http://www.moderntechno.de/index.php/meit/article/view/meit09-01-028
DOI: 10.30890/2567-5273.2019-09-01-028

УДК 628.9:536.3

THE MAIN PROBLEMS OF DEVELOPING POWERFUL LED SYSTEMS FOR OUTDOOR USE

ОСНОВНІ ПРОБЛЕМИ РОЗРОБКИ ПОТУЖНИХ СВІТЛОДІОДНИХ СИСТЕМ ДЛЯ ЗОВНІШНЬОГО ВИКОРИСТАННЯ

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Abstract. *The purpose of research and practical development performed by Ukrainians energy specialists is to reduce electricity consumption for outdoor illumination due to using the high quality LED lamps with minimal energy consumption and maximum light flux, implementation of lighting monitoring and automation systems. The main research objectives to accomplish this goal are formulated. The different types of lighting sources characteristics were analysed and there were demonstrate that modern effective LED light sources have as a number of advantages also negatives. According to the results of the researches the global problems of LED using to create powerful external lighting sources were declared. The most important problem is the need to provide constant heat removal from the crystal to prevent it from overheating and to increase its service life.*

Key words: *energy efficiency, outdoor light sources, LED, monitoring and automation systems.*

Introduction. Addressing energy efficiency and saving is one of Ukraine's top energy policy priorities. Reducing energy consumption has a significant impact on reducing imports of fuel resources and increasing the competitiveness of the Ukrainian economy. One of the essential directions is the saving of electricity consumed for lighting the amount of which reaches, according to experts' estimates, about 30% the electricity produced total amount.

Formulation of the problem. The purpose of the theoretical researches and practical developments complex performed by the Thermophysical Processes Monitoring and Optimization Department the Institute of Engineering Thermophysics NAS of Ukraine is to reduce electricity consumption, which is used for illumination of street roads and surrounding territories, due to using the high quality LED lamps with minimal energy consumption and maximum light flux, implementation of lighting monitoring and automation systems. To accomplish this goal, the following

main research objectives are formulated:

1) to carry out the existing lighting sources comparative analysis and to determine the main parameters that affect the luminous flux and lifetime;

2) to develop a lighting device using high quality light sources, which will allow to provide maximum light flux with minimal electricity consumption;

3) create a wireless automatic control and monitoring system for street lighting based on the developed device;

4) to solve problems the roads and adjoining territory illumination in places with no centralized electricity supply network;

5) consider ways to solve the problem of heat dissipation from LEDs.

This article presents the results of solving some of the tasks.

The lighting sources and LED characteristics review.

According to professional studies [1, 2], the electricity amount that is converted to light in a vacuum incandescent lamp is only 7 – 10%, the rest of the power is transformed into thermal infrared and other types of radiation. Fluorescent lamps generate 21% of visible light. Halogens create a ray in the visible range of which is only 27% of the total radiation intensity. LEDs only generate visible rays. The entire light temperature range of LED lamps is in the range of 3000…6500 K or 400…700 nm – from red to blue. We can compare the characteristics of light sources different types from the data presented in Table 1. These data prove that the LED lamps are the most effective in creating a powerful and bright luminous flux, do not flicker and have the longest working life which is what is needed in the creation of outdoor lighting sources.

Table 1

The lighting sources characteristics

The light element type	incandescence	luminescent	gas-discharge	LED
The luminous flux efficiency, Lm / W	10 – 15	30 – 45	50 – 90	90 – 210
Working life, h	5000	6000 – 10000	6000 – 10000	30000 – 100000
Stroboscopic effect (ripple),%	18%	20 – 30%	20 – 30	<5%
Power factor PFC, cos φ	0,95	0,6 – 0,8	0,6 – 0,8	0,95

For a careful approach to the development a powerful source of external lighting based on LED, a thorough study the characteristics of LED presented on the Ukraine's market was conducted (Table 2).

Table 2

LED characteristics

Manufacturer	Cree, LG, Osram, Seoul Semiconductor [3]	Epistar, Prolight, SmiLeds and other Chinese origin brands
Luminous flux, Lm / W	up to 210	80 – 90
Working resource, h	up to 100 000	10 000 – 30 000
The substrate temperature at the rated current applied to the LED, C °	50 – 65	80 – 105
The maximum permissible temperature of operation at which no crystal degradation occurs, C °	120 – 130	100 – 115
Static breakdown protection	present	not existing
Manufacturer's warranty, years	3 – 5	1

The main problems of LED using. Therefore, LED light sources have a number of undeniable advantages, such as high light output, low control voltages, long product life, mechanical durability and reliability, high electrical safety and environmental friendliness. At the same time, the disadvantages of the current LED devices include severe temperature limitation of light-emitting semiconductor crystals (from 85 to 125 °C) [1 – 3], which exceeds the sharp degradation of the LED's optical parameters.

