Novel LED standard source for absolute radiometry in the visible wavelength range

Gerloff, T.[1], Kallenbach, L.[1], Schrader, C. [1], Sperling, A.[1], Šmid, M.[2], Kliment, P.[2], Poikonen, T.[3]

[1] PTB, Braunschweig, GERMANY, [2] ČMI, Prague, CZECH REPUBLIC, [3] VTT, Espoo, FINLAND
Corresponding e-mail address: Thorsten,gerloff@ptb.de

Source-based radiometric calibrations are mainly based on the use of scientific grade incandescent lamps that are traceable to a black body radiators. In this publication we discuss the advantages and disadvantages of a radiometric standard based on LEDs.
Major advantages of thermal radiation sources are the continuous and calculable spectral distribution in a large wavelength range. However, the very large infrared component of thermal sources can lead to problems.
The LED standard source presented here has a very high reproducibility and is particularly suitable for the calibration of radiometric detectors in the visible spectral range.

LED REFERENCE SPECTRA

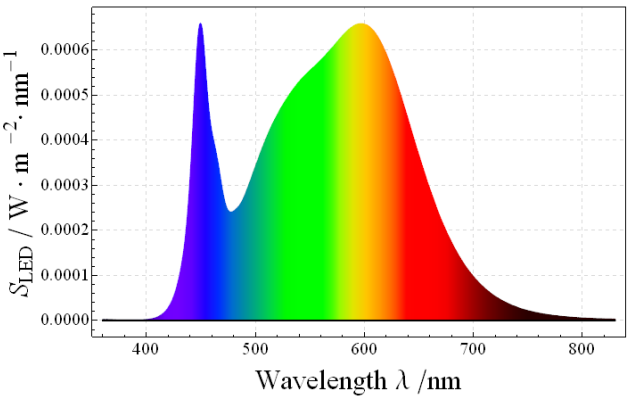
The European research project “Future photometry based on solid-state lighting products” (EMPIR 15SIB07 PhotoLED) has investigated the fundamental requirements for photometry based on white light-emitting diode (LED) sources. Many hundreds of LED spectra were analyzed and suitable LED reference spectra for photometric calibrations were derived [1,2]. In the CIE publication “Colorimetry” were 5 spectral distributions of typical phosphor-converted blue LEDs at colour temperatures, which are commonly used, published.[3]

LED STANDARD SOURCE LIS-A

The construction of the LED source (LIS-A) consists of an aluminium cylinder with a diameter of 100 mm and a length of 70 mm.
The heat exchange takes place via an internal heat sink to achieve a high degree of insensitivity to ambient temperature and air currents. The heat sink is actively cooled by a fan on the back. The temperature of the LED chip is controlled by an underlying Peltier element via an integrated active temperature controller.
24 SMD LEDs are arranged on the printed circuit board. Their typical correlated colour temperature in the standard configuration is between 4000 K and 4100 K.
Originally, the LED source LIS-A was developed as a luminous intensity standard.
During the subsequent characterization, however, it was shown that photometric as well as integral and spectrally resolving radiometric detectors can be calibrated with the LED standard source with low uncertainty.
The investigations include photometers, radiometers, trap detectors, PQEDs and spectroradiometers and show the general usability of the LED standard source.

SPECTRAL IRRADIANCE MEASUREMENT

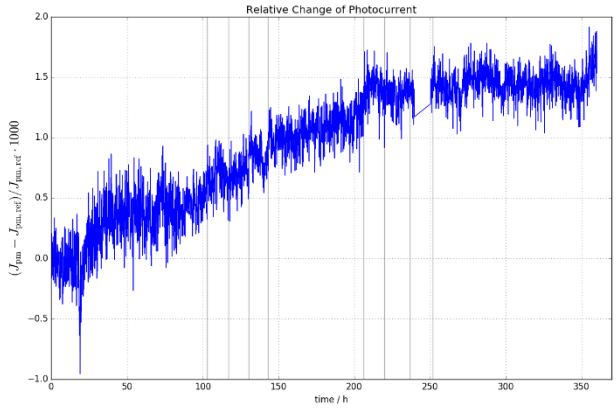
The spectral irradiance of the LIS-A sources was calibrated with scanning double monochromators and array spectroradiometers and also shows good agreement between different NMIs.
The measured spectrum is shown in the figure below.



SEASONING

The LIS-A standard lamps are operated with an external direct current of about 65 mA at a supply voltage of about 75 V.
The built-in temperature control unit keeps the surface of the LED board at a temperature of about 45°C. All LEDs have been seasoned for at least 1000

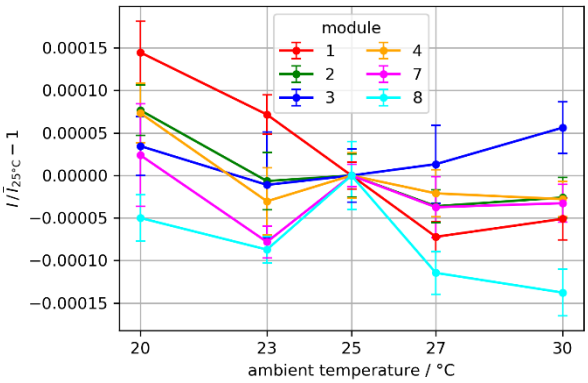
hours to reduce aging effects and ensure stability during operation. The relative changes of the photocurrent of a monitor detector during the last 360 hours of ageing are shown in the figure below.



The average photocurrent change is significantly less than 0.1% for the last 100 hours of seasoning.

EFFECTS OF AMBIENT TEMPERATURE

The figure below shows the relative changes of the detector photocurrent with temperature in relation to the value at the nominal temperature 25°C for 6 different LED modules. The influence of ambient temperature and humidity was determined in a climate chamber with an external photometer. The ambient temperature was varied between 20°C and 30°C and each measurement was performed after 20 minutes of stabilisation time. All measurements were performed at 50% relative humidity.



The deviations are below $1.5 \cdot 10^{-4}$, which can be considered negligible, especially considering the standard deviations at each measurement point.

SUMMARY

The presented LED standard source can be used for a variety of applications. Due to its very good stability and reproducibility, with very low noise, the standard can be used for both photometric and radiometric applications.

In the presentation the special possibilities are highlighted and quantified by analysis of the measurement uncertainties.

REFERENCES

1. Jost, S. et al, „Determination of illuminants representing typical white light emitting diodes sources", CIE x044:2017
2. Development of white LED illuminants for colorimetry and recommendation of white LED reference spectrum for photometry. Metrologia. 55. 526-534
3. CIE 015:2018. Colorimetry, 4th Edition. Vienna: CIE.