GOCE DELCEV UNIVERSITY, SHTIP, NORTH MACEDONIA

FACULTY OF ELECTRICAL ENGINEERING

ETIMA 2021

FIRST INTERNATIONAL CONFERENCE

19-21 OCTOBER, 2021

TECHNICAL SCIENCES APPLIED IN ECONOMY, EDUCATION AND INDUSTRY

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UNIVERSITY „GOCE DELCHEV" - SHTIP
FACULTY OF ELECTRICAL ENGINEERING

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PREFACE

The Faculty of Electrical Engineering at University Goce Delcev (UGD), has organized the International Conference ***Electrical Engineering, Informatics, Machinery and Automation - Technical Sciences applied in Economy, Education and Industry-ETIMA.***

ETIMA has a goal to gather the scientists, professors, experts and professionals from the field of technical sciences in one place as a forum for exchange of ideas, to strengthen the multidisciplinary research and cooperation and to promote the achievements of technology and its impact on every aspect of living. We hope that this conference will continue to be a venue for presenting the latest research results and developments on the field of technology.

Conference ETIMA was held as online conference where contributed more than sixty colleagues, from six different countries with forty papers.

We would like to express our gratitude to all the colleagues, who contributed to the success of ETIMA'21 by presenting the results of their current research activities and by launching the new ideas through many fruitful discussions.

We invite you and your colleagues also to attend ETIMA Conference in the future. One should believe that next time we will have opportunity to meet each other and exchange ideas, scientific knowledge and useful information in direct contact, as well as to enjoy the social events together.

The Organizing Committee of the Conference

ПРЕДГОВОР

Меѓународната конференција ***Електротехника, Технологија, Информатика, Машинство и Автоматика-технички науки во служба на економија, образование и индустрија-ЕТИМА*** е организирана од страна на Електротехничкиот факултет при Универзитетот Гоце Делчев.

ЕТИМА има за цел да ги собере на едно место научниците, професорите, експертите и професионалците од полето на техничките науки и да претставува форум за размена на идеи, да го зајканува мултидисциплинарното истражување и соработка и да ги промовира технолошките достигнувања и нивното влијание врз секој аспект од живеењето. Се надеваме дека оваа конференција ќе продолжи да биде настан на кој ќе се презентираат најновите резултати од истражувањата и развојот на полето на технологијата.

Конференцијата ЕТИМА се одржа online и на неа дадоа свој допринос повеќе од шеесет автори од шест различни земји со четириесет труда.

Сакаме да ја искажеме нашата благодарност до сите колеги кои допринесоа за успехот на ЕТИМА'21 со презентирање на резултати од нивните тековни истражувања и со лансирање на нови идеи преку многу плодни дискусии.

Ве покануваме Вие и Вашите колеги да земете учество на ЕТИМА и во иднина. Веруваме дека следниот пат ќе имаме можност да се сретнеме, да размениме идеи, знаење и корисни информации во директен контакт, но исто така да уживаме заедно и во друштвените настани.

Организационен одбор на конференцијата

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PHOTOMETRIC PARAMETERS OF LED LUMINAIRES WITH SWITCHABLE CORRELATED COLOUR TEMPERATURE

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Abstract

At present, there are lights on the market that are capable of emitting white light with an adjustable correlated color temperature. The advantage of these luminaires is the possibility of changing the correlated color temperature, for example, due to a change in the function of the room in which they are installed, with no replacement of the lamps. The disadvantage of such a correlated color temperature setting is that this setting is performed directly on the luminaire and it is not possible to set the correlated color temperature with the control system. When changing the color temperature, in most cases, it is undesirable to change the other photometric parameters. In this paper, attention is paid to changes of the photometric parameters caused by changing the correlated color temperature.

