UDC 535.241.3

High power LED based standard lamps for luminous flux and luminous intensity

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Abstract

BelGIM together with Cersys Analitycs designed and manufactured LED-based reference lamps. The lamp was originally designed for use not only as a part of the national measurement standards, but also as a transfer standard for verifications and calibrations of customers' equipment.

Our analysis of the sources of uncertainty of the LEDs' photometric parameters (associated with the light source itself) showed that the main ones are the uncertainties caused by the instability of the power source and the temperature regime of LED chip. Also in the works carried out within the framework of the EURAMET PhotoLED project it was shown that the lowest uncertainty of the results of measurements of photometric parameters (on equipment calibrated by the LED-based standard) is achieved when used as a reference LED with CCT of 4000 K. Based on this concept the reference lamp was created. COB LED manufactured by CREE is placed in an aluminum housing providing primary heat dissipation. Thermostabilization at a temperature of 20 °C is provided by a Peltier element and a feedback loop based on the pt-1000 temperature sensor located on the LED surface. Cooling of the Peltier element is performed by a supply fan, while the LED is completely shielded from the effect of air movement. The temperature controller of the LED is located outside the lamp and communicates with it, depending on the required configuration, either through the fittings of the calibrated equipment, or through an optional external cable. This measure reduces greatly the overall dimensions of the source, that allows to apply it in calibrations of photometric spheres with a diameter of 1 m or more. Lamps are equipped with a set of interchangeable connectors that provide compatibility with the power fittings of photometric spheres produced by Instrument Systems GmbH or by using E27 lamp cap. The lamps are powered by an external high-stabilized power source Keithley 2400. The light sources are made in two models: SELFI-I and SELFI-F (acronym for Standard Emitter for Luminous Flux [and luminous] Intensity), as reference lamps of luminous flux and luminous intensity respectively. The SIIP design differs from the SIIS by the presence of a diffuser for creation a uniform luminous flux and a horizontal orientation of the LED.

The following was established based on research of metrological characteristics of standard LED lamps:

- Instability of photometric characteristics during 4 hours of continuous operation is not more than 0.05 %.
- Instability of photometric characteristics during 500 hours is not more than 0.1 %.

Keywords: luminous intensity, luminous flux, standard lamp, LED, photometry.

Received: 07.02.2019 Edited: 26.02.2019 Approved for publication: 11.03.2019

Introduction

Intensive development of lighting technology, the complexity and improving of the ergonomic requirements, development of new types of lighting, all of this makes it necessary to solve more complex metrological tasks in the field of photometry. The progress achieved over the past 10 years in the field of energy-saving light sources is comparable, and in some ways superior to the revolution of the late 19th century, when there was a shift from the lights on the basis of organic fuel burning to electric light bulbs. The situation with metrological assurance of the measurement of luminous flux and luminous intensity in recent years has become much more complicated. Firstly, in accordance with the requirements of international standards, during calibration of photometric equipment, it is necessary to use a source with a spectral power distribution (SPD) as close as possible to the SPD of the DUT [1]. And SPD's of the incandenst lamps, compact fluorescent lamps and LED's are differ greatly [2]. Secondly, after the entry into force of the EU Directive 2005/32/EG, the world's major producers turned down the production of incandescent lamps [3]. At the same time, the production of the standard lamps for metrological propose was also closed. Similar

production lines in the countries of the former USSR were closed in the 90's. Thus the relevance of the problem is in no doubt.

Construction research and development

BelGIM has a more than 10 years experience in LED photometry [4] so together with Cersys Analitycs it was decided to design and manufacture LED-based reference lamps. The lamp was designed for use not only as a part of the national measurement standards, but also as a transfer standard for verifications and calibrations of customers' equipment. After analysis of state of art in the field of LED photometry, the work was divided into 2 phases: phase 1 – light source with natural cooling, phase 2 – light source with forced cooling.

At phase 1 it was decided to create a model of not cooled LED-based lamp. Analysis of similar studies has shown that light sources created at NIM, China, have sufficient stability [5]. As DUT we used COB LED and LED-filament lamps. First results of research showed encouraging results (example of measurement results see in Table).

