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M. Huriev

NSC "Institute of metrology" Kharkiv, Ukraine

THE STATE PRIMARY STANDARD OF LUMINOUS FLUX FOR METROLOGICAL SUPPORT OF MEASUREMENTS OF LED LAMPS IN UKRAINE

Describes the modern problems in the measurements of the luminous flux of LED lamps associated with their emission spectra, and describes the state primary standard of luminous flux, methods of reproducing the unit of luminous flux and transferring it to the working light sources. The results of theoretical and experimental studies of nodes in the reference standard trap- detector with a correcting filter, spherical photometer and the whole plant. Presented the uncertainty budget of measurements of the luminous flux of light sources. Considered its opportunities and prospects for measurement assurance in the field of LED lighting sources in Ukraine

Key Words: *trap-detector, correcting filter, spherical photometer, standard of luminous flux, actinic coefficient, LED lamps.*

Introduction

At the present time in connection with the increasingly accelerated development of production of lighting products based on led technology, which is associated with huge energy efficiency significantly greater (8 times more) than lighting fixtures based on incandescent bulbs, there are problems related to metrological assurance of this product.

Currently, there are standards of luminous flux, which were developed and calculated for standard filament lamps with a color temperature of 2800 K.

As a measure of the luminous flux spherical photometers are used with photodiodes (figures 1 and 2), mounted on the wall of the sphere and equipped by filters, correcting of relative spectral sensitivity of the photometer to the luminance function in accordance with DSTU GOST 8.332 : 2008 [6].

For the calibration of spherical photometers use either a reference lamp of known luminous flux (source type A) or the measured directional luminous flux from the source type A. Subsequently, these photometers measure the filament lamp with spectral characteristics close to the source of type A. In this case, the problems with accuracy for incandescent does not exist, as actinic coefficient for all these lamps will be the same. But if you measure the led sources, whose spectral characteristics differ greatly from a source of type A, the error associated with the difference of actinic coefficient will be significant.

This problem exists all over the world. As shown by recent studies led sources in the advanced laboratories of the world, the differences in the measured luminous flux was more than 5%. There are the metrological problems in this kind of measurement, and it must be solved.

With regard to metrological accuracy and uniformity of measurements of the luminous flux of led technology in Ukraine, In NSC "Institute of Metrology" at the end of 2012, the state primary standard unit of luminous flux lumen was developed. At this time, the problem of metrological assurance of led technology has been, therefore, during the development of the standard it is taken into account.

Description of the benchmark

Figure 1 shows a photograph of standard, and figure 2 shows the structural-functional scheme of the state primary standard of luminous flux for the reproduction and transmission of unit size reference radiation sources .

Figure 1. Picture of the state primary standard of luminous flux

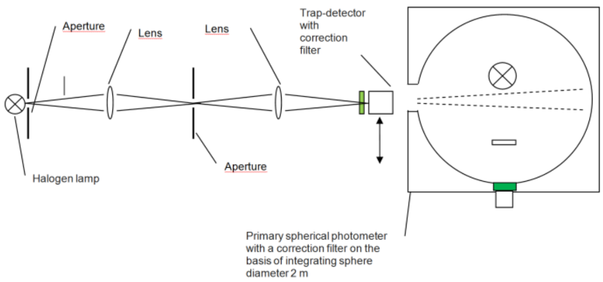

Figure 2. Functional diagram of apparatus for reproduction and transmission of luminous flux to the light sources of large size

Plant for reproducing and transferring the unit of luminous flux of the radiation sources of large dimensions provides the reproduction of unit of the integrated luminous flux with a source of optical radiation on the basis of halogen lamps with the opto-mechanical system forming a directional luminous flux, and reference the primary transmitter on the basis of the trap-detector with correction filter and the conspicuity of a system of automated mechanical movements.

The device ensures the transmission of the size of the unit of luminous flux working standards - the reference radiation sources with the help of spherical photometer with a photodiode with correction filter on the basis of integrating sphere 2 m.

For reproducing the unit of luminous flux through optical radiation source on the basis of halogen lamps and optical-mechanical system formed of the directional luminous flux, which comes in the reference of the primary measuring transducer on the basis of the trap-detector [1] with correction filter and the system of automated mechanical movements (figure 2).

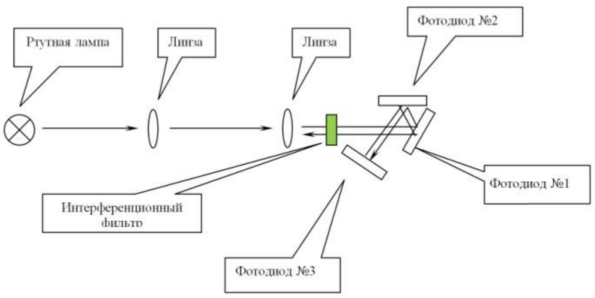

Figure 3 Scheme of plant for measuring the directional integral of the luminous flux by using the trap-detector with correction filter

System of measurement of the photocurrent measured by the reference signal of the primary trap-detector, it identifies the values of luminous flux in lumens.