Key words

LED, correlated colour temperature, luminous flux, tunable-white

Introduction

In the past, the colour temperature was fixed to a light source. Tunable-white lighting is one of the biggest trends in commercial lighting. Emerging studies on health, comfort, and productivity suggest that being able to change, or tune, the colour temperature of a light source to match the needs of the application, event, or occupant preference has significant benefits. Luminaires with switchable correlated colour temperature are determined where the future is expected a change in the functionality of the room. Sometime in the future, you might have plans to redecorate your living room and go from an ordinary, homely ambient tone to something whiter and more modern. Rather than replacing all of your lights to keep up with their new environment, you just change their colour temperature and keep them. When changing correlated colour temperature, it is expected that other photometric parameters will change only minimally. Luminaire manufacturers often indicate photometric parameters for only one correlated colour temperature. Change of photometric parameters can be dependent on the method used for changing correlated colour temperature and installed light sources [1].

Methods used to change the correlated colour temperature

There are several methods used to change the correlated colour temperature. Each method has its advantages and disadvantages. Selecting luminaire with a suitable method of change correlated colour temperature is the designer's job and depend on the function of the room.

- **Tunable whites use color mixing**

Standard LED color-mixing uses red, green and blue channels that are adjusted to deliver the entire range of the color spectrum. Tunable-whites work in a similar way, using a number of controllable channels to adjust the color temperature of the luminaires white light output. The channels in a tunable-white system all produce white light, but with varying colour temperatures, from a warm tone to a cool tone. [1]

- **Simple system use two or more lines of LEDs**

The most basic tunable linear systems use LED strips mounted side-by-side. One channel has a correlated colour temperature close to 2700K, with the other one has correlated colour temperature around a 6000K. The LED strips can be mount inside an aluminium extrusion fitted with an opal diffuser, which does the colour mixing as the light passes through it [1].

- **Multi-chip versions do the mixing at chip level**

More products are using ‘multi-chips’ where a number of tiny LED chips are combined into the same module. This means that the color mixing occurs as the light leaves the module. Their very small size means that tunable-white products can be made much smaller. These multi-chips tend to have a higher performance specification than the individual LED strips [1].

Changing the color temperature is done differently on each luminaire. Some luminaires with switchable correlated color temperature are adjustable by small dip switches that are located either on the front or on the back of the luminaire. Also known as CCT (correlated colour temperature) adjustable downlights, these types of lights provide you with the ability to change the colour temperature. Within one downlight, you have multiple colour temperatures that range from warm white to cool white. The variation of colour temperature ranges from each brand. The dip switch design should be called CCT select-able. The luminaire with dip switch is shown in the figure 1 and 2. Luminaires with a switch in the front have the advantage that the user is able to make a colour change. Luminaires with a switch located at the rear can have a more attractive design, but to switch correlated colour temperature is necessary to remove the luminaire [1] [2]. Figure 3 shows a typical spectral radiant flux distribution curves of LEDs used for adjusting correlated colour temperature.