According to the results of the researches, the following global problems of LED using to create powerful external lighting sources can be formulated:

1. The LEDs energy efficiency increasing problem, which requires the creating heteroepitaxial structures technology improving, the quantum yield and efficiency of phosphors increasing, the thermal resistance optimization. Leading developers of LED modules are working on its solution.

2. The problem in the physical principles of thermoregulation of the crystal through which sufficiently large current passes, heating it, which leads to the LED's degradation. Therefore it is necessary to effectively remove heat by creating the radiator systems. It is economically feasible to replace all the metal parts of the heat extraction system with heat-conducting ceramic or plastic ones. This requires the development and creation of new systems for light-emitting crystals thermal stabilization based on new heat-conducting materials.

3. The following problem is related to the electronic control principles of LED light sources and requires the development of special devices (drivers) with the appropriate efficiency, high power factor, reduced noise and optimized sizes. For this purpose, a number of electronic power control systems and spectral composition of

radiation with parameters and characteristics that meet the requirements of world standards have being developed and improved by the IET Thermophysical Processes Monitoring and Optimization Department [4].

4. The last problem is related to the optical principles of the light fluxes direction formation. Solving this problem will allow to implement different types of light distribution LED lighting systems and provide them with modern ergonomic parameters.

The thermal energy influence on the light flow of LED lamps. The problem of heat dissipation is one of the main in creating powerful luminaires for outdoor use based on LED. For stable and long-lasting operation they requires constant removal of heat energy from the crystal – the radiator. Constant overheating of the light-emitting crystals at times reduces the semiconductor device's life, contributes to a brightness smooth loss with the working wavelength displacement.

Structurally, all radiators can be divided into three groups: plate, rod and ribbed. In all cases, the area near the LED to the radiator may be in the form of a circle, square or rectangle. The thickness and area of the radiator is of fundamental importance when choosing, as these characteristics are responsible for the removal and uniform distribution of heat throughout the surface of the radiator.

Currently, the cooling of powerful LEDs is produced mainly on aluminum radiators. This choice is due to the lightness, low cost, machinability and good heat-conducting properties of this metal. Its thermal conductivity coefficient is in the range of 202…236 W/(m·K) and depends on the purity of the alloy. By this characteristic it is in 2,5 times higher than iron and brass. In addition, aluminum is subjected to various types of machining. To increase heat dissipation properties, an aluminum radiator is anodized.

In household LED lighting devices the radiator is usually the body of an LED lamp with which electronic control circuit of the LED device (driver) inside. Institute of Engineering Thermophysics in collaboration with the Institute of Semiconductor Physics NAS of Ukraine work was carried out on mathematical modelling of thermal mode of cooling systems of LED lamps based on thermally conductive ceramics and plastics. The analysis of the temperature distribution in the elements of the lamp showed that lamp's heat sink system provides the required thermal regime of the LED module. Numerical solution confirmed the efficacy of LED lamp's body-core to divert heat from the LED module [1]. The use of new composite materials (metal ceramics) in high-power industrial and outdoor LED luminaires is currently under development to further study their characteristics and predict their change during long-term operation.

Conclusions. High-quality LED lighting devices with minimal energy consumption and maximum light flux as well as lighting monitoring and automation systems are required to address the challenges of modern street and surrounding areas lighting. LED light sources have a number of advantages and several negative factors, the prevalent of which is the need to provide a constant heat dissipation from the crystal to prevent it from overheating and to increase its service life. Along with the use of traditional aluminium alloy, new materials - metal ceramics - may be used to make the LED lamp radiator, but this must be thermophysically and economically

justified. Addressing these problems is a topic for further IET NAS of Ukraine research.

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Анотація. *Метою досліджень та практичних розробок, проведених українськими енергетиками, є зменшення споживання електроенергії для зовнішнього освітлення за рахунок використання високоякісних світлодіодних ламп з мінімальним споживанням енергії та максимальним потоком світла, впровадження систем моніторингу та автоматики освітлення. В роботі сформульовано основні цілі дослідження для досягнення цієї мети. Проаналізовано характеристики різних джерел освітлення і продемонстровано, що сучасні ефективні світлодіодні джерела світла мають як ряд переваг, так і недоліків. За результатами досліджень було виокремлено глобальні проблеми використання світлодіодів для створення потужних джерел зовнішнього освітлення, найважливішою з яких є необхідність забезпечити постійне тепловідведення від кристала, щоб запобігти його перегріванню та збільшити термін його служби.*

Ключевые слова: *енергоефективність, зовнішні джерела світла, світлодіоди, системи моніторингу та автоматизації*

Статтю відправлено: 08.10.2019 г.