To measure the luminous flux in trap-detector used the Hamamatsu photodiodes with hundred-per-cen internal quantum efficiency for optical radiation in the wavelength range from 400 to 900 nm.

To ensure close to absolute external quantum efficiency, a scheme of measurement of luminous flux (figure 3). Due to the fact that the thread 5 times hits the photodiodes, only a small fraction, less than 0.1 % (in the visible wavelength range), comes back from the trap-detector. The coefficient of radiation absorption of the device is close to 1, which ensures almost one hundred percent external quantum efficiency of a trap-detector.

Spherical photometer has an internal coating of $BaSO_4$. The photodiode with milk glass and correction filter is placed on the lateral surface of the spherical photometer and adjusts the relative spectral sensitivity curve of the photometer to the luminosity curve *V(λ).*

Also the radiation source is placed inside the sphere, which is passed the size of the unit. Between the radiation source and detector are placed valve that prevents direct rays from the light source to get on the milk glass. In addition, the spherical photometer has a hole that allows the external luminous flux coming to the wall of the sphere so that the light spot from the radiation flux was situated in sight of milk glass receiver.

This design allows to measure the sensitivity of the spherical photometer by means of known external luminous flux and to use this sensitivity to measure the luminous flux from the reference light source that is calibrated.

The results of the research

One of the main metrological characteristic of the trap-detector with correction filter is the difference between the relative spectral sensitivity of the receiver and luminosity curve *V(λ)* [6].

The study of the spectral sensitivity of trap-detector was carried out at the State primary spectroradiometric standard of Ukraine DETU 11-06-06. The study of the correction filter was carried out on the State primary standard of spectral transmittance DETU 11-09-08. The results are shown in figure 4. The graph shows the difference between the relative spectral sensitivity of trap-detector with correction filter - *S(λ)* and the luminosity curve - *V(λ).*

As a result of research it was determined the actinic coefficient of the trap-detector with correction filter by the formula:

$$A = \frac{\int_{380}^{780} \Phi(\lambda)\cdot V(\lambda) d\lambda}{\int_{0}^{\infty} \Phi(\lambda)\cdot S(\lambda) d\lambda} \qquad (1)$$

Where *Φ(λ)* is the relative spectral characteristics of the luminous flux, *S(λ)* is the relative spectral sensitivity of trap-detector with correction filter.

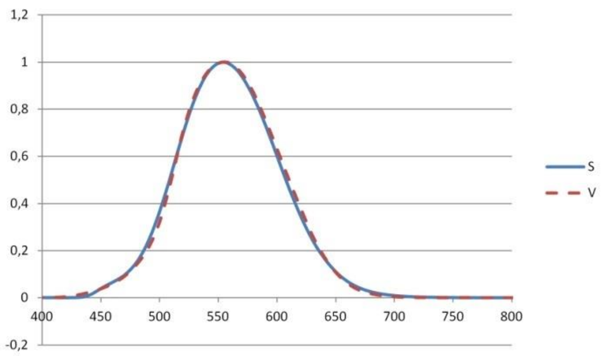

Figure 5. Graph of the relative spectral sensitivity of trap-detector with correction filter - *S(λ)* and the luminosity curve - V(λ).

The relative spectral sensitivity of trap-detector with correction filter can be represented as:

$$S(\lambda) = S_{trap}(\lambda)\times \tau(\lambda)/(S_{trap}(\lambda)\times \tau(\lambda))_{max} \quad (2)$$

Where $S_{trap}(\lambda)$ is the spectral sensitivity of trap-detector, *τ(λ)* is the spectral transmittance of the correction filter.

The value of the $S_{trap}(\lambda)$ and *τ(λ)* was determined with absolute methods on two state primary standards separately from the point of view of convenience, since reliable determination of actinically the value of *S(λ)* is desirable to know with a step of 1 nm.

The definition of this step for construction in the Assembly on the standard DETU 11-06-06 almost impossible (absolute inertial receiver, etc.), but check the linearity of the spectral characteristics of the trap-detector without the correction filter is task is quite doable, and that was done and we have seen the perfect linearity of the spectral characteristics of the trap-detector without the correction filter. The measurement spectral transmitance of the correction filter was carried out on the spectrophotometric plant of the start primary standard DETU 11-09-08 in increments of 1 nm for a short time and repeatedly. All this has allowed us to accurately determine actinic coefficient.

For lamps with a color temperature of 2800 K (source type A) the actinic coefficient of the trap-detector with correction filter A = 1,0077. If you change the color temperature of ± 100 K there is a change of the actinic coefficient A = 1,0077 ± 0,0003.

