The temperature-dependent changes of the photometrical and colormetrical parameters of today high power LEDs

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1 Introduction

Currently available high power LEDs have a big self-heating which is caused by their high power consumption. This is why thermal management is one of the main topics in the use of high power LEDs. The temperature of the pn-junction has a great influence on the photometrical and colormetrical parameters.
The main topic of this student research project is to determine the temperature-dependent changes of the photometrical and colormetrical parameters of representative power LEDs. Therefore a thermal controlled appliance for high power LEDs is built. It is also necessary to analyze different possibilities to measure or calculate the junction temperature and to estimate the errors of the calculation.

2 Measurement

2.1 Measurement of the junction temperature t_J

To determine the temperature-dependent changes of the photometrical and colormetrical parameters the junction temperature t_J has to be measured or calculated. Four different methods are mentioned in literature:

- Measurement of the forward voltage and calculation of the junction temperature by the current-voltage characteristics of the measured LEDs.
- Measurement of the spectral distribution and calculation of the junction temperature by the peak wavelength shift $\Delta\lambda_P$.
- Measurement of the surface temperature of the LED-chip by an infrared camera.
- Measurement of the substrate temperature of the LED and calculation of the junction temperature by the thermal static equivalent circuits.

All possibilities to calculate the junction temperature have been analyzed and checked if they can be used. The used method in this research is to measure the substrate temperature of the LED package and to calculate the junction temperature by using the thermal static equivalent circuit.

2.2 Measurement

For the analysis of the temperature-dependent change of the photometrical and colormetrical parameters of today high power LEDs more than 50 different LEDs of different manufactures has been analyzed.

At the beginning of the measurement the LED package is soldered onto the metal core board. Afterwards the combination of the LED and the metal core board is mounted on the temperature-controlled appliance.
The next step is to apply the needed current to the LED and wait until the structure is thermally stabilized. During the measurement each LED is measured at 5 till 6 different temperatures depending on the admissible temperature-range given by the manufacturer. The spectral power distribution is measured from 380 nm up to 780 nm with an INSTRUMENT SYSTEMS spectrometer. Additionally the temperature-dependent forward voltage change is measured with a KEITHLEY 2400 Multimeter.

3 Result

In this chapter the results are presented by typical data. They will be discussed and compared to the data of the datasheets given by the manufacturer.

3.1 Spectral power distributions

The temperature-dependent changes of the spectrum are shown in figure 1. The “yellow” Platinum Dragon has been chosen as the most representative Platinum Dragon because of its clearest temperature-dependent changes. All measured LEDs have a similar but not that pronounced behavior.

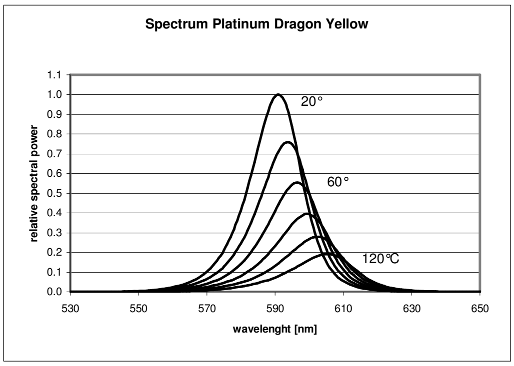

Figure 1: spectra of Patinum Dragon “yellow”

The “yellow”, “amber” and “red” are made of AlInGaP (Aluminum Indium Gallium Phosphide). The “deep-blue”, “blue” and “green” Platinum Dragon are much more insensitive to temperature. This depends on the different semiconductor materials (InGaN: Indium Gallium Nitride). The maximum intensity of the spectrum increases up to 20 % by a change of 100℃ of the junction temperature. The peak wavelength λ_P changes from 591 nm up to 605 nm and the dominant wavelength λ_D from 588 nm up to 599 nm. This phenomenon is caused by the higher thermal energy in the pn junction of the LED. This results in a lower band gap and a lower photonic energy of the emitted radiation and therefore it results in a longer wavelength.

3.2 Chromaticity coordinate shift

The temperature-dependent behavior of the chromaticity coordinates is shown by a Luxeon K2 “amber”. It demonstrates the clearest thermal behavior. See figure 2.

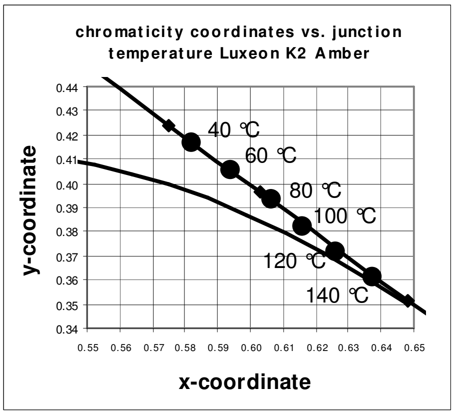

Figure 2: chromaticity coordinates Osram Ostar 4

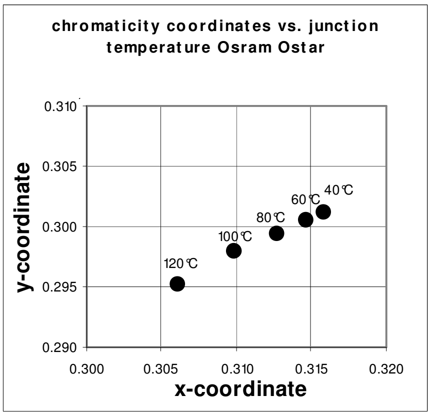

Figure 3: chromaticity coordinates Luxeon K2 “amber”

The chromaticity coordinates clearly change into the red region of the chromaticity coordinates diagram. The coordinates of the LED are located on the perimeter so this behavior directly describes the behavior of the dominant wavelength. All measured high power LEDs show this change to longer wavelengths. All chromaticity coordinates change along the perimeter. The chromaticity coordinates’ temperature-dependency of the Osram Ostar is shown in figure 3. The coordinates shift into the blue region. The correlated color temperature is rising, although the peak wavelength of the blue chip is getting longer. This behavior is caused by the wavelength shift of the phosphor. The spectrum of the used converter switches to shorter wavelength. The addition of both effects causes the rising color temperature with rising junction temperature.

4 Conclusion

All measured high power LEDs based on the InGaN material-system are more insensitive to temperature than the LEDs based on the AlInGaP material-system. This is a typical behavior. The ”amber” respectively “yellow” colored LEDs show the most considerable temperature-dependent behavior of all measured LEDs. The maximum spectral intensity of these LEDs decrease to 20 % of the maximum intensity. However the “blue” ones only decrease down to 60 %. Furthermore all measured values are in the range of the information given in the manufactures’ datasheets. This mainly depends on the wide range of this information. To get the desired result of the use of high power LEDs it is essential to know all parameters of the LEDs exactly. The information given by the manufactures is sometimes not sufficient.

[LUX06] Phillips Lumileds: *Luxeon thermal design guide*, Application brief AB05, 2006

[K206] Phillips Lumileds: *Luxeon K2 Emitter technical datasheet DS51*, 2006

[SIN07] Singer, C.: *Lichtstrommessung an LED-Bauelementen jüngster Generation*, Studienarbeit, TU-Darmstadt Fachgebiet Lichttechnik, 2007