# Problems and requirements of the optical characterization of LEDs

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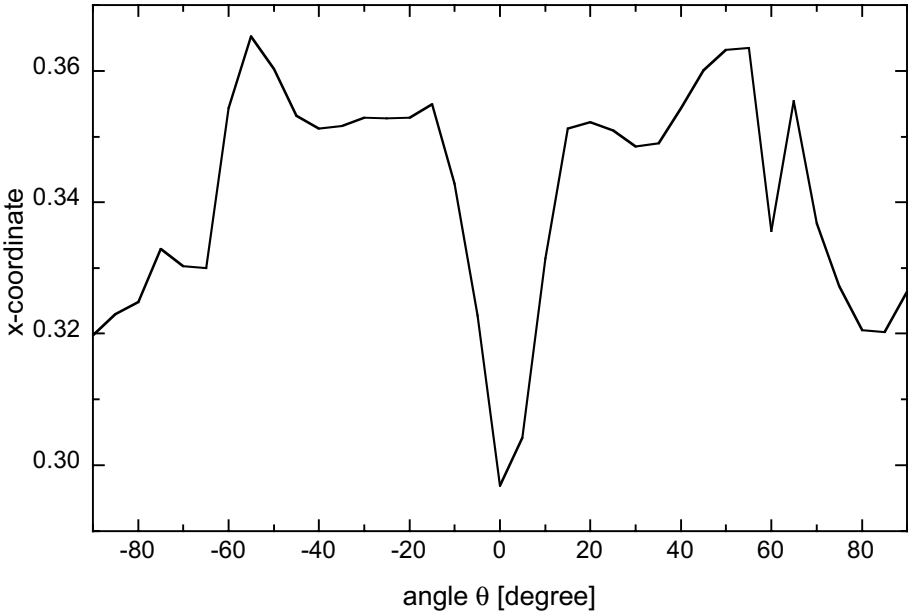
Pushed forward by the development of high brightness blue and white LEDs the field of applications for light emitting diodes is experiencing an incredible growth. The need for characterization of LEDs is increasing more and more, as their optical properties are defining their use.

Because of the wide variety of types and packaging, a lot of problems have to be solved to quantify the optical parameters of LEDs according to the CIE recommendations [1]. This paper is giving an overview of the physical properties of LEDs. The special demands of optical measurement equipment and some examples are discussed. The focus will be on white LEDs, that have other spectral characteristics than standard LEDs.

Two important physical properties of LEDs can influence the measurement results dramatically: The burn in time; which lasts up to minutes for white LEDs made with phosphor, and the spatial radiation pattern which is determined by the design of the LED. White LEDs typically show a variation of color coordinates depending on the viewing angle.




This effect can have influence on the measurement result of color coordinates. It depends on whether the LED is tested within an integrating sphere or the setup corresponds to the CIE recommendation A or B for luminous intensity measurements.

Besides the physical properties of LEDs, the optical setup and the measurement principle have great influence on the measurement accuracy. Either broadband detectors with V(λ)-

adaption of the V(λ)-filter to the real CIE-curve is always poor at the borders of the visible spectral range. This can lead to significant errors for blue and white LEDs.
To avoid these problems a spectroradiometer measures the spectral distribution. Then, the software calculates the photometric and colorimetric values using the exact CIE-curves. To characterize white LEDs, the color rendering index becomes more and more important. This calculation requires a known spectrum of the light source.

High end spectroradiometers are needed to get accurate results. The performance of the measurement system depends on the optics and electronics. Important criteria for the optical parts are wavelength accuracy, spectral resolution and stray light rejection. For the electronics low noise, perfect linearity and high signal dynamic range are separating low from high-end systems.

Only with a correct calibration a spectrometer becomes a spectroradiometer. For LED measurements the following procedure has turned out as most suitable: The wavelength calibration is done with a line source, for example a Hg-lamp. The spectral calibration is carried out with a 1000 Watt FEL-lamp. For the absolute calibration temperature stabilized LEDs are used. They are calibrated to luminous intensity or luminous flux by a national laboratory. During the past few years the absolute calibration with the help of LEDs became common practice.

In principle a spectroradiometer offers many advantages for testing LEDs. But its characteristics like spectral resolution, dynamic range and stray light rejection have an influence on measurement results.
Errors can be produced during the calibration process. The difference in spectral shape of a typical halogen lamp used for the spectral calibration to that of a white LED leads to a different amount of stray light within the spectrometer. Depending on the optical quality and design of the spectrometer this effect can have a significant influence on the results of the color coordinates of white LEDs (see table).

| **Stray light reduction** | **x-coordinate** | **deviation** | **y-coordinate** | **deviation** |
|---|---|---|---|---|
| **> 10e-4** | 0.2894 | - | 0.3041 | - |
| **~ 1E-3** | 0.2915 | 0.0009 | 0.3065 | 0.0024 |
| **~1 E-2** | 0.2915 | 0.0021 | 0.3098 | 0.0058 |

For the correct optical measurement of LEDs certain basic requirements have to be met, to achieve the highest possible accuracy: an optical setup according to the CIE recommendation, traceable calibration standards and a very accurate spectroradiometer are a must.

Bibliography:

[1] Commission Internationale de l´Éclairage, „ Measurements of LEDs“, Publication CIE 127-1997