From these results it can be concluded that the actinic coefficient of the receiver is only weakly dependent on the color temperature of halogen lamp and allows high precision (in terms of the actinic coefficient) to determine the sensitivity of the receiver to luminous flux for a source type A. which amounted to $S_\Phi = 3{,}5985 \times 10^{-4}$ A/lm.

$$S_\Phi = S(555))/(683\times A) \qquad (3)$$

Where *S(555)* is the sensitivity of trap-detector with correction filter at the wavelength $\lambda = 555$ nm was determined by the absolute method on the State primary spectroradiometric standard of Ukraine DETU 11-06-06.

Studies of the relative spectral sensitivity of the spherical photometer was carried out on the State primary standard of the DETU 11-06-06 (spectral response of the photodiode with correction filter, and milk glass) and the DETU 11-09-08 (spectral characteristic of the coating of the sphere).

The results are shown in figure 5. The graph shows the difference between the relative spectral sensitivity of the spherical photometer - *S(λ)* and the luminosity curve - *V(λ)*.

For a spherical reference photometer on the basis of integrating sphere diameter 2 m the actinic coefficient for lamps with a color temperature of 2800 K was the follows: A = 0,9963. If you change the color temperature of ± 100 K there is a change of the actinic coefficient: A = 0,9963 ± 0.002.

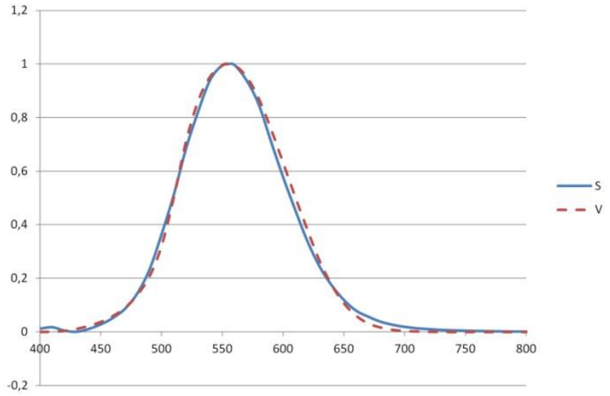

Figure 5. Graph of the relative spectral sensitivity of spherical photometer - *S(λ)* and the luminosity curve - V(λ).

The reliability of the results of research of characteristics of spherical photometer was validated using the developed experimental method for the determination of actinic coefficient.

Uncertainties

Table 2 shows the values of relative standard uncertainties from different sources.

Table 2. Uncertainty of measurement of luminous flux in NSC "Institute of Metrology"

The source of uncertainty	Value relative standard uncertainty (%)
Measurement of the photocurrent at the output of the trap-detector	0,023
Measurement of the photocurrent at the output of the spherical photometer	0,023
Determination of the sensitivity (A/lm) of trap-detector with correction filter for directional luminous flux from a halogen lamp	0,116
The heterogeneity of the spherical photometer band sensitivity	0,12
The difference between actinic coefficient of the spherical photometer for the reference lamp and actinic coefficient for halogen lamp	0,3
Current measurements of the lamps with the adjustment	0,04
Uncertainty type B	**0,35**
Uncertainty type A (non-reproducibility in independent measurements)	**0,01**
Total standard uncertainty	**0,35**

These uncertainties were confirmed by the results of international key comparisons within COOMET, the results of which are currently issued.

Conclusion

Developed in NSC "Institute of Metrology", state primary standard lumen allows high accuracy to reproduce and pass the size of the unit of luminous flux, a work measuring lamps of all types, including led. This gives you the ability to provide traceable production and certification of led technology in Ukraine, which is currently the most urgent problem connected with the implementation of energy-efficient technologies.

This has been achieved through the research components of standard and experimental methods of actinic coefficient, which confirms their reliability.

LITERATURE

[1] M. Huriev, A. Kupko, and L. Nazarenko. Double-diode configuration of self-calibrating photodiodes // SPIE Annual Meeting. Advanced Characterization Techniques for Optics, Semiconductors, and Nanotechnologies. Volume 5188. – San Diego, CA, USA – 2003. - P. 351-357

[2] Zalewski E.F. Silicon photodiode absolute spectral response self-calibration/ E.F. Zalewski, J. Geist//Appl. Opt., 1980, 19, pp. 1214 – 1216.

[3] Geist J. Spectral response self-calibration and interpolation of silicon photodiodes/J. Geist, E.F. Zalewski, A.R. Schaefer//Appl. Opt., 1980, **19**, pp. 3795 – 3799.

[4] Geist J. High accuracy modeling of photodiode quantum efficiency/ J.Geist, H.Baltes//Appl. Opt., 1989, **28**, pp. 3929 – 3939.

[5] Zalewski E.F. Silicon photodiode device with 100% external quantum efficiency/ E. F. Zalewski and C.R. Duda//Appl. Opt., 1983, **22**, pp. 2867 – 2873.

[6] ДСТУ ГОСТ 8.332:2008 ГСИ. Световые измерения. Значения относительной спектральной эффективности монохроматического излучения для дневного зрения.