The results of stability studies of luminous flux of the lamps with natural cooling

lamp type					
	10 h	**20 h**	**30 h**	**40 h**	**50 h**
LED-filament 1	830	826	812	798	770
LED-filament 2	850	824	816	803	890
LED-luminophore 1	1550	1530	1525	1521	1518
LED-luminophore 2	1550	1550	1540	1530	1525

But after 55–60 hours of burning all COB-lamps burnt out. In our opinion, this was due to the use of adherent hemispherical diffuser. This design was chosen to achieve the uniformest light distribution, as close as possible to that of conventional luminous flux standard lamps. Nevertheless, this construction also prevented sufficient heat transfer from LED chip. The use of LED-filament lamps also had to be abandoned due to insufficient stability.

At phase 2 we tried another approach. Deep analysis of the sources of uncertainty of the LED's photometric parameters (associated with the light source itself) showed that the main ones are the uncertainties caused by the instability of the power source and the temperature regime of LED chip. Also in the works carried out within the framework of the EUROMET PhotoLED project it was shown that the lowest uncertainty of the results of measurements of photometric parameters (on equipment calibrated against the LED-based standard) is achieved when used as a reference LED with CCT around 4000 K [6]. Based on this concept the reference lamp was created.

Characteristics and construction of the lamps

COB LED CXA 2530 manufactured by CREE is placed in an aluminum housing providing primary heat dissipation. Thermostabilization at a temperature of 20 °C is provided by Peltier element and a feedback loop based on the pt-1000 temperature sensor located on the LED surface. Cooling of the Peltier element is performed by a supply fan, while the LED is completely shielded from the effect of air movement. Flowchart of the lamp's heat-stabilizing device is shown in Fig. 1. Fig. 2 shows the thermogram of the lamp after stabilization.

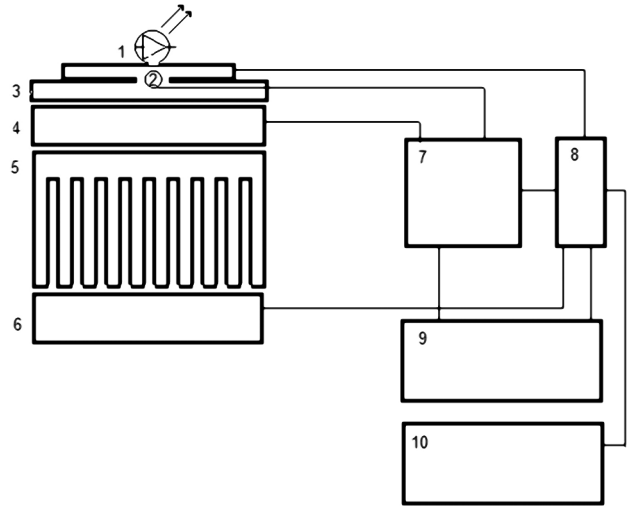

Fig. 1. Flowchart of the lamp's heat-stabilizing device: 1 – COB LED CXA 2530; 2 — temperature sensor; 3 – heat-integrating plate; 4 – Peltier element; 5 – dissipating radiator; 6 – the fan; 7 – controller of the Peltier element; 8 – system for blocking of LED power supply with non-operating cooling system; 9 – power supply of Peltier element and controller unit; 10 – LED power supply

