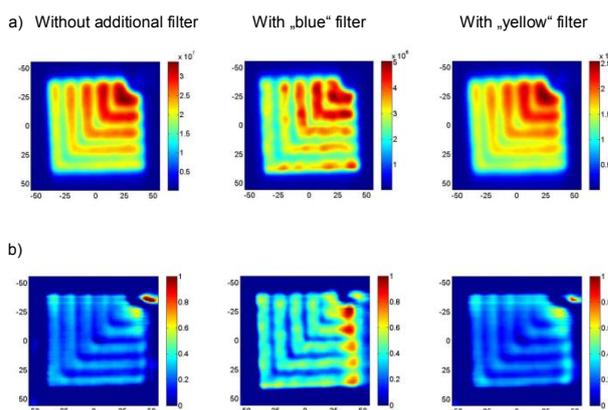


Fig. 4 (a) Amplitude $L_0(x_i, y_i)$ and (b) directional coefficient $g(x_i, y_i)$ matrix obtained for the luminance distribution without and with additional “blue” and “yellow” filters.

5 Conclusions

The investigation of the spatial-angular luminance distribution of a cool-white LED has been shown. A model fitting to the measurements was achieved, which can be used to evaluate the lambertianity of the radiation emission of the LED.

References

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- [2] Bredemeier Knut, Jordanow Wladimir and Franz Schmidt, “Messung der Ausstrahlcharakteristik (Strahlendaten) von LED” LICHT 2008, Ilmenau 10-13.Sept. 2008, Tagungsband, pp. 130-137.