Aufbau und Analyse eines vollautomatisierten Goniometers zur präzisen Messung von Lichtverteilungskurven

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LEDs and optical fibers need the knowledge of light power vs. angle distribution. The presented fully-automated goniophotometer measures the light distribution from 0° until 360° with a minimal resolution of 0.007°. After mounting and testing all components/software a maximal deviation of < 0.7% (1 standard deviation) was reached, which is currently limited by noise of the integrating sphere.

1 Introduction

The knowledge of the light distribution curve (optical power vs. angle) is needed for illumination purposes to optimize the light scenario. In addition, the numerical aperture of an optical fiber can be determined from the measured light distribution curve [1], [2].

2 Basic measurement principle

The basic measurement principle of a goniophotometer, which we use, shows Fig. 1. In our set-up a light source is mounted on a rotation stage and the optical power is measured with a detector in a distance d for each angle φ. The distance d is chosen to fulfill the photometrical limiting distance [3].

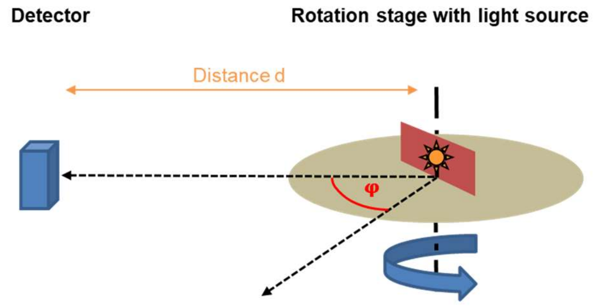

Fig. 1 . Basic set-up of our goniophotometer. A light source is mounted on a rotation stage and in a distance d the optical power is measured for each angle φ.

The photometrical limiting distance states the following: if the distance d is chosen to be larger than 10 times the largest distance of the source, the measurement uncertainty is below 1 % [3].

3 Current goniophotometer measurement unit

The current setup – see Fig. 2 - consist of:

- a source (1) mounted on the
- rotation stage (2), and
- a detector (3), which is a calibrated 2 inch integrating sphere detecting signals between about 400 nm and 1000 nm wavelength, and
- blackening to suppress stray light

The whole setup is mounted on an optical granite bench to suppress fluctuations and inside a dark room for stray light suppression (controlled via computer from outside).

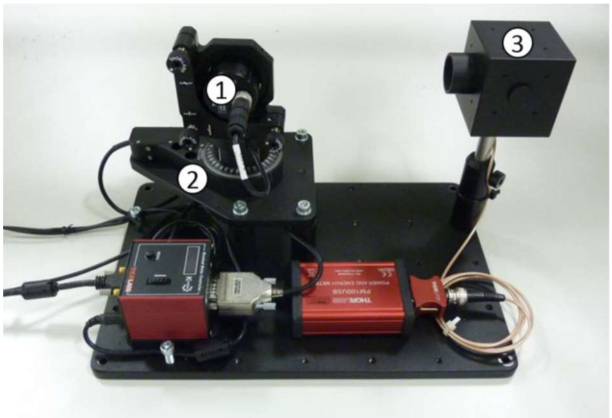

***Fig. 2** Current goniophotometer setup (here not mounted on an optical bench and outside the dark room for illustration): A source (1) mounted on a rotation stage (2) and the optical power measured with a calibrated integrating sphere (3).*

By using LabView the whole set-up is controlled by a computer located outside the dark room and thus fully automated.

Specifications:

The current setup has the following specifications:

- Angle: 0° ≤ φ ≤ 360° (around y-axis)
- Angle resolution: $\Delta\varphi \geq 0.007°$
- Distance d: variable

By rotating the source around the x-axis all possible angles (directions) are measured, see Fig. 3.

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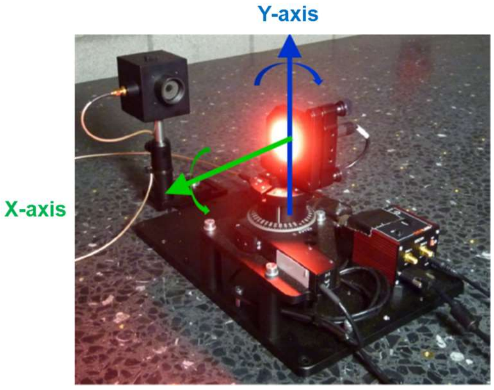

Fig. 3 *Rotating around the Y-axis (angle φ) is fully automated. All other directions are obtained by rotating around the X-axis.*

4 Measurement results

After manufacturing and mounting all components, the control software was developed. All components and the software was tested and verified.

