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Features of Wall-Mounted Luminaires with Different Types of Light Sources

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ABSTRACT

The authors use goniophotometer to experimentally measure the light flux distribution of a wall-mounted luminaire with a luminous light bulb, a direct-replacement light-emitting diode (LED) lamp, and a three-dimensional LED module with a heat pipe-based cooling system. The change dynamics of integral characteristics of the light flux is determined. The stabilized light flux for different types of light sources at different power supply voltages is measured. The obtained experimental data are used to calculate the luminous efficacy of the luminaire with the direct-replacement lamps and to determine its dependence on the supply voltage. The thermal conditions for using LEDs in direct-replacement lamps and in lamps with an original cooling system based on heat pipes are also determined.

Keywords: Wall-mounted lamp, heat pipe, light source, light distribution, thermal characteristics

Introduction

In today's high-tech world, lighting has become one of the most important of all the basic human needs. It consumes approximately 20% of global electricity and creates 5% of CO_2 emissions [1]. Therefore, improving the luminous efficacy of modern lighting systems has a significant positive impact on environment and economy. However, apart from high performance and economy, there is also a need to ensure high quality of lighting system, as studies on the effect of illumination on human health and psychophysical status evidently demonstrates in references [2-4]. So, this makes creating efficient lighting devices capable of providing high-quality lighting system an important area of research.

The most effective modern lighting systems are based on replacement light-emitting diode (LED) light sources. LEDs have longer lifespan, do not contain hazardous substances (e.g., mercury and cadmium), and allow using lenses to create the light distribution and meet the requirements of the lamp developers [5-7]. Another way to form the desired light flux distribution is to place the LEDs on three-dimensional frames or use light-reflecting and light-diffusing elements.

At present, many countries completely stopped using high and medium power incandescent lamps and the lighting devices using this type of fluorescent light [8]. Therefore, much attention is being paid on the study of photometric characteristics of powerful LEDs as outdoor and indoor lighting devices. High luminous efficacy, stable photometric parameters, and a longer lifespan of LED light sources are owing to their light generation mechanism that differs from the traditional one [9]. However, the temperature of the diode, especially the temperature of the *p-n* junction, has a significant influence on the characteristics of LED lights [10, 11].

The influence of temperature on photometric parameters of powerful LEDs has been studied in numerous works. The authors of reference [12] carried out a complex study on the effect of temperature on the changes in photometric parameters of LEDs of different types. The results

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of the study help in making the optimal choice of LEDs when designing lighting devices, considering the thermal dependence of their electro-optical parameters. Study in reference [13] shows how the photometric characteristics of LEDs are affected by temperature. This study also emphasizes on the importance of ensuring optimum LED temperatures for increasing their lifespan.

Various cooling systems (passive, active, and hybrid) are used to control the operating temperature of LED lighting devices.

The most commonly used are passive cooling systems for LED lighting, such as heat sinks of different designs [14-18]. Passive cooling systems effectively remove heat throughout the whole lifetime of the LED lighting devices. The advantages of such systems include increasing the lifespan of the lighting device and no need of power source. The disadvantages include the large size of the cooler when used to cool high-power lighting systems.

Active cooling systems for powerful LED lighting devices [19, 20] reduce the size and mass of the passive part of the heat sink, create forced air flow, and increase the heat transfer coefficient between the radiator and the surrounding air. The disadvantages of such cooling systems are limited lifespan and the need for additional power systems. In some experimental designs of active cooling systems, the air flow is created using the phenomenon of electron wind [21]. The advantage of such systems is that they have no moving elements, which significantly increase their lifespan. In comparison to that the need for additional electronic circuits to create high voltage is an obvious disadvantage.

Considering the high concentrations of thermal power on the LED casing, it is advisable to use a two-phase heat transfer devices, heat pipes and vapor chambers, to disperse the high local heat flux to a larger heat transfer surface [22-26]. The use of such designs for cooling LEDs allows effectively distributing and removing heat throughout the radiator. As a result, the temperature of the LEDs decreases. For example, the authors of [27] state that the use of heat pipes allowed them to reduce the thermal resistance between the LEDs and the heat sinks down to 0.34 K/W in an LED module with a power exceeding 100 W.

