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Implementation of Energy Efficient LED Lighting System in Classrooms at TU- Sofia

Dimitar Pavlov, Dilyan Ivanov, Iva Petrinska, Maya Tanovska

Technical University of Sofia, Bulgaria

Abstract

Reconstruction of the lighting system of five lection halls in the Technical University of Sofia has been made and is the topic of the current paper. Three types of luminaires with different optical systems, LEDs and drivers are developed. Thus assembled the luminaires under consideration apply with the parameters described in the normative documents and standards for education facilities and lecture halls. Also a control system is developed with functionality allowing different light scenes and regimes.

Index Terms: energy efficient lighting, LED lighting, science and education establishments, DALI

1 Introduction

The application of energy efficient LED light sources itself is not enough as an action for improvement of the qualitative and quantitative parameters of a lighting system. When assembling a lighting system it is necessary a convenient optical system to be chosen in order to improve the uniformity Uo and to reduce the UGR with as little luminous flux losses as possible [1]. The use of a high quality and suitable driver would lead to increase of the energy efficiency of the lighting system and decreases the flicker to maximum extend. Multiple investigations show that the minimum criteria do not always fulfill to maximum extend the needs of the observer for a given visual task. In order to increase the functionality of the lighting, a lighting control system with different working schedules is developed [2] [3].

The aim of the paper is to describe a methodology for assembling and design of a lighting system, developed with most up to date and modern components. This aim can be fulfilled by solving the following problems: 1. Measurement of the light distribution curves when using different optical elements and reflectors; 2. Measurement of the flicker of the luminous flux induced by the assembled luminaires; 3. Implementation of energy efficient lighting system and lighting control system for the lection halls.

2 Luminaires

Lighting systems together with control systems have been developed and implemented in five lecture halls in the Technical University of Sofia. The old and useless luminaires are demounted ant the fluorescent lamps have been removed from them as well as the ballasts. The housings and the double parabolic anodized aluminum reflectors are kept and used for assembling the new luminaires, described in the publication. In order to assemble a suitable luminaire for lecture halls different combinations of LEDs, optics and drivers are used. The experiments are made with three different types of LED modules, four types of optical systems and three types of drivers, by making different combinations of these elements in search for the best one.

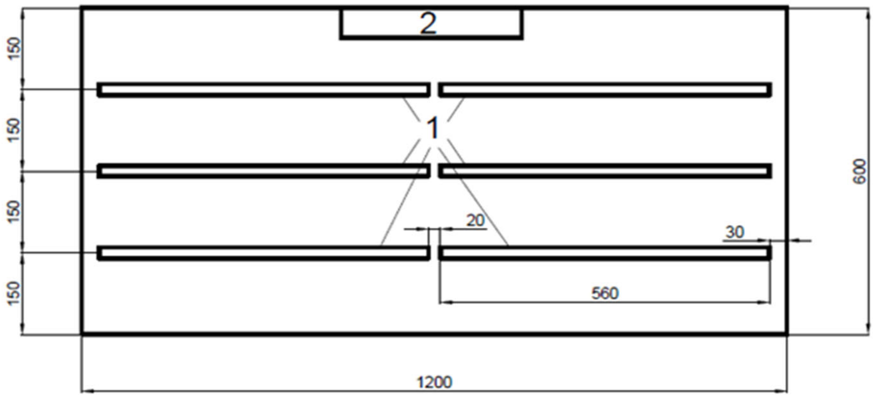

Figure 1. Geometry of the luminaire

Figure 1 shows the location of the LED modules (1) and the driver (2) on the housing.

