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Full Length Article

Study of the Light Emitting Diode as a photoreceptor: Spectral and electrical characterization as function of temperature and lighting source

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ABSTRACT

In this study, the temperature influence on the spectral responsivity of a Light Emitting Diode (LED) used as a photoreceptor, combined to light source spectrum is correlated to electrical characteristics in order to propose an alternative method to estimate LED junction temperature, regardless of the absolute illumination intensity and based on the direct correlation between the integral of the product of two optical spectra and the photo-generated currents. A laboratory test bench for experimental optical measurements has been set in order to enable any characterizing of photoelectric devices in terms of spectral behaviour, in a wavelength range placed between 400–1000 nm, and of current-voltage characteristics as function of temperature by using two different illumination sources. The temperature is analysed in a range from 5 °C up to 85 °C, so as to evaluate thermal variation effects on the sensor performance. The photo-generated current of two LEDs with different peak wavelengths has been studied. Research has observed and mathematically analysed what follows: since the photo-generated current strictly depends on the combination between the spectral response of the photoreceptor and the lighting source response, it becomes possible to estimate indirectly the junction temperature of the LEDs by considering the ratio between the photogenerated currents obtained by using two different illumination sources. Such results may for one thing increase knowledge in the fields where LEDs are used as photo-detectors for many applications and for another, they could be extended to generic photodetectors, thus providing useful information in photovoltaic field, for instance.

1. Introduction

When aiming at increasing the photoreceptor performance, such as a solar cell, it is important to study the impact of temperature on the generated photocurrent [1–3], together with the spectral response changes [4–8]. Since 1980 s, some researchers [9,10] have investigated in this field, in order to determine the dominant factors influencing efficiency at elevated temperatures [11,12]. It is noted that the more the temperature increases, the more the short circuit current density (J_{sc}) grows [4–8] and theoretical models have been developed to support this dependence [8,13,14].

As we know, there is a significant dependence of the bandgap energy in semiconductor on junction temperature T: as temperature increases, bandgap energy decreases, producing both a shift of the emission and absorption spectra towards higher wavelenghts (lower energy) [6].

Actually, a complete characterization of the photo-detector's behaviour should take into account the source optical spectra and the absorption spectra as temperature functions.

This paper presents results on the characterization of photo-detectors, by considering the different matching between source and absorption spectra as the receiver's temperature changes. A practical solution to carry out the study has focussed on using Light Emitting Diodes (LEDs) as a bandwidth-limited photo-detector. Their narrow absorption bandwidth [15–17] combined with the different wavelength ranges has allowed selecting different mutual overlaps between source and absorption spectra.

In literature, studying LED as a photoreceptor had initially a very limited scope, namely characterizing the dependence of junction temperature on the internal efficiency [18] in order to investigate materials for LED construction, thus increasing optical