Most of the researchers used heat pipes to remove heat from LED light sources without linking the pipes to the structure of the luminaire. Apparently, there are no researches on the use of heat pipes in wall-mounted LED lamp designs, which are frequently used to create local lighting and improve the interior design of a room. A large number of such lighting devices have a standard E14 cartridge in their design, which restricts the power of the lamps that can be installed in them. The designs of such lamps often contain light-diffusing shades and other decorative elements that restrict the flow of cool air to the light source. When LEDs are used in such lamps, it should be taken into account that the photometric characteristics of the LEDs, as well as their degradation rate, depend on their temperatures. The authors of reference [28] have shown that the use of direct-replacement LEDs with a power exceeding 4.5 W in luminaires of this type happens under temperature conditions significantly reduce the service life of the devices. This circumstance does not allow increasing in luminous flux of wall-mounted luminaires.

Thus, designing and creating powerful wall-mounted LED lamps of small sizes with more efficient cooling systems based on heat pipes, as well as studying their electro-optical characteristics are relatively important problems.

Designing a Wall-mounted Lamp and Studying its Luminous Flux Distribution with Different Types of Light Sources Using Goniophotometric Method

For this study, we chose a wall-mounted lamp of the sconce type (Figure 1). Such lamps are widely used to create comfortable lighting conditions in living. They are designed to use light sources with an E14 base. Given the decorative nature of this type of lamp, it is advisable to explore the spatial distribution of light power and light distribution uniformity.

Figure 1. Sconce-type lamp chosen for the study

The maximum recommended power of incandescent lamps used in such luminaires is 60 W, which, with respect to the light flux, is analogous to a 7 W or 8 W direct-replacement LED lamp.

Six lamps with E14 base were selected for this research: four incandescent lamps with 15 W, 25 W, 40 W, and 60 W power; and two direct-replacement LED lamps, Svetkomplekt with 7 W power and MAXUS with 8 W power. The correlated color temperature of the LEDs was chosen to be 2300-3000 K considering that such luminaires are used in recreational areas.

The spatial distribution of light was studied using a GO-2000 goniophotometer (Everfine Corporation, Binjiang National Hi-Tech Zone, Hangzhou, China).

In the process of measurement, the goniometer and photodetector determine the spatial distribution of the light force that creates the object of study. The space surrounding the light source is conventionally divided into planes in which the dependence of the light force on the direction of observation is measured. Three most common systems of measurement planes, the A-, B-, and C-planes, have been chosen in which the measurement takes place. For A- and B-planes, the intersection line of the planes passes through the photometric center of the light source. This intersection line of A- and B-plans is parallel to the radiating surface andperpendicular to or parallel to the longitudinal axis of the light source. For C-planes, the intersection line of the planes coincides with the optical axis of the light source and perpendicular to the radiating surface. When graphically presenting the results of goniophotometric measurements of the light flux distribution, representations in the C-planes are used to understand the spatial distribution of the light flux and analyze its features.

The results of the research made it possible to determine the shape of the photometric body and luminous intensity indicatrices of the luminaire with each lamp with or without a light-diffusing shade. It can be seen that the shapes of the photometric body and the luminous intensity indicatrices of the luminaires are similar for incandescent lamps with power of 15 W and 25 W and with power of 40 W and 60 W, but different for direct-replacement LED lamps with power of 7 W and 8 W. Figure 2 shows the distribution of the luminous flux of MAXUS with 8 W power direct-replacement LED lamp.

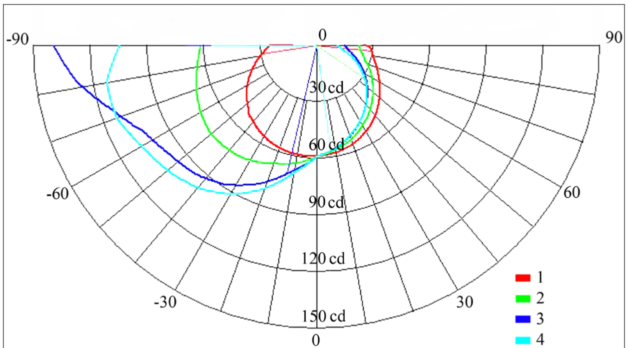

Figure 2. Luminous intensity indicatrices of the luminaire with installed diffusing shade for a MAXUS 8W LED lamp for C-planes rotated to the horizon at angles: 1-0°; 2-30°; 3-60°; 4-90°

The obtained data make it possible to conclude that the maximum values of the light intensity of the lighting fixtures being studied with existing incandescent lamps and direct-replacement LED lamps are concentrated under the luminaires. This form of light distribution leads to uneven illumination and formation of sharp and parasitic flares on the walls and on the floor under the lamp, which stands out on the overall lighting design of the room.