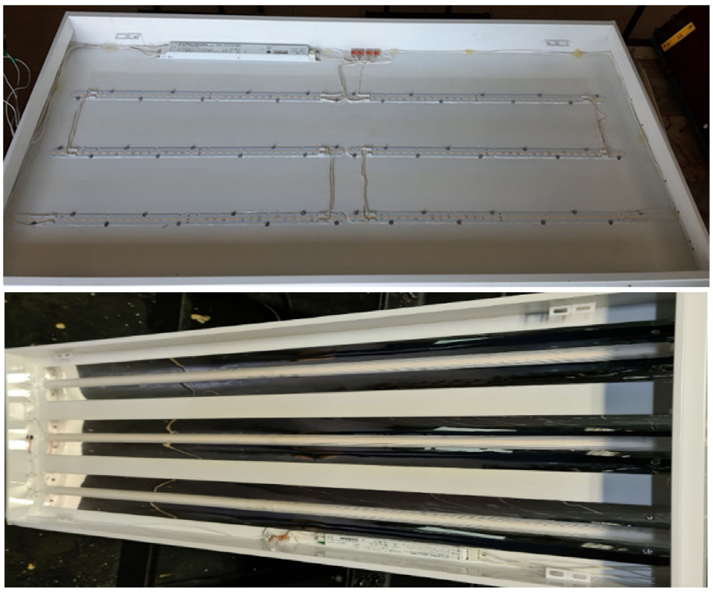

Figure 2. LED luminaire assembling a) without optical system b) with aluminum reflectors previously implemented in the fluorescent luminaire

After placement and electrical wiring of the LED modules and drivers (Fig. 1 a) in order to assemble ready for use luminaire a choice of optical system is made. The last step of the assembling the luminaire is mounting of the aluminum reflector used for increasing of the shielding angle and decreasing of the glare. The luminaires assembled include two types of LEDs and three different configurations of the optical systems including aluminum reflectors, opal diffusor and micro prismatic diffusor.

After the installation of the "best" luminaires in a lecture hall the electrical and light parameters of the lighting systems are measured.

3 Prerequisites for choice of optical system for the luminaires

The use of LED modules without optical systems increases their energy efficiency because there are less light losses, but significantly decreases the quality parameters of the lighting system [4]. By choosing a proper optical system, the light emission of the luminaire can be made in a way so that minimum UGR and maximum uniformity in the premises considered can be achieved. In order to receive reliable results for the light distribution of the assembled luminaires, it is measured by means of a goniophotometer (Fig. 3) in an accredited laboratory in Bulgaria [5] [6] [7].

Figure 3. Measurement of the light distribution curves of the assembled luminaires

For the three different optical systems, three different light distributions are received. They are shown on figure 4 a) b) c)

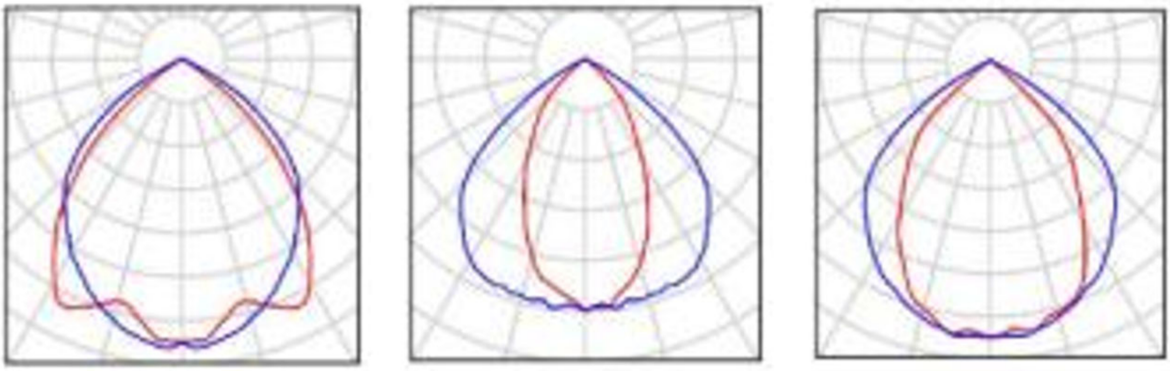

Figure 4. a) Light distribution curve of a luminaire, constructed with LEDs with CRI 80 and diffuse optical system b) 60° optical system c) LEDs with CRI 90 and 90° optical system

The luminaires assembled are mounted in three lecture halls in the Technical University of Sofia. The illuminance achieved in a grid of control points is measured and and compared with previously developed simulation models of the lighting system of the premises.