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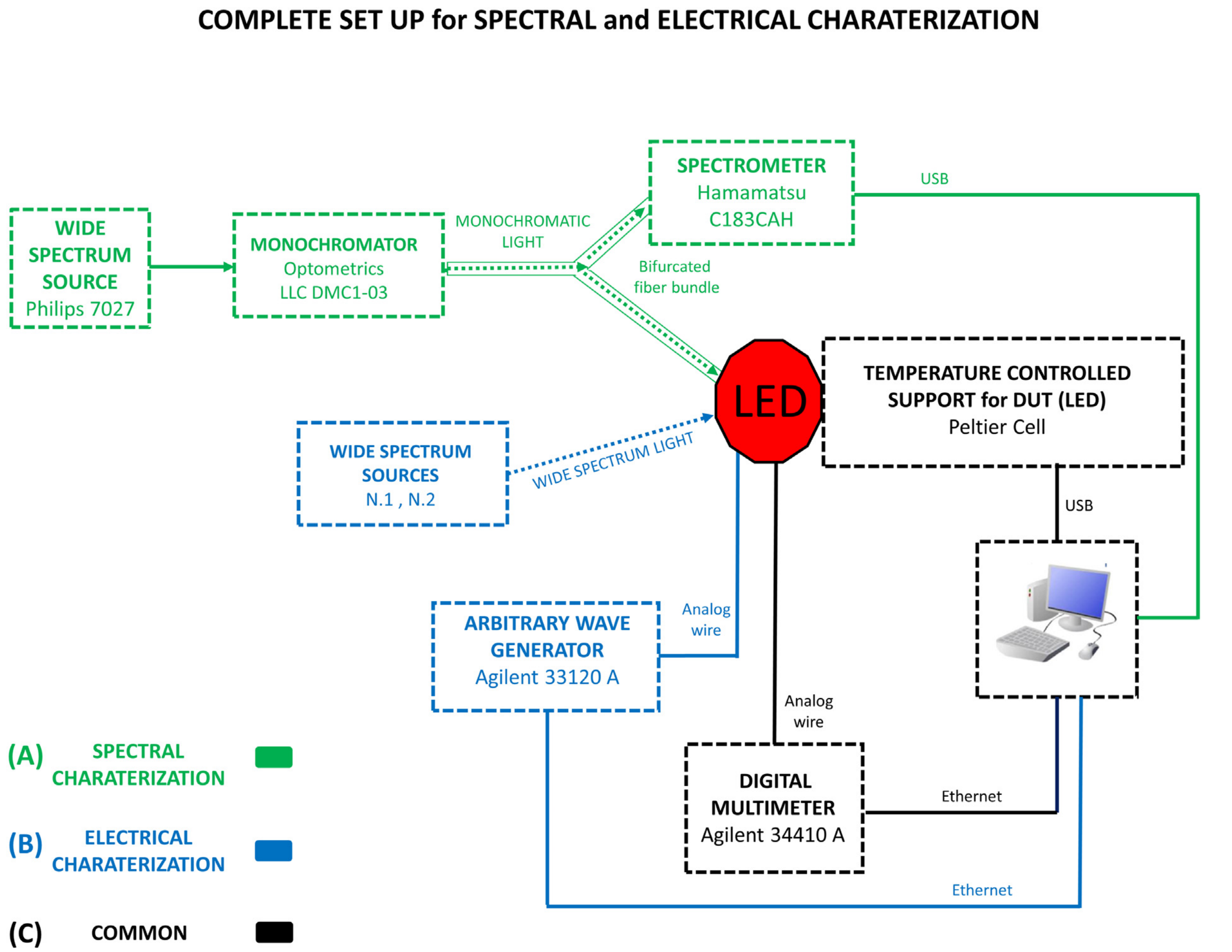

Fig. 1. Scheme of the measurement bench for inverse spectral and electrical LED characterization. The green and black blocks are involved in the spectral characterization, while the blue and black blocks in the electrical characterization.

performances [19–22] or when exploiting LED as a sun photometer [23–27]. On the other hand, recently, the dual LEDs functioning has been largely analysed and exploited within many other new and interesting applications [28–32], such as two-way communication systems [33–35], as colour sensing and illumination devices, as photo-detector in the biomedical field [36,37], and also as field radiometers [38,39].

The current study presents results which may improve knowledge in this emerging field; moreover, it provides the user with a full characterization of LEDs' inverse functioning that is not available in the technical paperwork.

A complete test bench has been set in order to perform, at the same time, spectral and electrical characterization of the optical devices used as light detectors, as temperature changes.

Two different LED models have been analysed to measure absorption spectra and current-voltage characteristics in the fourth quadrant, at five different temperature values and with two different light sources.

Junction temperature is one of the key parameters in LED applications and it has been extensively studied in literature. In particular, in Ref. [40] the junction temperature has been evaluated by measuring the LED inverse current. In this work a novel method to evaluate LED junction temperature is suggested. LED junction temperature has been estimated by measuring a short circuit photocurrent ratio measured on the analysed device and illuminated by two different sources. This technique allows for temperature assessment regardless of the source's illumination intensity.

2. Materials and methods

2.1. LED spectral characterization

Authors have spent their efforts to define an experimental measurement system able of performing repeatable, representative and reliable measurements, where multiple parameters can be controlled and varied at once. As to the inverse characterization, an appropriate measurement bench, schematically reported in Fig. 1, has been set. The green and black blocks in the measurement chain of the Fig.1 represent the instrumental components used to analyse the absorption spectrum of the LED employed as a photoreceptor. The optical equipment consists of:

1 A wide spectrum halo source, Philips 7027, with a nominal power of 50 W;
2 A monochromator (Optometrics LLC DMC1-03) with a range of 300–850 nm that selects a narrow (3 nm at -3 dB) spectrum light, which is guided, through an optical fiber bundle, towards LED to be characterized. In this experimentation the monochromator range has been modified to enlarge its wavelength range up to 1000 nm;
3 A 6.5 digit Multimeter Agilent 34410 A which allows for any measuring of voltage or current with high accuracy;
4 A Peltier cell performing a temperature control from 5 °C up to 85 °C and allowing for the analysis of the LED behaviour at