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The Means for Evaluation of Light Source Characteristics

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***Abstract*—Light emitting diodes have many positive features comparing with incandescent and fluorescent lamps like its small size; high luminous efficiency, long lifetime and reliability. That features increases the popularity of LEDs using in lighting. However there are many cheap, non-certified light emitting diodes bulbs in the market, where the parameters of the light emitting diodes bulbs are undeclared or declared incorrectly. The simple and low cost evaluation methods for evaluation of efficiency of light sources are presented in the paper.**

***Index Terms*—Light emitting diodes, energy consumption, luminous flux measurement, directional diagram, evaluation.**

I. INTRODUCTION

About 20 % of all global electricity is used for lighting. The biggest problem regarding energy consumption is that the efficiency of the incandescent light bulbs is low and the major part of the electricity is converted into radiated heat. The growing scientific research is carried out to increase the efficiency of electricity for electronic equipment and reduce global warming [1].

Currently, the light sources of light emitting diodes (LEDs) are rapidly developed. LEDs applicability comparing with incandescent or fluorescent lamps depend on [1]:

1) *its small size,*
2) *long lifetime,*
3) *higher luminous efficiency,*
4) *reliability, which is related with shocks and vibrations,*
5) *there is no gas or filament to light emission.*

The efficiency of LEDs has become significant only in the last decade, which until recently were used only as indicators [1]. Market offers large variety of LEDs lighting devices or bulbs, however efficiency and operational features are not declared or declared incorrectly.

The aim of the paper is to present the simple and low cost evaluation means for estimation of efficiency of light sources. It allows estimating the preliminary efficiency by measuring the luminous flux and the directional diagrams of the light sources.

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II. LUMINOUS FLUX MEASUREMENT MEANS

Overall, the total luminous flux of the light source is measured with a photometer or with an Ulbricht sphere [2], [3]. The last method is widely used by the LEDs light sources manufacturers. The measurement of the luminous flux of the light source with an Ulbricht sphere is rather fast, but expensive method (due equipment cost). It is possible to measure and estimate the luminous flux and the preliminary efficiency of the light source using low cost equipment.

The luminous flux Φ is described as how much energy the light brings to the surface area *S* of the body per 1 s. The unit for the luminous flux of a light source is known as the lumen (lm). The illuminance is equal to the ratio of the luminous flux $d\Phi$ and illuminating surface area *dS* [3], [4]

$$E = \frac{d\Phi}{dS}, \ [lx]. \tag{1}$$

If the luminous flux has equitable distribution then illumination of the surface is calculated as

$$E = \frac{\Phi}{S}, \ [lx], \tag{2}$$

where Φ – the luminous flux; *S* – illuminating surface area.

When the light of the light source goes:

1) *To the surface perpendicularly then the illuminance is directly proportional to the intensity of the light source (I). In such case the illuminance reaches the maximum;*
2) *By a certain angle φ between the normal and the beam of the light then the illuminance depends on the angle of the light and distance r between the light source and the illuminated surface*

$$E = \frac{I}{r^2}\cos\ \phi, \tag{3}$$

where I – the intensity of the light source; r – the distance between the light source and the illuminated surface; φ – the angle between the normal and the beam of the light.

The simple evaluation methods are proposed for illuminance estimation of any size light sources in the paper. Depending on the type of the light source there is recommendation to use one of three suggested schemes (Fig. 1–Fig. 3).

The measurement scheme for light sources with axial symmetry with large and medium width directional diagram is presented in Fig. 1.

The measurements were carried out using the AX-L230 lux meter in the dark laboratory. In this case the light source is fixed in the selected distance (eg. $R=0,5$ m) from the measurement plane and the lux meter sensor. The lux meter sensor is placed perpendicularly to the light source longitudinal axis. The measurements of illuminance are taken by choosing suitable radius from the lux meter sensor and shifting the sensor every 15 degrees from 0° to 180°. The angle of shifting $\Delta\alpha$ can be changed to ensure proper accuracy of evaluation.

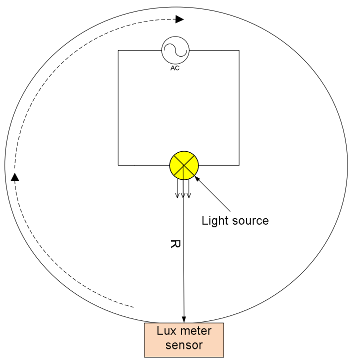

Fig. 1. Luminous flux and light diagram estimation scheme for light source with the axial symmetry with large and medium width directional diagram.