Table 1 Dimming of the luminous flux of a luminaire with leds with cri 90 and 90° optical system

Luminous flux	**100%**	**80%**	**60%**	**40%**	**20%**	**4%**
Power [W]	81	64	47	32	17	5
Maximum luminous flux	1	1	1	1	1	1
Minimum luminous flux	0,9571	0,9356	0,9224	0,8990	0,8444	0,6898
Average luminous flux	0,9802	0,9724	0,9588	0,9449	0,9221	0,8298
Uniformity	0,9764	0,9621	0,9620	0,9514	0,9157	0,8312
Frequency [Hz]	15000	15000	15000	15000	15000	15000

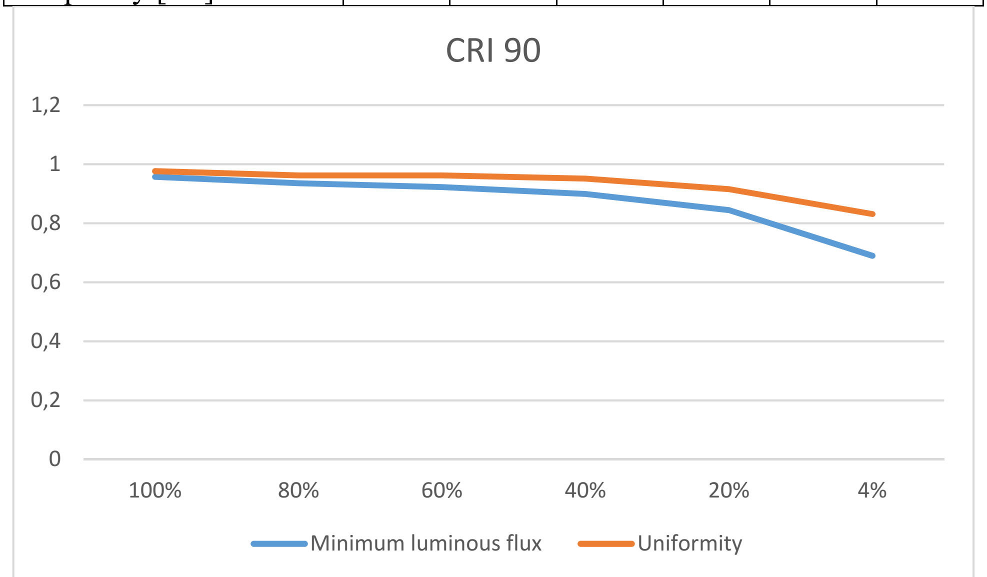

Figure 5. Graphical representation of the change of the uniformity and the minimum luminous flux of a luminaire with LEDs, CRI 90 and 90° optics

Table 2 Dimming of the luminous flux of a luminaire with leds with cri 80 and diffuse optical system

Luminous flux	**100%**	**80%**	**60%**	**40%**	**20%**	**4%**
Power	81	64	47	32	17	5
Maximum luminous flux	1	1	1	1	1	1
Minimum luminous flux	0,9327	0,9495	0,9106	0,875	0,8403	0,5104
Average luminous flux	0,9695	0,9727	0,9569	0,9414	0,9309	0,7360
Uniformity	0,9620	0,9762	0,9515	0,9294	0,9027	0,6934
Frequency [Hz]	15000	15000	15000	15000	15000	15000

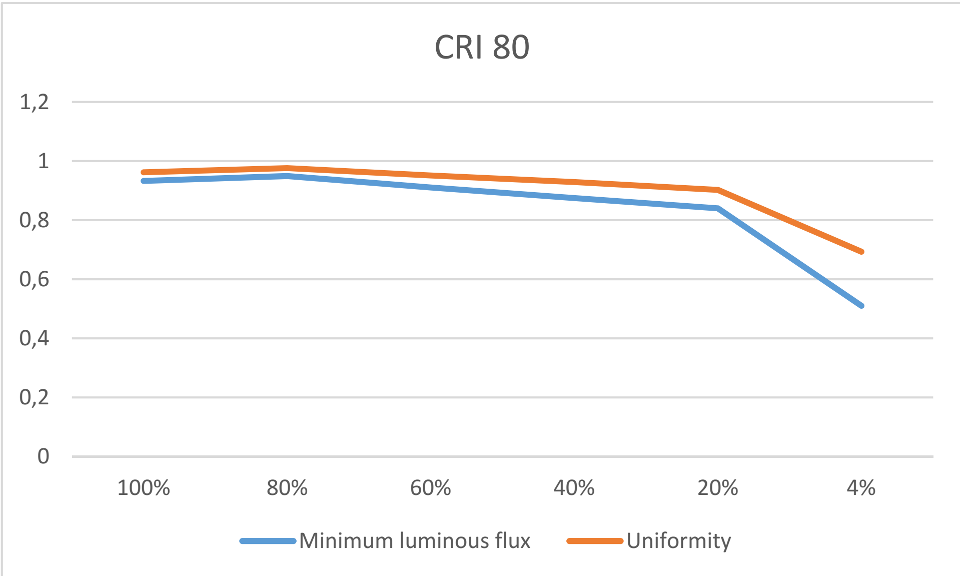

Figure 6. Graphical representation of the change of the uniformity and the minimum luminous flux of a luminaire with LEDs, CRI 80 and diffuse optical system