Determining Integral Luminous Flux Characteristics of Wall-mounted Lamps with Different Types of Light Sources

To study the change dynamics in the luminous flux of different lamp types, we used an integrating photometric sphere with diameter of 2 m, a high-precision matrix spectroradiometer "CES-140" (Instrument System, Munich, Germany), and an AC power source Agilent 6812B (Agilent, Santa Clara, CA, USA).

Studies have shown that when using direct-replacement LED lamps in the voltage range (200–250 V) recommended by the manufacturer, the light characteristics stabilize after reaching the operating mode irrespective of the voltage supply. Simultaneously, the electro-optical characteristics of the incandescent lamps depend linearly on the voltage change, as shown in Figures 3 and 4.

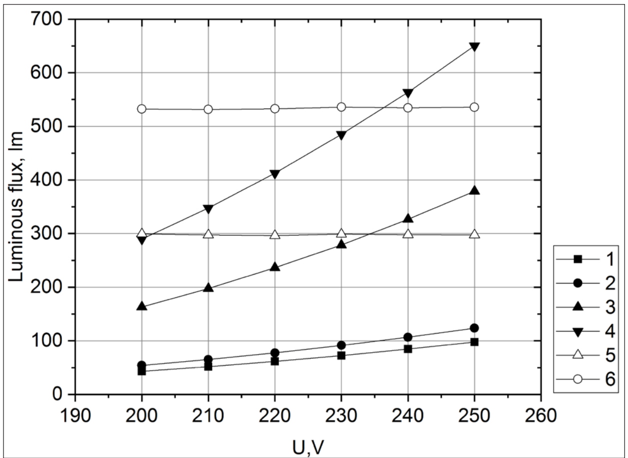

Figure 3. Effect of voltage change on the luminous flux of the luminaire with incandescent lamps (1 — 15 W, 2 — 25 W, 3 — 40 W, 4 — 60 W) and LED lamps (5 — Svetkomplekt 7 W, 6 — MAXUS 8W)

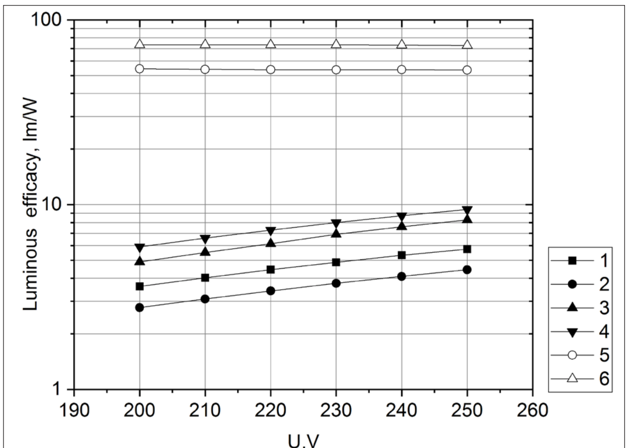

Figure 4. Effect of voltage change on the luminous efficacy of the lighting device with incandescent lamps (1 — 15 W, 2 — 25 W, 3 — 40 W, 4 — 60 W) and LED lamps (5 — Svetkomplekt 7 W, 6 — MAXUS 8W)

Table 1. Electro-optical parameters of lamps of different types

Lamp type	U, V	I, A	Pf	P, W	F, lm	T, K	X	Y	Ra	lm/W
15 W	230	0.065	1	14.95	105	2388	0.492	0.416	99.4	7.1
25 W	230	0.106	1	24.38	131	2220	0.510	0.419	98.2	5.4
40 W	230	0.176	1	40.48	402	2646	0.468	0.413	99.8	10.0
60 W	230	0.264	1	60.72	730	2701	0.464	0.412	99.6	12.0
Svetkomplekt-7 W	230	0.046	0.54	5.71	422	3054	0.434	0.404	81.3	71.9
MAXUS-8 W	230	0.058	0.56	7.47	743	3031	0.428	0.390	82	95.9

Table 2. Electro-optical parameters of the luminaires with lamps of different types

Lamp type	U,V	I, A	Pf	P, W	F, lm	T, K	X	Y	Ra	lm/W
15 w	230	0.065	1	14.95	72	2314	0.495	0.417	99.4	4.9
25 w	230	0.106	1	24.38	91	2157	0.513	0.419	98.2	3.8
40 w	230	0.176	1	40.48	279	2571	0.471	0.413	99.8	6.9
60 w	230	0.264	1	60.72	485	2602	0.469	0.413	99.6	8.0
Svetkomplekt-7 W	230	0.046	0.54	5.71	299	2979	0.439	0.406	81.3	53.7
MAXUS-8 W	230	0.058	0.56	7.47	536	2957	0.434	0.392	82	73.3