If the light source does not have axial symmetry, but the directional diagram of the light source has symmetry in two planes, then the measurement scheme presented in Fig. 2 should be used. The example of this kind of light source could be the fluorescent lamp (T8 type). In this case the light source is fixed horizontally in the centre of the imaginary circle (Fig. 2, (a)). The centre of the lamp must tally with the centre of the circle. The measurements of illuminance are taken by choosing suitable radius from Lux meter sensor and shifting the sensor every 15 degrees from 0° to 180°. As with the first scheme the angle of shifting can be changed to ensure proper accuracy of evaluation. In the second part of the measurements the light source is fixed vertically in the centre of the circle (Fig. 2, (b)). The sequence of the measurements is analogous to the previous sequence. Any size light source can be estimated using this method and choosing suitable radius of measurement the luminous flux and directional diagrams.

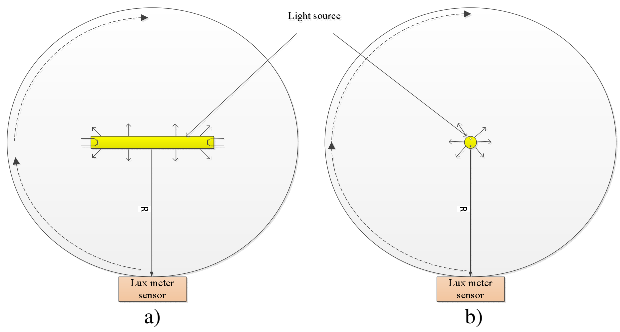

Fig. 2. Luminous flux and light diagram estimation scheme for light source without axial symmetry.

The measurement scheme for light sources with axial symmetry and narrow directional diagram (eg. flashlight) is presented in Fig. 3.

The light source (flashlight) should be fixed in the selected distance from the measurement plane (eg. L=5 m). The lux meter sensor is placed perpendicularly to the flashlight longitudinal axis. The measurements are taken by shifting the sensor every 10 cm in the measurement plane. The distance L and step a should be selected considering the characteristics of light source.

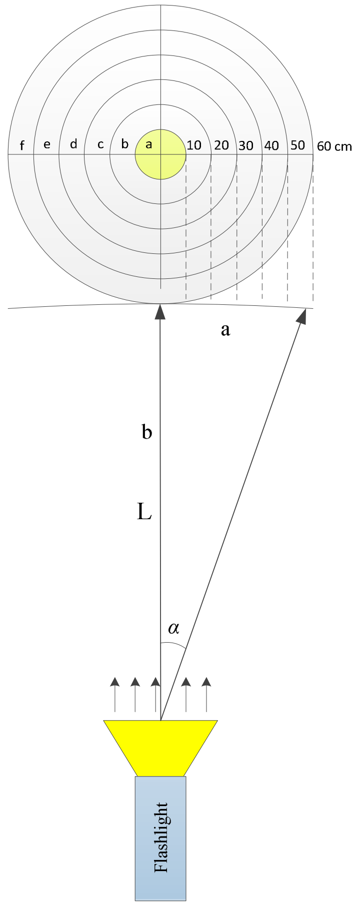

Fig. 3. Luminous flux and light diagram estimation scheme for light source with the axial symmetry with narrow directional diagram.

Evaluation of the light sources for all mentioned measurement schemes is performed according to the algorithm presented in Fig 4.

III. INVESTIGATION OF LIGHT SOURCES WITH AXIAL SYMMETRY

The light sources with axial symmetry were investigated according to the schemes presented in Fig. 1 and Fig. 2. If directional diagram of the light source is wider than 10 degrees the first method (Fig. 1) should be used for the evaluation.

For the measurement results processing the sphere (with radius R=0.5 m) was sliced every 15 degrees from the centre ($\Delta\alpha$=15°). The area of each section is calculated using the following equation

$$S_{\mathrm{section}_n} = S_{slice_n} - S_{slice_{n-1}}, \tag{4}$$

where the area of slice $S_{slice} = 2\pi Rh.$.