Table 3 Change of the luminous flux of a luminaire with two types of leds, allowing change of the correlated color temperature and microprismatic diffusor

Luminous flux	**100%**	**80%**	**60%**	**40%**	**20%**	**4%**
Power	74	59	44	30	17	6
Maximum luminous flux	1	1	1	1	1	1
Minimum luminous flux	0,7656	0,7435	0,6844	0,5892	0,3858	0,0056
Average luminous flux	0,8833	0,8704	0,8368	0,7979	0,6903	0,4027
Uniformity	0,8667	0,8542	0,8178	0,7384	0,5589	0,0139
Frequency [Hz]	15000	15000	15000	15000	15000	15000

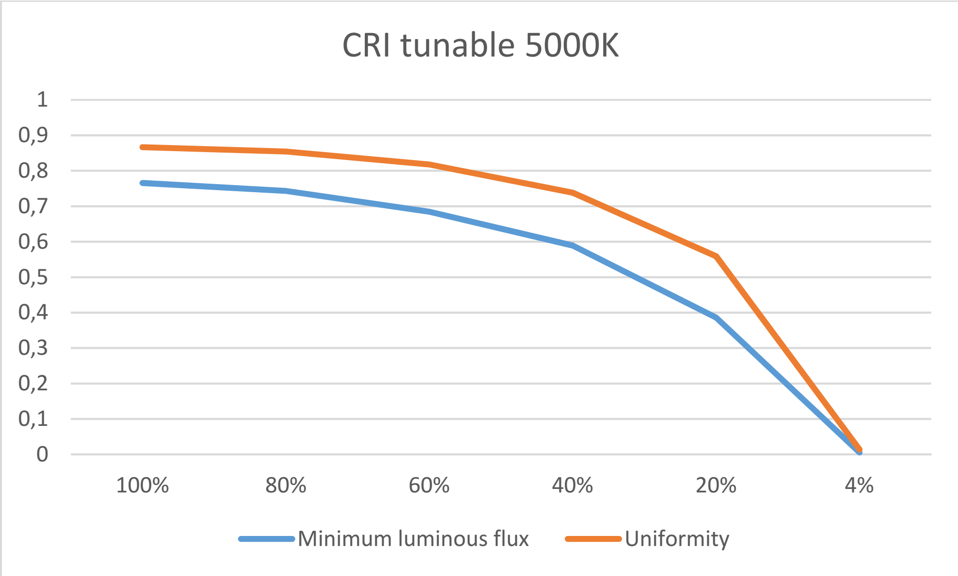

Figure 7. Graphical representation of the changes in the uniformity and minimum luminous flux of a luminaire with microprismatic diffusor allowing different color temperatures

Based on the experimental results and the simulation data, the luminaires with microprismatic diffusor allowing different color temperatures have been used for reconstruction of the lighting systems of the premises under consideration.

4 Analysis of the results

After the reconstruction carried out in the lection halls the following results have been achieved:

- The installed power for lighting in the experimental hall has been reduced four times;
- In dimming regime, the lighting system consumes reactive-capacitive energy only at the lowest power level, that re not used for the current application;
- At “Stand By” regime of the lighting system reactive-capacitive energy is consumed, thus reducing the energy efficiency of the lighting system;
- The lighting system allows different colour temperatures by means of a suitable control. Different light scenes and scenarios can be achieved, making it a Humancentric lighting system.

5 References

[1] EN 12464 - 1 "Lighting of work places - Part 1: Indoor work places".

[2] Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of electrical lamps and luminaire ANNEX VI

[3] Energy efficiency classes Human Centric School Lighting Evidence based design of light characters and automatic light variation, for a classroom in Malmö Tove Karlsson, 2015

[4] www.osram.com

[5] CIE №121 „THE PHOTOMETRY & GONIOPHOTOMETRY OF LUMINAIRES".

[6] EN 13032-1:2004+A1:2012 Light and lighting - Measurement and presentation of photometric data of lamps and luminaires - Part 1: Measurement and file format.

[7] CIE №127 MEASUREMENT OF LEDS