Fig. 1. Luminaire with dip switch on the front

Fig. 2. Luminaire with dip switch on the back

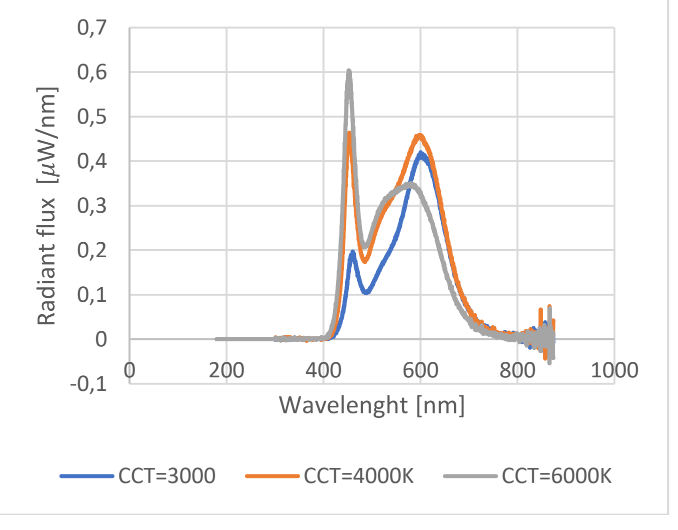

Fig. 3. Spectral radiant flux distribution curves

Measurement

Devices under test were luminaire with switchable correlated color temperature. The luminaires use three lines of LEDs with different correlated colour temperature. Switching between correlated color temperature was performed by the dip switch placed on the back of the luminaire. Measurement of luminous intensity distribution curves was measured on the far-field goniophotometer. The goniophotometer used for the measurement is shown in figure 4. Luminous flux was measure in photometric integrator spherical with a diameter of 3 meters. Photometric integrator spherical is shown in figure 5. The measurement was performed according to STN EN 13032-4 - Light and lighting - Measurement and presentation of photometric data of lamps and luminaires. Part 4: LED lamps, modules and luminaires [3].

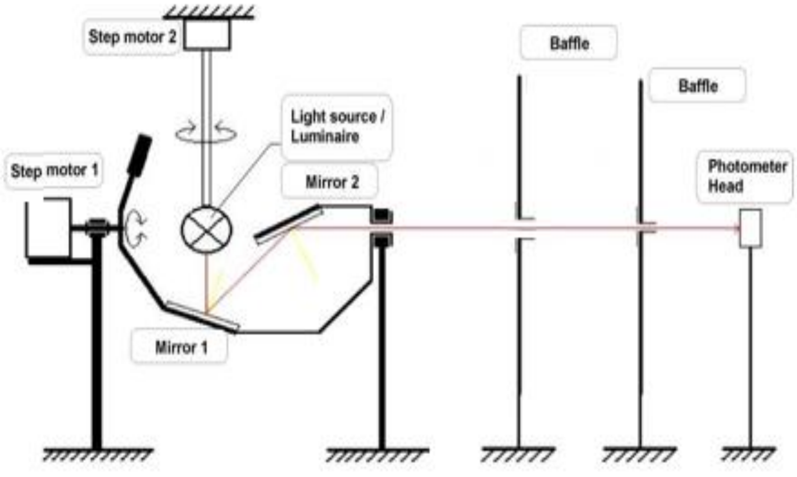

Fig. 4. Farfield goniophotometer

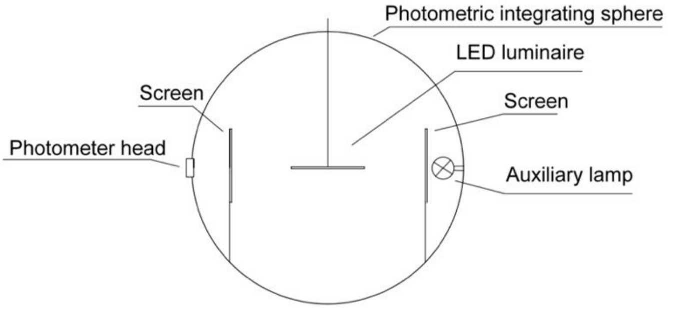

Fig. 5. Fotometric spherical integrator

The measurement results are shown in tables 1, 2 and in figures 6, 7 and 8.

Expanded uncertainty of measurement is shown in table 3. The reported expanded uncertainty of measurement in table 1 is stated as the standard uncertainty of measurement multiplied by the coverage factor k=2, which for a normal distribution corresponds probability of approximately 95%.The standard uncertainty of measurement has been determined in accordance with EA-4/02 [4].