Table 1 shows the results of determining the electro-optical parameters of lamps of different types installed in any place except ceiling. Table 2 represents the results of measuring the electro-optical parameters of the luminaires with lamps of different types installed in ceiling. Comparative analysis of the results of the photoelectric parameters given in Tables 1 and 2 shows that when you install the lamps in ceiling, then the light flux and the light efficiency are reduced by 18-22% depending on the type of the lamp. The difference in the magnitude of the decrease in luminous flux and efficiency when installing in ceiling for different types of lamps are caused primarily by different types of spatial distribution of the brightness of the lamps. Simultaneously, there is a steady decrease in the correlated color temperature by 3–4% and changes in the color coordinates within 1%. At the same time, the royalties index remains constant.

It should be noted that when the incandescent lamps are operating, their bulbs and plinths are substantially heated, which makes them dangerous when touched or replaced. To measure the temperatures of the components of the incandescent lamp, thermocouples were first installed on the bulbs of the lamp and on the base. The lamp was then covered with a shade and the temperature was determined using YF-500 multichannel measuring device (Everfine Corporation, Binjiang National Hi-Tech Zone, Hangzhou, China). The dynamics of change of light flux and temperature for an incandescent lamp with a power of 60 W is shown in Figure 5. This figure shows that the steady-state incandescent bulb temperature exceeds 180°C. The changes in the luminous flux of the incandescent lamps were less than 1%.

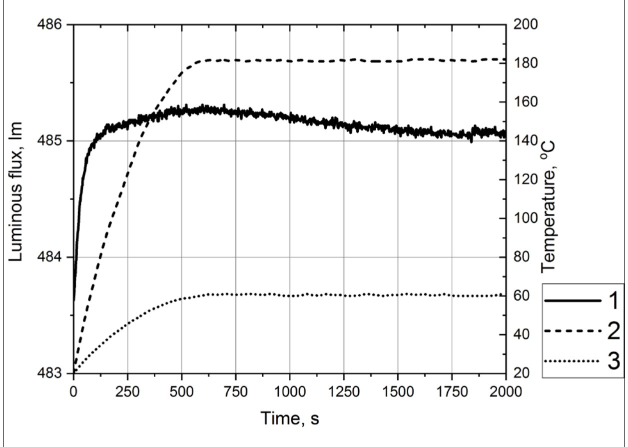

Figure 5. Change dynamics in the luminous flux (1), the temperature of the incandescent lamp bulb (2) and the temperature of the E14 holder(3) with 60W incandescent lamp during the operation of the luminaire

In contrast to the incandescent bulbs, when the temperatures of the LED bulbs were changed, the direct diminution of their brightness decreased their light efficiency.Thermocouples were mounted on the mounting board of the diode and on the LED lamp casing to control the temperature. Figures 6 and 7 show the dependence of the luminous flux on the temperature of the LED lamps in the luminaire.

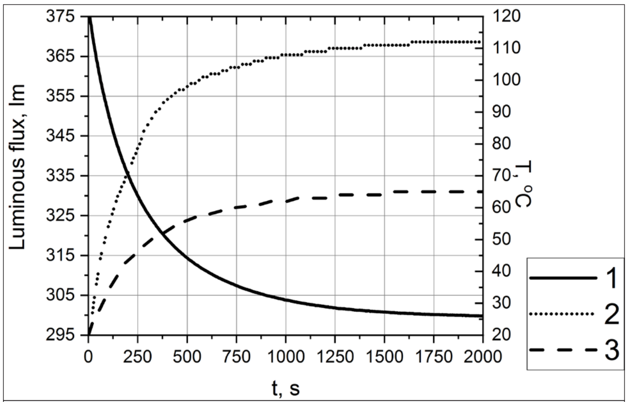

Figure 6. Change dynamics in the luminous flux (1), the temperature of the diode mounting board (2) and the temperature of the LED lamp casing (3) with Svetkomplekt 7W LEDs during the operation of the luminaire