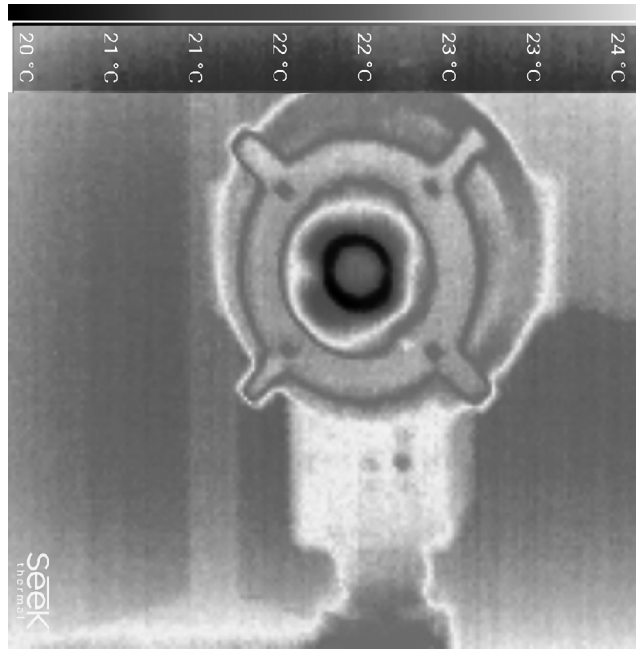

Fig. 2. The thermogram of the lamp after stabilization

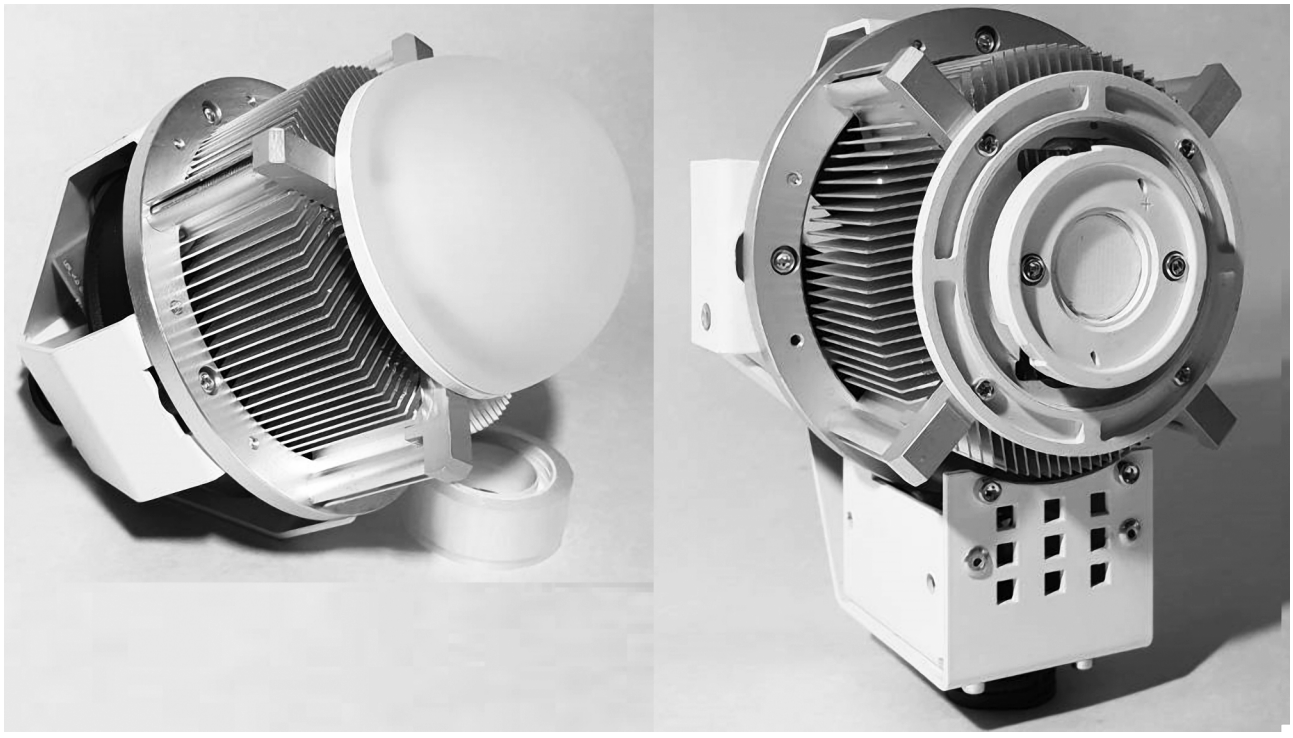

Fig. 3. Appearance of SELFI-F (left), SELFI-I (right) lamps

The light sources are made in two models: SELFI-I and SELFI-F (acronym for **S**tandard **E**mitter for **L**uminous **F**lux [and luminous] **I**ntensity) as reference lamps of luminous flux and luminous intensity respectively. The SELFI-F design differs from the SELFI-I by the presence of a diffuser for creation a uniform luminous flux and a horizontal orientation of the LED. Appearance of lamps is shown in Fig. 3. Spatial distribution of luminous intensity of SELFI lamps presented in Fig. 4. It is seen that luminous intensity distribution of SELFI-F lamp has better homogeneity compare to incandencet standard lamps of luminous flax of SIP type.

The temperature control unit of the LED is located outside the lamp and communicates with it, depending on the required configuration, either through the fittings of the calibrated equipment, or through an optional external cable. This measure reduces greatly the overall dimensions of the source, that allows to apply it in calibrations of photometric spheres with a diameter of 1 m or more. Lamps are equipped with a set of interchangeable connectors that provide compatibility with the power fittings of photometric spheres produced by Instrument Systems GmbH or through a E27 socket. The lamps are powered by an external high-stabilized power source Keithley 2400.