First a white LED (diameter 5 mm) from Everlight (EL5 14250KW [4]) was measured at a distance d = 100 mm for test purposes. The result shows Fig. 4.

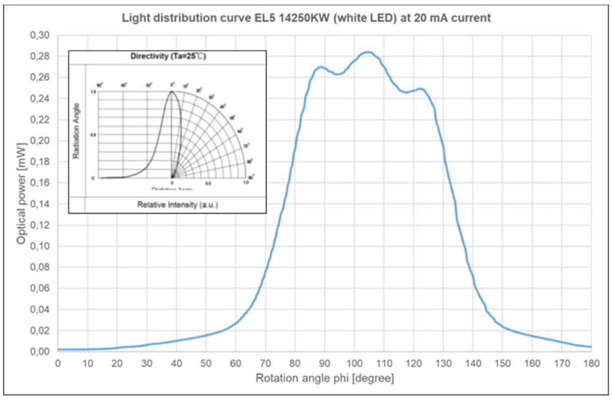

Fig. 4 *. Example: light distribution curve of a white LED (EL 14250). The inset shows the values according the data sheet [4].*

The measurement starts from 0° until 180° and the center of the curve is around 105°. Some deviations between the datasheet curve and the real LED test measurement are obvious.

A repeatability test was done with N = 10 repeated measurements to estimate the current performance of the whole setup. For this purpose a red LED array with 630 nm center wavelength (optical intensity: 4mW/cm^2) at a distance of d = 200 mm was measured. Here the angle varied from φ = 0° to 180° with a resolution of $\Delta\varphi$ = 0.1°. The result shows Fig. 5.

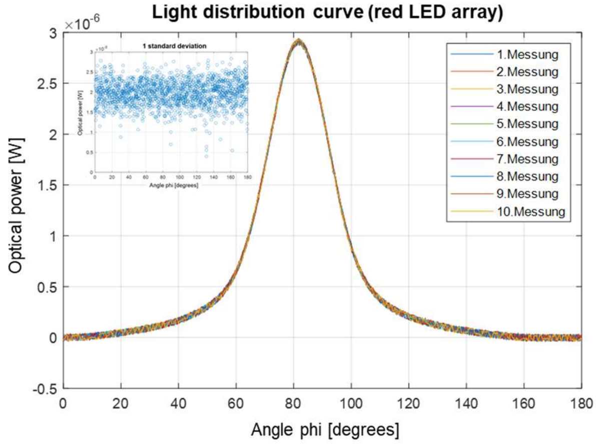

Fig. 5 *Repeated measurements of a LED array. The inset (upper left) shows the calculated 1 standard deviation showing that the current set-up is noise limited by the detector. At the peak (i.e. at around 80°) the percentaged deviation was calculated.*

For this N = 10 repeated measurements the standard deviation s was calculated at the peak power (at ~ 80°) according to:

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{10}[P_i - \bar{P}]^2} \quad (1)$$

Where P_i is the measured optical power of the i-th measurement and $\bar{P}$ is the average power obtained from all 10 repeated measurements at peak power.

5 Result

Due to noise limitation of the detector, one standard deviation at the peak ($\varphi \approx 80°$) was calculated. Currently a uncertainty of 1 standard deviation is $s = \frac{2.0\cdot 10^{-8}}{2.9\cdot 10^{-6}} \approx 0.7\%$. A new detector is in development to overcome the detector noise limit and to test the "real" accuracy of the set-up.

References

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[2] Dietrich Marcuse, *Principles of Optical Fiber Measurements*, (Academic Press, New York 1981)

[3] Hans-Jürgen Hentschel, *Licht und Beleuchtung: Grundlagen und Anwendungen der Lichttechnik*, Hüthig-Verlag (2002)

[4] Data sheet Everlight EL5 14250KW, see: https://www.reichelt.de/led-5-mm-bedrahtet-kalt-weiss-14250-mcd-30-led-el-5-14250kw-p164210.html?&trstct=pos_0 (download, 17.5.2019)