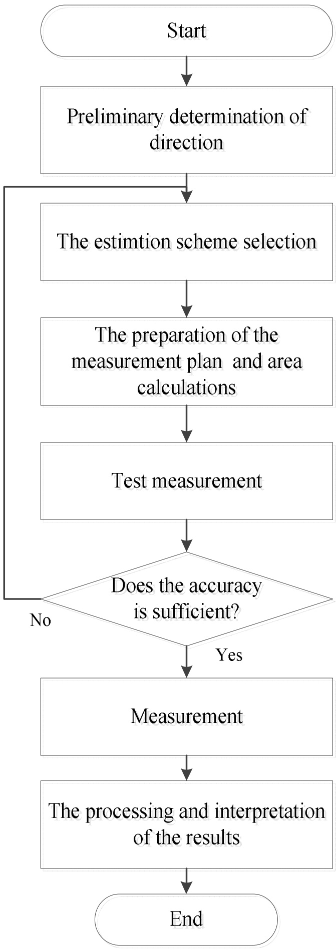

Fig. 4. The light source evaluation algorithm.

The height of the slice

$$h = R \cdot (1 - \cos\alpha_{rad}), \tag{5}$$

where $\alpha_{rad} = \Delta\alpha / 180 \times \pi$.

The area of the first section is coincident with the area of slice at 15°. Other calculation results are presented in Table I.

TABLE I. CALCULATION RESULTS.

R=0.5 m, $\Delta\alpha$=15°			
α, deg	**Height of slice h, m**	**Area of slice S_{slice}, m²**	**Area of section $S_{section}$, m²**
15	0.017	0.053	0.053
30	0.067	0.210	0.156
45	0.146	0.460	0.249
60	0.250	0.785	0.325
75	0.370	1.164	0.378
90	0.500	1.570	0.406
105	0.629	1.977	0.406
120	0.750	2.356	0.378
135	0.853	2.681	0.325
150	0.933	2.931	0.249
165	0.982	3.088	0.156
180	1.000	3.141	0.053

The luminous flux on the surface of the first section can be calculated by equation

$$\Phi_{\text{section}} = \frac{E_{0^\circ} + E_{15^\circ}}{2} \times S_{\text{section}}. \tag{6}$$

The calculation results for all sections and total luminous flux are presented in Table II.

TABLE II. RESULTS OF LIGHT SOURCE EFFICIENCY ESTIMATION.

LED bulb CREE XPE 3x2W			
Area of section $S_{section}$, m²	**E, lx**	**E_L for section, lx**	**Φ for section, lm**
0.053	600	625	33.45
0.156	165	382.5	60.02
0.249	40	102.5	25.59
0.325	25	32.5	10.57
0.378	15	20	7.58
0.406	5	10	4.07
0.406	0	2.5	1.02
0.378	0	0	0
0.325	0	0	0
0.249	0	0	0
0.156	0	0	0
0.053	0	0	0
Total luminous flux			**142.29 lm**
Efficiency of light source			**36.88 lm/W**

Note: Voltage – 223 V; current – 17,30 mA; power – 3,86 W.

The efficiency of the light source is described as how many lumens per watt is obtained from light source (Table II).

As it can be seen from Table II the luminous flux of the LED bulb CREE XPE 3x2W is equal to 142.29 lm and the efficiency – 36.88 lm/W.

IV. INVESTIGATION OF LIGHT SOURCES WITH TWO PLANES SYMMETRY

For the light sources with two planes symmetry the measurement scheme presented in Fig. 2 should be used. Using this method and selecting proper distance between the light source and the lux meter sensor, the characteristics of any size light sources can be estimated (eg. typical fluorescent lamps, LED illuminators etc.).

For investigation were selected T8 fluorescent lamp and its LED analogue (60CM_LED_T8_ReTUBE). The measurements were taken according to the schemes presented in Fig. 2. The shift of the angle was $\Delta\alpha$=15°, radius of imaginary sphere R=1 m. Calculations were performed according to the means presented in Section III The total luminous flux of the light source was obtained by averaging the values of the luminous flux from the first and second calculation parts (for horizontal and vertical measurements). The obtained results are presented in Table III.

TABLE III. THE PARAMETERS OF EVALUATED LIGT SOURCES.

Light source	Power consumption, W	Luminous flux, Lm	Efficiency, Lm/W
60CM_OSRAM	24.61	1031	41.93
60CM_LED_T8_ReTUBE 11W	10.95	519	47.42

The efficiencies of both light sources are in similar range, but the luminous flux of the LED illuminator is twice lower, so on the purpose to illuminate the room it will require twice as many LED illuminators. The luminous flux versus angular displacement is presented in Fig. 5.