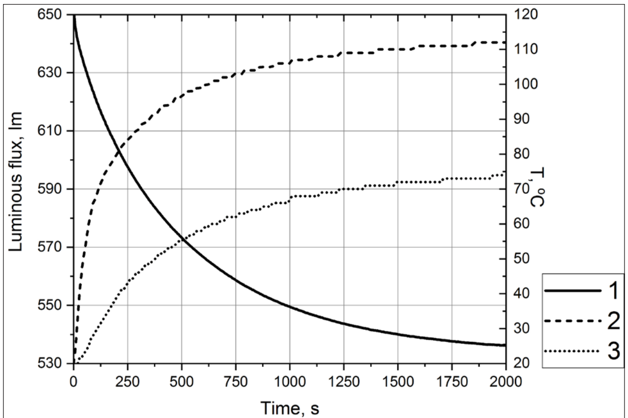

Figure 7. Change dynamics in the luminous flux (1), the temperature of the diode mounting board (2) and the temperature of the LED lamp casing (3) of the MAXUS 8W lamp during the operation of the luminaire

While studying the dependence of the photometric characteristics of the lightening device during its operation, decrease in brightness of 20% and 18% was noted when using direct-replacement LEDs with the power of 7 W and 8 W, respectively.

As the graphs in Figures 6 and 7 represent, temperatures of the LED mounting boards reached 111°C and 112°C, respectively. The temperatures of the LED crystals were even higher, reaching the limit values for LED chips used for mass application. Using LEDs in such temperatures reduces their brightness much faster and significantly accelerates the degradation of the driver components of the LED lamps (e.g., capacitors and transistors). Thus, using the luminaire with LED light bulbs equivalent of 40 W or 60 W incandescent light bulbs, in relation to the luminous flux, causes the LEDs to overheat, which significantly reduces their estimated lifespan. Using LED light bulbs of even greater power in the studied luminaire design leads to an even more significant overheating of the components.

Figure 8. Photograph of a demonstration sample of the luminaire with a heat pipe

LED Luminaire with a Cooling System Based on Aluminum Heat Pipes

A new original lamp design was proposed [28] (Figure 8) based on one of the existing lighting fixture designs to increase the maximum luminous flux, to improve the light distribution uniformity, and to reduce the operating temperature of the LEDs. An element with high thermal conductivity, such as an aluminum heat pipe with a threaded capillary structure, was integrated into the luminaire design. As our previous studies represented, such design can reduce the temperature of the LEDs without increasing the size of the lamp and allows increase in luminous flux of the lamp without raising its temperature.

In this lamp design, we used a three-dimensional LED module with a cooling system based on heat pipe instead of using a direct-replacement LED light bulb. The module consists of four MHB-6 CREE type LEDs (Figure 9), electrically connected in series. The scheme of connection of LEDs within the module makes it possible to supply current in the range of 0–750 mA, which allows by changing the magnitude of the current through the LEDs to provide the necessary value of the electric power of the module in the range of 0-32.16 W.

A goniophotometric unit was used to study the shape of the photometric body and luminous intensity indicatrices for the luminaire with a light-diffusing shade on (Figure 10).

Figure 9. Three-dimensional LED module used in the luminaire

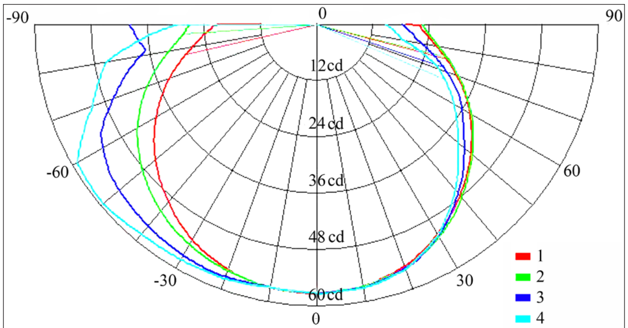

Figure 10. Luminous intensity indicatrices of the luminaire with installed diffusing shade for a luminaire with used three-dimensional LED module with a heat pipe for C-planes rotated to the horizon at angles: 1-0°; 2-30°; 3-60°; 4-90°

The results of comparison of the measurements (Figure 10) with the results for incandescent light bulbs and direct-replacement LED light bulbs (Figure 2) represent that a shaded luminaire with a three-dimensional LED module has higher uniformity of luminous flux distribution than the one with an incandescent lamp or a direct-replacement lamp.