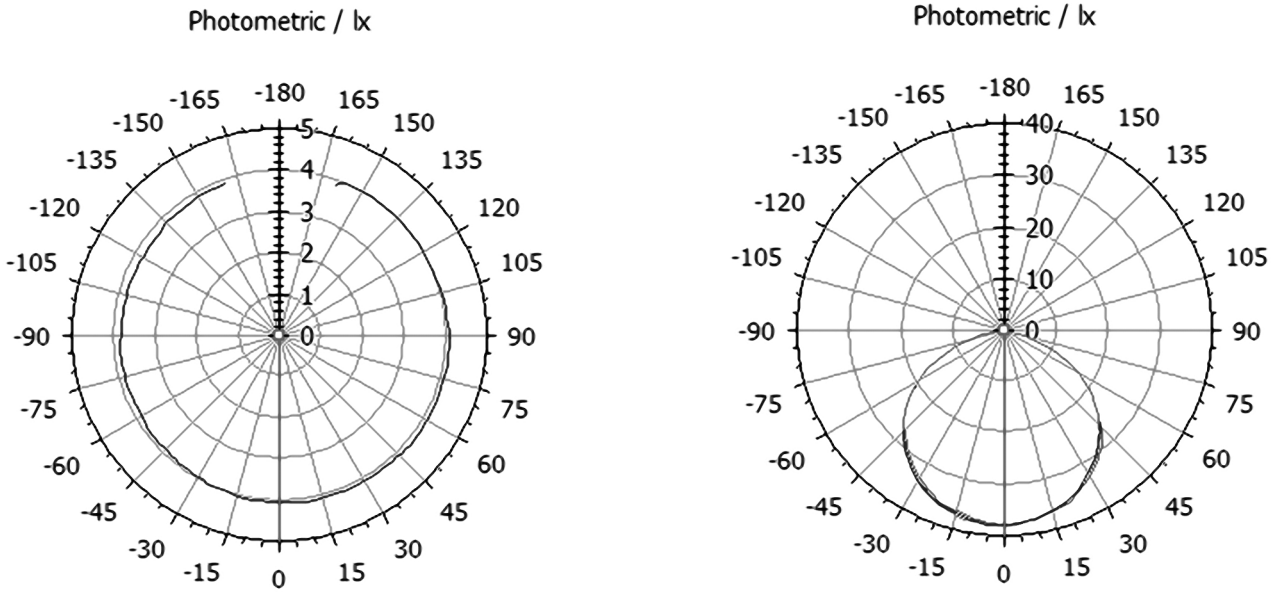

Fig. 4. Spatial luminous intensity distribution of SELFI-F (left) and SELFI-I (right) lamps

In general, the open design of the lamp makes it possible to use any COB LED depending on the customer's requirements for the amount of luminous flux, luminous intensity or CCT.

Before starting study of the characteristics lamps have been pre-burned 200 hours at a current of 0.700 A. Studies were carried out on short-term stability (during up to 8 hours of continuous operation) and long-term stability (100 hours of total operating time with interruptions from several hours to several days). The study of long-term stability is ongoing.

The following was established based on research of metrological characteristics of standard LED lamps:

• Instability of photometric characteristics during 8 hours of continuous operation is not more than 0.05 %. The value of the luminous flux is from 3000 to 4000 lumens, depending on the lamp current.

• Instability of photometric characteristics for 100 hours is not more than 0.08 %.

Conclusions

The design of high power LED-based standard lamps for luminous flux and luminous intensity has been developed. Lamps showed sufficient stability for use as transfer standards for verifications and calibrations of customers' equipment. Work on the inclusion of the lamps in the State Register of measuring instruments approved for use in the field of legal metrology is underway. In addition, it is planned to use SELFI-I lamps as a light source for PQED-based primary luminous intensity reproduction.

Эталонные лампы силы света и светового потока на основе светодиодов высокой мощности

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Аннотация

В БелГИМ совместно с компанией "Церсис Аналитик" спроектированы и изготовлены эталонные лампы на основе светодиодов. Лампы были изначально спроектированы не только для применения в составе национальных эталонов силы света и светового потока, но и в качестве рабочих средств измерения для поверки и калибровки оборудования заказчиков.

Анализ источников неопределенности измерения фотометрических параметров светодиодов (связанных с самим источником света) показал, что основными являются неопределенности, вызванные нестабильностью источника питания и температурного режима светодиодного чипа. Также, в рамках работ, выполненных по проекту EURAMET PhotoLED, было показано, что наименьшая неопределенность результатов измерений фотометрических параметров (на оборудовании, откалиброванном с помощью эталона на основе светодиодов) достигается при использовании в качестве эталонного светодиода с КЦТ 4000 К. Исходя из вышеизложенных условий, нами был спроектирован референсный источник излучения.

