Development of a led based standard for luminous flux

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Abstract: Incandescent lamps, simple artifacts with radiation spectrum very similar to a black-body emitter, are traditional standards in photometry. Nowadays leds are broadly used in lighting, with great variety of spectra, and it is convenient to use standards for photometry with spectral distribution similar to that of the measured artifact. Research and development of such standards occur in several National Metrology Institutes. In Brazil, Inmetro is working on a practical solution for providing a led based standard to be used for luminous flux measurements in the field of general lighting. This paper shows the measurements made for the developing of a prototype, that in sequence will be characterized in photometric quantities.

Keywords: led, luminous flux standard, optical metrology, photometry.

1. INTRODUCTION

For a long time, laboratory standards for photometry have been incandescent lamps calibrated at the correlated color temperature (CCT) of 2 856 K, which corresponds to the so called illuminant A[1,2]. The spectral power distribution of light emitted by incandescent lamps is very similar to that of a blackbody radiator, which was mathematically described by Planck. Following Planck's law, the measurement of the spectrum of an incandescent lamp allows for the calculation of its CCT and, conversely, the knowledge of the CCT allows the determination of its spectrum.

Since the spectral response of instruments do not match perfectly to the V(λ) function, the spectrum of the standard to be used should be similar to the spectrum of the lamp to be measured, or of the existing luminous source where a calibrated instrument will be used. Thus, the development of led based standards is crucial.

Spectral power distributions of led sources used in general lighting (phosphor-based white led) have great similarity, with a rather sharp peak emission in the blue region accompanied by a broad peak in the yellow, what permits the use of a small number of different spectra to cover the entire range of non-special led light sources [3]. This boosted the application of led to general lighting.

Led standards generally require control of the junction temperature because of its strong influence on the luminous emission [5]. Alternatively, this can be achieved by waiting the stabilization of temperature and emission, within the bounds specified by the led manufacturer. The first solution has greater complexity and costs, and the second leads to long waiting periods (sometimes, in excess of one hour), to obtain the stabilization, which implies in waste of time and reduced number of utilizations of the standard between calibrations.

At Inmetro, we are working on an alternative solution without controlling the temperature. Instead, we monitor it during a fixed amount of time in which the led is supplied with constant electric current. Using this approach avoids the need for an active electronic temperature control, simplifying the project and reducing costs.

2. DEVELOPMENT STEPS OF THE PROTOTYPE

Aging tests were conducted with several led chips of different technologies. Due to easier integration in the project, the COB (chip on board) type led was selected. COB's performance dependence on temperature was specified by the manufacturer. The temperature of a COB is easily monitored, in a point designed for this in the chip support, named Tc, and shown in figure 1.

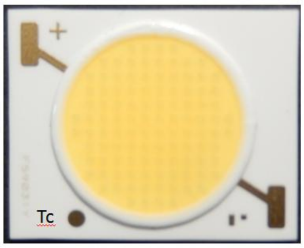

Figure 1 – Selected model of COB led

The selected COB is supplied with an electrical current so that the luminous flux is around 1 000 lm, which is the typical luminous flux found in commercial lamps tested in integrating spheres. The electrical current is significantly smaller than the nominal value of the COB. Additionally, a housing was designed to fit the COB, composed by: a copper baseplate, a diffusing glass enclosure, thermocouple wires soldered to Tc, and electric wires.

Three units of the selected COB mounted in the housing were aged and monitored during more than 6 000 h, to check its stability. The luminous flux was measured each 100 h or 200 h. These measurements were made using an active temperature control and the results are in figure 2.

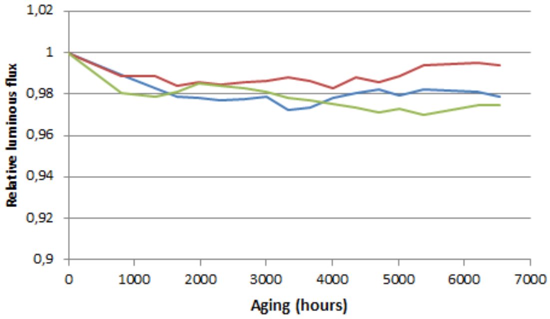

Figure 2: Relative luminous flux of 3 COBs used in the tests

To select the heat sink, the temperature at Tc was monitored as a function of the operation time with several models of heat sinks. The curve for the selected heat sink is shown in figure 3.

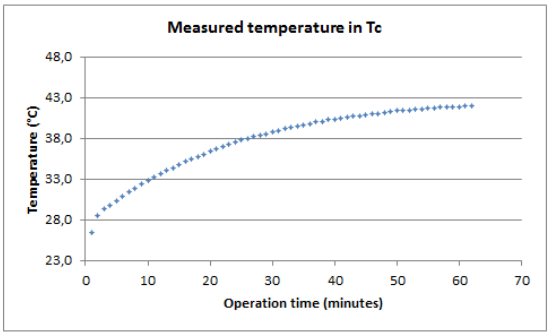

Figure 3: Tc temperature versus operating time

Figure 4 shows an image and a schematic drawing of the prototype.

The luminous flux was measured as a function of the temperature at Tc at the selected current (0.202 A) (figure 5). This allowed the determination of the best temperature interval to perform the measurement.

