High power LED standard light sources for photometric applications

Evgeniy Ivashin, Sergey Ogarev, Boris Khlevnoy, Stanislav Shirokov, Dmitry Dobroserdov and Victor Sapritsky

All Russian Research Institute for Optical and Physical Measurements (VNIIOFI), Moscow, Russia

Corresponding e-mail address: ivashin@vniiofi.ru

Abstract. High power LED light sources have been developed as possible new VNIIOFI standard sources for luminous intensity, luminous flux and colour measurements. Stability, repeatability and spatial uniformity of the sources were investigated and demonstrated high accuracy and homogeneity. The paper describes different tests on one of the manufactured sources. In the future, these LED light sources are planned to be used as standard luminous flux sources to transfer the units of luminous intensity and luminous flux from goniometer to sphere-spectrometer.

1. Introduction

For the purpose of dissemination of the units of luminous intensity and luminous flux, incandescent lamps are currently used. The use of incandescent lamps involves a number of difficulties: transportation, large heat emission during operation (for large levels of luminous intensity and luminous flux), the effect of ambient temperature on metrological characteristics, and relatively short service life. The main trend at present is the use of light-effect-diodes (LEDs) for transfer of a unit of luminous intensity and luminous flux. Growing-up LED lighting industry and lack of incandescent lamps rises the need for developing of new photometric standards on the basis of LEDs. Activities aimed at such development are carried out at CCPR, CIE and a number of NMIs [1-4]. In particular, in the presentation [1] of Dr. Y. Ohno at the 23rd Meeting of CCPR (Sevres, France) in September 2016, dedicated to LED sources in Photometry at NIST, the following related activities in CCPR are mentioned: (1) Working group of KC TG-4 Pilot study for the use of alternative standards for photometric comparisons, which is devoted to investigate the use of white LED products (but not limited to those) as artifacts for future photometric comparisons in CCPR; (2) Working group of SP Discussion Forum on use of white LED sources for photometry.

VNIIOFI has also started a project on developing and investigating high power LED light sources, which are to be used as standard sources for luminous intensity, luminous intensity distribution, luminous flux and colour measurements. To transfer a unit of luminous intensity and luminous flux, LED sources on the basis of powerful chip on board (COB) diodes and a control device for these sources were developed to replace SIS 107-500, SIS 107-1000, and SIP 107-1500 lamps.

The design of the source, its stability investigation results, spectral spatial uniformity, and luminous intensity spatial uniformity are presented in this paper. Further, in this work we describe in few words VNIIOFI realization of power supply for precision stabilizing of high power LED sources.
2. Design of LED source

The source consists of two parts: a light head and a parametric current source. The design of the light head (Figure 1) allows using any LEDs of the COB type. Three heads were built: two white with power of 36 W and 68 W and a blue one of 30 W. White LEDs were selected as the most stable from a batch after seasoning for 250 hours. When the sources were assembled they were additionally seasoned for 100 hours. The blue LED was manufactured specially for VNIIOFI and was pre-aged by manufacture. For reference sources, LEDs were selected for the following parameters: spatial distribution of luminous intensity, correlated color temperature, luminous intensity, luminous flux, operating temperature range at rated current, type of substrate.

The light head contains a Peltier element and a temperature sensor Pt1000 for high-accuracy temperature stabilization of the LED. The choice of platinum thermo resistance as a diode temperature control sensor is due to the high stability and the possibility of using this type of sensors in the bridge circuit, which is necessary to control the diode temperature in the selected stabilization control circuit. Peltier element was selected with double power reserve on cooling productivity. The LED is surrounded by a diffuse wall chamber consisting of a PTFE tube and a transparent opal glass, which makes angle radiation homogeneous with a good approach to the lambert law and makes spectral distribution independent from the angle of observation. Moreover, using the PTFE tube and opal glass establishes a volume like a «temperature chamber» surrounding the LED, which is a good location for the temperature sensor. LEDs have a special point with minimal thermal resistance to light emitting crystals on the same side with them. In front of the opal glass there is an aperture with diameter of 20 mm. All connections of elements placed on different sides of the Peltier element are made with special thermo isolated screws. Heatsink with cooler was selected by power dissipation according to Peltier electrical power. All orange elements in fig.1 are made from copper, because it has well enough thermal conductivity.

Figure 1. Design of light-head. 1. High power chip on board (COB) LED, 2. Opal glass, 3. PTFE tube, 4. Aperture, 5. Peltier, 6. Heatsink, 7. Fan, 8. Pt1000.

The values of axis luminous intensity of the built white LED sources are approximately 650 cd and 1000 cd, and the values of luminous flux are 1500 lm and 2500 lm.