Светодиод, изготовленный по технологии COB, производства фирмы CREE размещен в алюминиевом корпусе, обеспечивающем первичное рассеивание тепла. Термостабилизация при температуре 20 °С обеспечивается элементом Пельтье и контуром обратной связи на основе датчика температуры pt-1000, расположенного на поверхности светодиода. Охлаждение элемента Пельтье осуществляется приточным вентилятором, при этом сам светодиод полностью экранирован от воздействия движения воздуха. Модуль управления температурой светодиода расположен снаружи лампы и подключается к ней, в зависимости от требуемой конфигурации, либо через разъемы калибруемого оборудования, либо через дополнительный внешний кабель. Эта мера значительно уменьшает габаритные размеры источника, что позволяет применять его для калибровки фотометрических шаров диаметром 1 м и более. Лампы оснащены набором сменных разъемов, которые обеспечивают совместимость с арматурой фотометрических шаров, производимых фирмой Instrument Systems GmbH, или через цоколь Е27. Лампы питаются от внешнего высокостабилизированного источника питания Keithley 2400. Источники света выполнены в двух моделях: СЭЛФИ-П и СЭЛФИ-С (акроним Светодиодные Эталонные Лампы (для) Фотометрических Измерений), эталонная лампа светового потока и силы света соответственно. Конструктивно лампы СЭЛФИ-П и СЭЛФИ-С отличаются наличием диффузора для создания равномерного светового потока у первых и горизонтальной ориентации светодиода вторых.

Ключевые слова: сила света, световой поток, эталонная лампа, СИД, фотометрия.

Еталонні лампи сили світла і світлового потоку на основі світлодіодів високої потужності

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Анотація

У БелГІМ спільно з компанією "Церсіс Аналітик" спроектовано і виготовлено еталонні лампи на основі світлодіодів. Лампи було спочатку спроектовано не лише для застосування у складі національних еталонів сили світла і світлового потоку, але і як робочі засоби вимірювання для звірення та калібрування обладнання замовників.

Аналіз джерел невизначеності вимірювання фотометричних параметрів світлодіодів (пов'язаних із самим джерелом світла) показав, що основними є невизначеності, викликані нестабільністю джерела живлення і температурного режиму світлодіодного чипу. Також, у рамках робіт, виконаних за проектом EURAMET PhotoLED, було показано, що найменша невизначеність результатів вимірювань фотометричних параметрів (на обладнанні, відкаліброваному за допомогою еталона на основі світлодіодів) досягається при використанні як еталонного світлодіода з ККТ 4000 К. Виходячи з вищевикладених умов, нами було спроектовано референсне джерело випромінювання.

Світлодіод, виготовлений за технологією COB, виробництва фірми CREE розміщено в алюмінієвому корпусі, що забезпечує первинне розсіювання тепла. Термостабілізація за температури 20 °С забезпечується елементом Пельтьє і контуром зворотного зв'язку на основі давача температури pt-1000, розташованого на поверхні світлодіода. Охолодження елемента Пельтьє здійснюється припливним вентилятором, при цьому сам світлодіод повністю екранований від впливу руху повітря. Модуль управління температурою світлодіода розташований зовні лампи і підключається до неї, залежно від необхідної конфігурації, або через розніми каліброваного обладнання, або через додатковий зовнішній кабель. Цей захід значно зменшує габаритні розміри джерела, що дозволяє застосовувати його для калібрування фотометричних куль діаметром 1 м і більше. Лампи оснащено набором змінних рознімів, які забезпечують сумісність із арматурою фотометричних куль, котрі виробляє фірма Instrument Systems GmbH, або через цоколь Е27. Лампи живляться від зовнішнього високостабілізованого джерела живлення Keithley 2400. Джерела світла виконані у двох моделях: СЕЛФВ-П і СЕЛФВ-С (акронім Світлодіодні Еталонні Лампи (для) Фотометричних Вимірювань), еталонна лампа світлового потоку і сили світла відповідно. Конструктивно лампи СЕЛФВ-П і СЕЛФВ-С відрізняються наявністю дифузора для створення рівномірного світлового потоку у перших і горизонтальної орієнтації світлодіода других.

Ключові слова: сила світла, світловий потік, еталонна лампа, СВД, фотометрія.

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