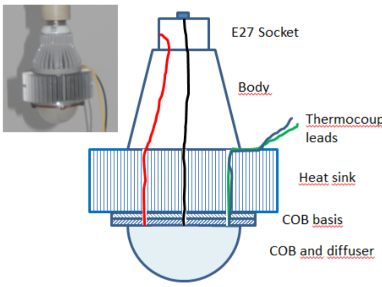

Figure 4 – Image and schematic drawing of the prototype

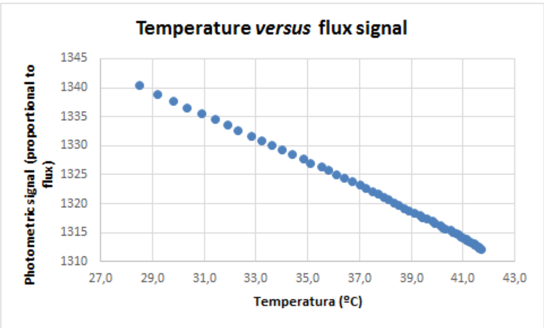

Figure 5 – Luminous flux as a function of Tc temperature during an interval of 60 minutes (supplied current 0.202 A).

The measurement of the temperature at Tc is performed using a thermocouple. The electric wiring is shown in figure 6.

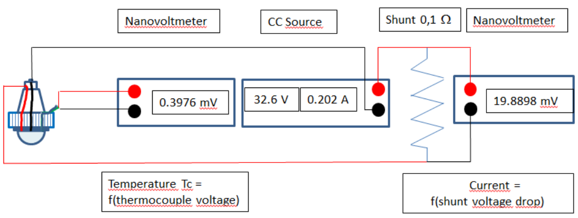

Figure 6 – Instruments and connections to the DC supply, and measurements of the current and Tc temperature

3 ANALYSIS OF RESULTS

Luminous flux standards are not routinely used. At Inmetro, we estimated that 50 hours of use, which is a typical interval in between calibrations, allows at least 150 measurements, each taking until 20 minutes. After the 6 000 h aging, the maximum observed drift in luminous flux was 0.04 % during 50 h, that is suitable for luminous flux standards.

The evolution of the temperature at Tc (figure 3) shows that it could be necessary more than 60 minutes for full stabilization. However, in figure 5 one can note that the luminous flux varies uniformly with Tc temperature. This allows the selection of a Tc temperature, that should trigger the beginning of the measurements, and a time interval, that describes the duration of the measurement.

A numerical data analysis, based on R^2 parameter of straight line segments fitted to the data, showed that when the Tc temperature reaches 34 ºC, the measurement could be started, with readings being taken in a time interval of 5 minutes. During this period, luminous flux variation is approximately linear and the temperature at Tc changes less than 1 ºC.

This process, i.e., supplying electric current to the lamp and waiting for the temperature reaching the suitable value, takes from 8 to 10 minutes due to the dependence on the initial temperature of the prototype.

Once the specified Tc temperature is reached, a series of readings of luminous flux signal are made during a 5 minutes period (figure 7).

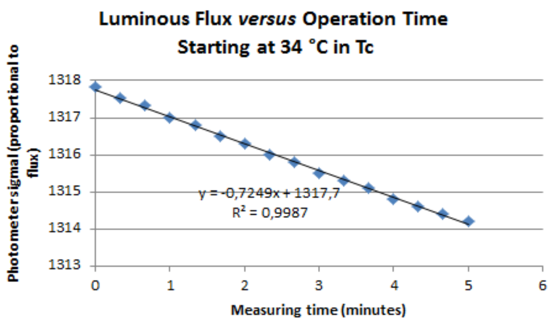

Figure 7 – 16 readings of luminous flux made during a 5 minutes period

The value of the luminous flux is obtained by the average of the readings. Though it is possible to analyze the dispersion considering the interpolated line, this was not necessary because the standard deviation of the readings in the 5 minutes interval was only 0.1 %, which is negligible to the measurement uncertainty, at least in the current phase.

The change in the prototype's colorimetric properties was also evaluated as a function of the temperature at Tc. This parameter can be considered constant, within the instrument uncertainty, which is 17 K for CCT, for the range of Tc temperature in the measurements.

Uncertainty estimation was based in the Brazilian translation of Guide to the Expression of Uncertainty in Measurements – GUM 2008 [6]. The uncertainty components are presented in Table 1. These components are related to the measurement of the prototype using an integrating sphere with a standard incandescent lamp.

Table 1. Uncertainty budget for the measurement of luminous flux of the prototype.

Entries	Symbol	Contribution [%]
Standard lamp uncertainty	ΦN	33.82
Standard lamp repeatability	YN	0.08
Instrument resolution w/standard lamp	δYN-res	0.09
Test lamp repeatability	YT	5.28
Instrument resolution w/test lamp	δYT-res	0.14
Auxiliary lamp repeatability w/standard	YHN	3.04
Non-stability auxiliar lamp w/standard	δYHN-ins	5.31
Auxiliary lamp repeatability w/test lamp	YHT	2.83
Non-stability auxiliary lamp w/test lamp	δYHT-ins	5.35
V(λ) filter uncertainty	δYf1	35.50
Reproducibility	δΦT-rpr	8.56

The estimated expanded uncertainty *U* of the measurement was 1.7 %. The more important contributions to the uncertainty were the working standard lamp (U_{ws} = 1.1 %) and the V(λ) filter ($U_{V(\lambda)}$ = 1.0 %).

4. CONCLUSION AND OUTLOOK

This paper presents an alternative to mount, characterize and use of led based standard for luminous flux, by the determination of a Tc temperature suitable for the measurement, instead of waiting for the stabilization or using active temperature control. The calibration of the standards will be made using an integrating sphere and a reference luminous flux standard.

5 REFERENCES

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ACKNOWLEDGEMENTS

We would like to thank Inmetro for providing scholarships through the program Pronametro; Elo Sistemas Eletrônicos for providing material and expertise to the project; Renato N. Teixeira, Robson Chagas and Klaus N. Quelhas for the technical support in the temperature measurements.