The second part of the stabilized LED light sources is fine enough power supply for the LED, and a power supply with temperature measurements from Pt1000 and feedback to regulate the current of the Peltier depending on the temperature. Each power supply in VNIIOFI standard LED supply is
a stabilized current sources. Both the power supply and the temperature measurement system are realized in one package and named also parametric power supply.

The block diagram of the parametric power supply is shown in Figure 2. It consists of two independent current sources (one for LED and another for Peltier), a temperature measurement system, a control block for realizing feedback for temperature stabilization and one fixed source with 12 volts up to 0.5 ampere for cooler on heatsink in LED construction (Figure 1). The current source supplying the LED is a stabilized source with a discreteness of the current setting of $30 \times 10^{-6}$ A. The discreteness of the setting of the current generated by the power source of the Peltier element is $50 \times 10^{-6}$ A. The small step of setting the Peltier current is due to the need for high-precision stabilization of the diode temperature with a small change in the ambient temperature. The control unit generates a control signal for the power source of the Peltier element based on the diode temperature. Besides, power supply system has connection port RS232 to control the system via computer. Each current channel provides current up to 2.1 A with resolution of 0.03 mA. The range of the stabilized temperatures can vary from 30°C to 45°C with resolution of 0.01°C. For the LEDs mentioned above, the temperature of 36°C was used.

Typical current for the chosen LED’s is about 1 ampere. Stability of the current source for LED on 1 ampere level is the same as its resolution, 0.03 mA.

![Figure 2. Flowchart of power supply system (parametric current sources).](image)

3. Investigation of stability
At the first stage of investigation of the new sources their stability and repeatability were determined. First the temperature stability of the diode was checked for different levels of ambient temperature. The result of this test is shown in Figure 3. The LED temperature was stable within ± 0.05°C for 3.5 h while the ambient temperatures gradually varied from 20°C to 33°C and ±0.2°C for the range from 33°C to 36°C. This experiment was carried out to make sure that the cooling productivity of the chosen Peltier will be enough to stabilize the temperature of the LED in quite wide temperature range. Wide ambient temperature range is important because standard LED’s are planned to be used in industrial laboratories to calibrate their facilities.

Photometric stability of the source was investigated using a temperature stabilized LMT photometer equipped with a precision amplifier. The LED source and the photometer were placed in a light-tight room with ambient temperature of 22°C. The distance from the source to the photometer was 3.162 m. The luminous intensity of the LED was recorded automatically during a whole working
day (Figure 4). The luminous intensity demonstrated slight drift of about 0.02% for 7 h. The reason of
the observed drift could be stability of the LED power supply as well as the stability of the
measurement system.

![Figure 3. Relation of LED temperature stability from ambient temperature (green - LED temperature, red-ambient temperature)](image)

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![Figure 4. Relative change of luminous intensity.](image)

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Repeatability of the source was estimated by 10 measurements; each measurement was performed after turning the LED off, re-alignment and on again. Standard deviation of the measurements was 0.035% with drift of luminous intensity included.

4. Investigation of spatial homogeneity
The LED-based thermostabilized sources were investigated for their spatial homogenities of the luminous intensity distributions and spectral distributions in different angles with a C-γ goniometer including a thermo stabilized LMT photometer with low-current precision measurement system and a
spectroradiometer Konica Minolta CS-2000A. Spectral measurements were provided in reflectance mode using a small barium-coated plate.

**Figure 5a.** Luminous intensity distribution with lambert distribution.

Spatial luminous intensity distribution of the source is shown in Figure 5a. Luminous intensity distribution has good homogeneity. Standard deviation of luminous intensity between different C-angles (for fixed γ-angles) is less than 2% for the range of γ-angles from -70° to 70°. This fact is very important because it made possible calibration of industrial gonio-spectrometers and gonio-photometers with bigger angular steps to decrease time of calibration. But tests show that form of aperture in front of the light-head is bad, because we saw reflectance from the aperture bevel (10° and 170° peaks on the graph in Figure 5b).

After spectral distributions measured in different directions colour coordinates were calculated and the results are shown in Figure 6.

**Figure 5b.** Deviation from average distribution.

**Figure 6.** Relation between colour coordinates and angle of observation.

The maximum deviation of the colour coordinates is Δx=0.006 and Δy=0.004 from the 0° axis colour coordinates. This small deviation is simplifying calculations of uncertainties for the spectral mismatch correction factor when we calibrate gonio-photometers with this thermo-stabilized LED.
5. Conclusions
The design of quasi-lambertian high power LED sources for chip on board type LEDs has been developed. Two white LED sources have been built with luminous intensity of 500-1000 cd and luminous flux of 1500-2500 lm and photometric stability of 0.02% for approximately 10 h.

The developed LED sources can be used as standard photometric sources and may, in future, replace incandescent lamps.

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