The change dynamics in luminous flux and temperature were determined for the electric current values at which the luminous flux corresponds to that of direct-replacement LED lamps:

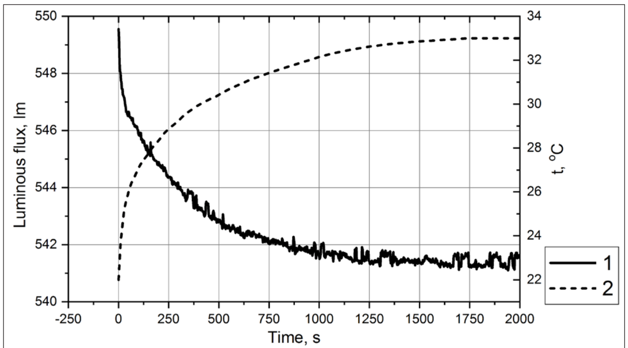

Figure 11. Change dynamics in luminous flux (1) and temperature in the zone of diode installation (2) in the luminaire with a cooling system based on heat pipes and a power of 6.72 W

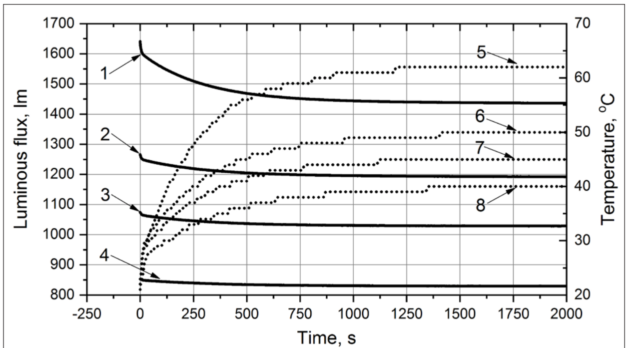

Figure 12. Change dynamics in luminous flux (1-4) and temperature in the zone of diode installation (5-8) in the luminaire with a cooling system based on heat pipes and a power of 32.16 W (1 and 5, respectively), 20.37W (2 and 6, respectively), 15.93W (3 and 7, respectively), 11.63W (4 and 8, respectively)

Table 3. Electro-optical parameters of the LED luminaire with a heat pipe-based cooling system

No.	P, W	F, lm	CCT, K	Ra	x	y	lm/W
1	3.61	317	2859	83.7	0.45	0.41	87
2	6.72	541	2872	83.3	0.45	0.41	80
3	11.63	829	2889	82.8	0.45	0.41	71
4	15.93	1028	2907	82.4	0.44	0.41	64
5	20.38	1191	2928	81.9	0.44	0.40	58
6	32.16	1435	3014	81.2	0.44	0.40	44

the module operating at 3.61 W (equivalent of Svetkomplekt 7W) and module operating at 6.72 W (equivalent of MAXUS 8W). Change in values of the luminous flux and the temperature in the zone of installation of LEDs at a module of power 6.72 W is shown in Figure 11.

The measurement results demonstrate that the temperature of LEDs in three-dimensional LED module with a heat pipe is much lower, which makes it possible to significantly increase the power supply to the LEDs and thus the luminous flux of the lamp, while keeping the temperature of the LEDs low.

The dynamics of the change in the light flux and temperature of the LED body with current 300 mA, 400 mA, 500 mA, 750 mA (maximum recommended current) corresponding to the power supply of 11.63W, 15.93W, 20.37 W, and 32.16 W, respectively. As shown in Figure 12, even with a maximum power of 32.16 W, the body temperature of LED does not exceed 62°C.

The measurement results on the electro-optical parameters of the luminaire with a heat pipe-based cooling system are shown in Table 3. The LED lamp was equipped with a power management system (driver) for LEDs with an efficiency factor of 92%.

The developed LED luminaire can be used for illumination of working spaces both in dwelling houses and in places of temporary stay, such as train compartments, airplane salons, and cabins and deckhouses on board ships. The operating conditions of such vehicles are characterized by mechanical effects (vibrations, acceleration, and shocks). The developers of heat pipe-based cooling systems should consider the possible negative impact of mechanical factors on the characteristics of heat pipes [29, 30] and the cooling system. In the proposed luminaire design, not only mechanical factors have no unwanted impact on the operation of the heat pipe, but contribute to its work by helping in return the condensation to the evaporation zone, as the latter is located below the condensation zone. This increases the heat transfer efficiency and extends the range of use of the developed LED luminaire.

Conclusion

The newly-developed original design of the cooling system for wall-mounted LED lamps was created by directly integrating the heat pipe into the design of the lighting device. This concept makes it possible to increase the luminous flux by almost three times compared to the maximum recommended values for incandescent lamps.