It should be noted that the price of LED illuminator is more than 10 times higher, moreover it has drawbacks – the luminous flux is pulsing at 100 Hz (more details will be presented in the other publications) and directional diagram in vertical plane is narrower.

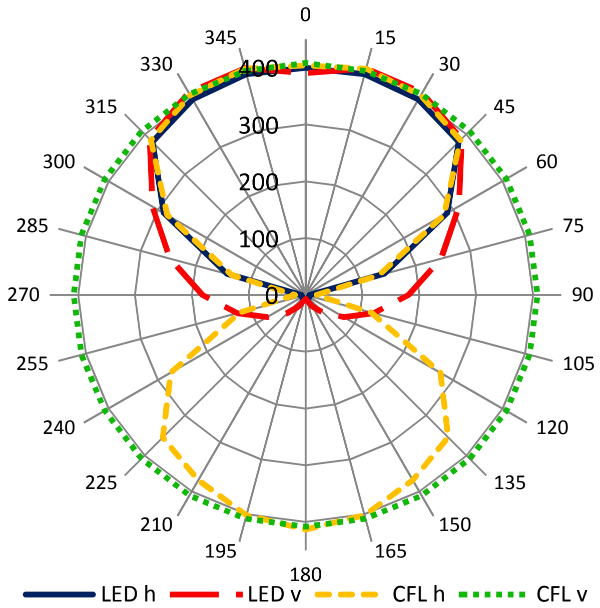

Fig. 5. Luminous flux versus angular displacement (60CM_LED_T8_ReTUBE 11W and 60CM_OSRAM_CFL); h – horizontal plane, v – vertical plane.

V. INVESTIGATION OF LIGHT SOURCES WITH NARROW DIRECTIONAL DIAGRAM

The investigation was carried out with the flashlight „Tiablo A9". The characteristics of the flashlight with collimator were evaluated using the measurement scheme presented in the Fig. 3. Processing the measurement results from the areas of the rings (a, b,…f) the illuminance was calculated on the measurement plane (Fig. 3) and on the each ring (7)

$$\Phi_{ring} = \frac{E_a + E_b}{2} \cdot S_{ring}. \tag{7}$$

The illuminances on all rings were summed and total luminous flux of light source was evaluated. It's equal to 186.45 lm, efficiency of the flashlight – 67.64 lm/W. The directional diagram is presented in Fig. 6.

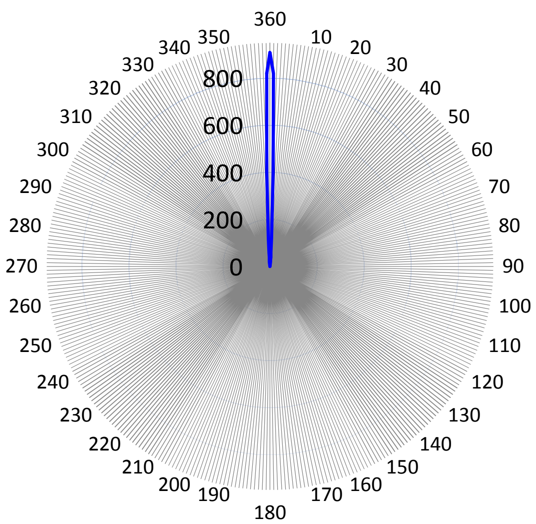

Fig. 6. Luminous flux versus angular displacement (flashlight "Tiablo A9" with collimator).

As seen from Fig. 6 the directional diagram of the flashlight is fairly narrow – moving away from the centre by 0.3 m the illuminance reduces seven times (from 910 lx to 120 lx).

More than 50 different light sources were evaluated. The obtained results were compared with the characteristics declared by the manufacturer (in most cases only luminous flux). The results of measurements coincided with the technical specifications provided.

VI. CONCLUSIONS

The quality and efficiency of light sources can be evaluated in dark room with the area about 30..50 m^2 without extraneous light sources and performing simple measurements using lux meter. For smaller room light anti-reflective wall is desirable, but not necessary condition, since the luminous flux of reflections is weakening according ~$1/R^2$ law and affects the total amount of the flux marginally.

The proposed methods allow the evaluation of light sources with virtually unlimited sizes, who can't be done using Ulbricht sphere. Using those simple methods is easy to evaluate the characteristics and the efficiency of not only the individual bulbs, but also illuminators (along with the entire construction).

As the measurement results obtained coincide with the characteristics declared by the manufacturer, the proposed methods can be used for fast and cheap light source efficiency and evaluation of the light direction.

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