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ABSTRACT

The main aim of the work was to develop a method of modeling the distribution of photometric and colorimetric luminaire parameters with semiconductor light sources, stabilizing the illumination intensity and achieving the intended correlated color temperature on the reference surface.

Before proceeding to solve the problem, an analysis of spectrophotometric parameters of generally available semiconductor light sources in the visible range was carried out. Taking into account the purpose of this work, the necessary parameters were the *x, y* trichromatic coordinates of the radiation emitted by diodes and the control characteristics of their output luminous flux Φ. Measuring stations were designed and constructed to determine the mentioned parameters. Based on the results of the study, four models of light emitting diodes have been selected for the design of LED luminaires:

- Cree XP-E XPE**PHR** – Photo Red,
- ProLight 3W PK2N-3L**G**E-SD – Green,
- Cree XP-C XPC**BLU** – Blue,
- Cree XP-G XPGBWT – Cool White.

The choice of these LED models was decided by several factors. First, the chromaticity points of the selected diodes emitting color radiation were near the spectral color curve. The selection of such components allowed the resultant mixture of their light streams from almost the entire field of the triangular unit. Secondly, in the case of creating a mixture from the achromatic color range, it increased the stability of its chromaticity point. In addition, the selected light emitting diodes were characterized by the highest luminous flux among all tested. The choice of the Cree XP-G XPGBWT diode as a achromatic source was dictated by the fact that its chromaticity point lies near the center of gravity of the unit plane (0.33, 0.33).

According to the assumptions of the work, the constructed model of LED luminaire is equipped with an integrated color sensor allowing for measuring photometric parameters on the work surface. Using the measurement system developed by the author, several commercially available integrated color sensors were tested:

- TCS3200 (TAOS - Texas Advanced Optoelectronic Solutions),
- TCS3104 (ams AG),
- S9706 (Hamamatsu),
- MTCSiCS (MAZeT GmbH),
- MMCS6CS (MAZeT GmbH).

Based on the results obtained from the output characteristics and relative spectral sensitivity, Mazet's: MTCSiCS and MMCS6 sensors have been selected for more accurate measurements. First, the senesors were characterized by high linearity of the output signal irrespective of the relative spectral distribution of the radiation they were illuminated. In

addition, the developed measuring paths, with adjustable gain amplifiers, allowed for obtaining a wide range of measurement of both detectors. Chapter 5 also presents a method for calibrating the mentioned color sensors and the transformation matrix was determined between the sensors local colorimetric systems and the CIE *XYZ* 1931 colorimetric system. The color difference ΔE_{LAB} between the MTCSiCS sensor data and the professional Minolta CL-200 colorimeter was 0.6, while the MMCS6 was characterized by a difference ΔE_{LAB} of 2.45. On this basis, it was decided to use the MTCSiCS sensor in the design of the model of LED luminaire.

Chapter 6 describes the mathematical bases of the developed algorithms for controlling the models of LED luminaires. The first one concerned the LED luminaire model with three color components. The second model was based on three color sources and one achromatic source. The purpose of both control algorithms was to obtain an additive mixture of light streams emitted by individual base sources, with a set output light flux and a specified color temperature closest to the color temperature of the daylight. The developed control algorithms have been implemented in an eight-bit AVR Atmega8 microcontroller and used to control the constructed models of LED lighting luminaires.

The results of laboratory tests prove that it is possible to produce the intended distribution of the spatial luminous flux and to achieve the intended color temperature and color rendering index on the reference surface by modeling the light emission from the luminaire using semiconductor LED sources and measuring the spectrophotometric parameters with an integrated color transducer. In most of the analyzed cases, the system correctly stabilized the light intensity value on the work surface. The surface illuminance in any variant did not exceed 8.5% of the target value. However, with the color temperature of daylight of 2753 K and 3327 K, the controller was unable to adequately control the luminaire model of the three component sources - due to the low light output of the Cree XP-E XPEPHR LEDs.

Based on standard guidelines, it was found that in all the variants considered, the system correctly regulated the correlated color temperature value of the luminous flux emitted by the luminaire model. In no case, regardless of the value of light output, exceeding of the tolerance thresholds specified in the standard recommendations has been noted.

Measurement of the color rendering index R_a value showed that the three-component luminaire model does not meet requirements of the minimum value for this parameter for lighting sources in which people stay permanently - in none of the cases considered the color rendering index R_a indicator has exceeded the value of 65.

Compared to a model based on three component colors, the model with an additional achromatic source was characterized by a higher color rendering index R_a value. In the case of correlated color temperature characteristics for the luminaires used in interior lighting the result of more than 80 has been obtained. This means that luminaires based on the proposed solution can also be used for self-illumination of interiors in which people constantly stay.

The constructions of electronic control systems and models of lighting modules based on semiconductor light sources developed within the framework of this work are described in the patent application no. P.416671, znak: RO-185.412/03/2016, *System oświetleniowy LED oraz oprawa oświetleniowa LED*.

The author plans to continue work on the constructions and algorithms of light luminaire control - based on many component sources emitting color radiation. It should also be borne in mind that numerous manufacturers of visible radiation detectors plan, in the next few years, to launch to distribution modern compact sensors. This will expand the application possibilities of control methods developed by the author to control the adaptive lighting systems.

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