Comparison of the distribution of luminous flux of the original three-dimensional module design and the wall-mounted luminaire with light bulbs of different types (incandescent and direct-replacement LEDs) shows that the new design can provide a higher uniformity in light flux distribution.

The measurement results on electro-optical parameters of wall-mounted luminaires with different types of light sources showed a significant advantage of the new luminaire design with a three-dimensional LED module over standard designs using direct-replacement lamps of different types and capacities.

The design of a wall-mounted lamp with a heat pipe-based cooling system allows stabilizing the temperature of the LED casing at a level of 30-60°C, which is significantly lower than that of LED lamps with direct-replacement LED light bulbs (111°C and 112°C).

The original design of the LED module with a heat pipe-based cooling system makes it possible to significantly increase the light flux stability during the operation of the luminaire. The decrease in the luminous flux of the studied industrial LED lamps in the process of temperature stabilization is 20%, while for the original design it does not exceed 10% at three times higher power capacity.

The principal possibility of using the design under the impact of mechanical effects significantly expands the range of its application.

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References

1. R. Karlicek, C. Sun, G. Zissis, R. Ma, "Handbook of Advanced Lighting Technology", 1st Edition, New York: Springer, 2017. [CrossRef]
2. J. V. Duijnhoven, M. P. J. Aarts, M. B. C. Aries, A. L. P. Rosemann, H. S. M. Kort, "Systematic review on the interaction between office light conditions and occupational health: Elucidating gaps and methodological issues", Indoor and Built Environment, vol. 28, no. 2, pp. 152-174, 2017. [CrossRef]
3. I. Acosta, M.A. Campano, R. Leslie, L. Radetsky, "Daylighting design for healthy environments: Analysis of educational spaces for optimal circadian stimulus", Solar Energy, vol. 193, pp. 584-596, November, 2019. [CrossRef]
4. M. Rossi, "Circadian Lighting Design in the LED Era", 1st Edition, Springer Nature Switzerland AG, 2019. [CrossRef]
5. X. Zhang, Q. Zhang, L. Guo, Z.Zhang, Y. Xu, "Design and simulation of optical system for novel LED solar simulator", Journal of Applied Optics, vol. 40, no. 5, pp. 882-886 and 928, September, 2019. [CrossRef]
6. S. Liang, M. Hu, C. Zhang, X. Hu, Z. Bi, Q. Li, Y. Lu, M. Bi, G. Yang, X. Zhou, "Design of high power LED uniform illumination system based on near-focus aspheric lens", High Power Laser and Particle Beams, vol. 31, no. 9, September, 2019.
7. C.-S. Wu, K.-Y. Chen, X.-H. Lee, S.-K. Lin, C.-C. Sun, J.-Y. Cai, T.-H. Yang, Y.-W. Yu, "Design of an LED spot light system with a projection distance of 10 km", Crystals, vol. 9, no. 10, October, 2019. [CrossRef]
8. R. Zamprogno Rebello, M.T. Weitzel Dias Carneiro Lima, L.H. Yamane, R. Ribeiro Siman, "Characterization of end-of-life LED lamps for the recovery of precious metals and rare earth elements", Resources, Conservation and Recycling, vol. 153, February, 2020. [CrossRef]

9. F.E. Schubert, "Light-Emitting Diodes", 3rd Edition, E. Fred Schubert, New York, USA, 2018.
10. G. dos S. Oliveira, E. P. de Oliveira, A. P. da Silva, C. C. M de M. Carvalho, "Power quality of LED lamps", 17th International Conference on Harmonics and Quality of Power (ICHQP), Belo Horizonte, Brazil, 2016, pp. 575-580. [CrossRef]
11. Cree Inc. URL: https: //www.cree.com/led-components/media/documents/ LM80_Results.pdf (reference date: 10.12.19)
12. M. B. Yurtseven, S. Mete, S. Onaygil, "The effects of temperature and driving current on the key parameters of commercially available, high-power, white LEDs", Lighting Research & Technology, vol. 48, no. 8, pp. 943-965, 2015. [CrossRef]
13. A. Rammohan, C. Kumar Ramesh, "A Review on Effect of Thermal Factors on Performance of High Power Light Emitting Diode (HPLED)", JESTR, vol. 9, no. 4. pp. 165-176, 2016. [CrossRef]
14. P. Xue, S. Wei, Z. Wang, "Thermal optimization design of high-power LED fin-tubular radiator", 2015 International Conference on Estimation, Detection and Information Fusion (ICEDIF), Harbin, 2015, pp. 418-423.
15. L. Xue, W. Wan, Q. Chen, H. Rao, P.Xu, "Optimization design of LED heat dissipation structure based on strip fins", in Young Scientists Forum 2017, International Society for Optics and Photonics, 2018. vol. 10710, pp. 107102H.
16. F. Tang, Z. Guo, "Slotted and Staggered Design of LED Sunflower Radiato," Acta Optica Sinica, vol. 38, no. 1, January, 2018. [CrossRef]
17. L. Shan, X.-G. Hu, J.-H. Wang, H. Tian, "Orientation Effects Experiment on Natural Convection of High Power LED Heat Sink", CJL, vol. 40, no. 6, pp. 781-787, June, 2019. [CrossRef]
18. Y. Chen, T. Hou, M. Pan, "Comparative Analysis Between Water-Cooled and Air-Cooled Heat Dissipation in a High-Power Light-Emitting Diode Chipset", Journal of Thermal Science and Engineering Applications, vol. 11, no. 6, December, 2019. [CrossRef]
19. M. Maaspuro, "Piezoelectric oscillating cantilever fan for thermal management of electronics and LEDs - A review", Microelectronics Reliability, vol. 63, pp. 342-353, August, 2016. [CrossRef]
20. X. Deng, Z. Luo, Z. Xia, W. Gong, L. Wang, "Active-passive combined and closed-loop control for the thermal management of high-power LED based on a dual synthetic jet actuator", Energy Conversion and Management, vol. 132, pp. 207-212, January, 2017. [CrossRef]
21. D. H. Shin, D. K. Sohn, H. Ko, "Analysis of thermal flow around heat sink with ionic wind for high-power LED", Applied Thermal Engineering, vol. 143, pp. 376-384, October, 2018. [CrossRef]
22. Yu. E. Nikolaenko, E. S. Alekseik, D. V. Kozak, T. Yu. Nikolaienko, "Research on two-phase heat removal devices for power electronics", TSEP, vol. 8, pp. 418-425, December, 2018. [CrossRef]
23. R. S. Melnyk, Yu. E. Nikolaenko, A. S. Alekseik, V. Yu. Kravets, "Heat transfer limitations of heat pipes for a cooling systems of electronic components", in: The 2017 IEEE First Ukraine Conference on Electrical and Computer Engineering (UKRCON), Kyiv, Ukraine, May 29 - June 2, 2017, pp. 692-695. [CrossRef]
24. Yu. E Nikolaienko, "Schematics of the architecture of heat rejection from functional modules of a computer with the help of two-phase heat-transfer devices", Upravlyayushchie Sistemy i Mashiny, no. 2, pp. 29-36, January, 2005.
25. Yu. E. Nikolaenko, V. Yu. Kravets, A. N. Naumova, and A. V. Baranyuk, "Development of the ways to increase the lighting energy efficiency of living space", IJECE, vol. 18, no. 3, pp. 275-285, 2017. [CrossRef]
26. J. Ma, X. Fu, R. Hu, X. Luo "Effect of inclination angle on the performance of a kind of vapor chamber", J of Solid State Lighting, vol. 1, September, 2014. [CrossRef]
27. J. Li, W. Tian, L. Lv, "A thermosyphon heat pipe cooler for high power LEDs cooling", Heat Mass Transfer, vol. 52, pp. 1541-1548, September, 2016. [CrossRef]
28. Yu. E. Nikolaenko, D. V. Pekur, V. M. Sorokin, "Light characteristics of high-power LED luminaire with a cooling system based on heat pipe", SPQEO, pp. 366-371, vol. 22, no. 3, September, 2019.
29. O. Marchenko, K. Prisniakov, V. Prisniakov, V. Kravez, Yu. Nikolaenko, "Influence of non-stationary conditions on reliability of space systems with heat pipes under the effect of vibrations", in: 55th International Astronautical Congress of the International Astronautical Federation, the International Academy of Astronautics, and the International Institute of Space Law, International Astronautical Congress (IAF), Vancouver, British Columbia, Canada, 2004, vol. 4, pp. 2301-2311.
30. K. Prisniakov, O. Marchenko, Yu. Melikaev, V. Kravetz, Yu. Nikolaenko, V. Prisniakov, "About the complex influence of vibrations and gravitational fields on serviceability of heat pipes in composition of space-rocket systems", Acta Astronautica, vol. 55, no. 3-9, pp. 509-518, August, 2004. [CrossRef]

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