Table 1. Measurements results I

Tested samples	**Measured parameters**			
	Ra [-]	***CCT [K]***	***ϕ [lm]***	***Luminous efficacy [lm/W]***
LED 1 / 3000K	82	2858	959	58,96
LED 1 / 4000K	88	3905	1223	80,67
LED 1 / 6000K	87	5937	1104	67,44
Declared by the manufacturer	> 80	-	1200	-
LED 2 / 3000K	83	2796	431	50,68
LED 2 / 4000K	87	3738	521	65,06
LED 2 / 6000K	87	5425	491	58,05
Declared by the manufacturer	> 80	-	600	-
LED 3 / 3000K	82	2836	914	54,87
LED 3 / 4000K	87	3865	1137	71,07

Tested samples	Measured parameters			
	Ra [-]	*CCT [K]*	*ϕ [lm]*	*Luminous efficacy [lm/W]*
LED 3 / 6000K	86	5970	991	57,3
Declared by the manufacturer	> 80	-	1200	-
LED 4 / 3000K	83	2889	1663	69,34
LED 4 / 4000K	88	3910	2012	90,72
LED 4 / 6000K	87	6231	1742	72,52
Declared by the manufacturer	> 80	-	2000	-

Table 2. Measurement results II

Power of tested samples	Correlated colour temperature of luminaires		
	3000K	*4000K*	*6000K*
LED 1 P [W]	16,27	15,16	16,37
LED 2 P [W]	8,51	8,01	8,46
LED 3 P [W]	16,66	16,01	17,11
LED 4 P [W]	23,99	22,18	24,02

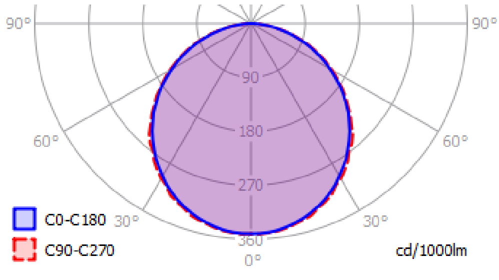

Fig.6. Light distribution curve / CCT=3000K

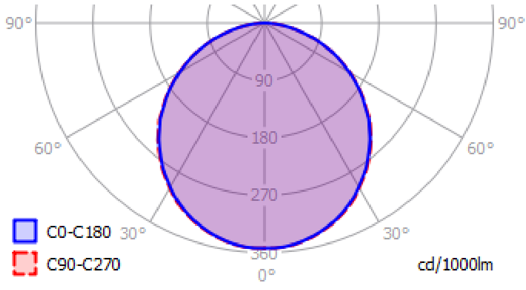

Fig. 7. Light distribution curve / TCC=4000K

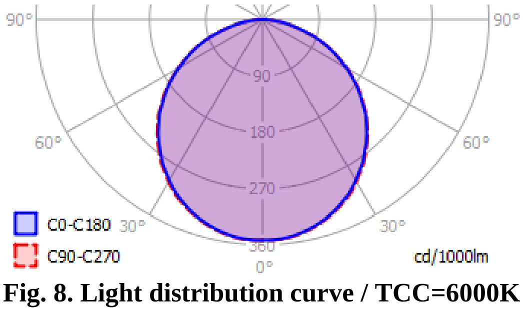

Fig. 8. Light distribution curve / TCC=6000K

Table. 3. Expanded uncertainty of measurement

Parameter	*Expanded uncertainty U (k=2)*
ϕ [lm]	7,5%
P [W]	1,0%
Ra [-]	2
TCC [K]	200K
Luminous efficacy [lm/W]	6,6%

Simulations in software Dialux evo

The problem that may occur when using the photometric parameters specified by the manufacturer is described in this chapter. Photometric parameters of the luminaires with switchable correlated colour temperature are often given for only one correlated colour temperature or generally for the luminaire. The measurement results in the previous chapter show that the photometric parameters are different for each correlated colour temperature. In our case, the parameters declared by the manufacturer correspond to the measured parameters only at a correlated colour temperature of 4000K. The problem that arises from the above is shown in simulation in the Dialux software. The office visualization used to compare simulations is shown in figure 9. The office project has been designed according to STN EN 12464-1 Light and work lighting. Part 1: Indoor work places [5]. In the first design, were used luminaires LED 4 with a correlated colour temperature of 4000k because of their photometric parameters correspond to photometric parameters declared by the manufacturer. The number of luminaires and their location are chosen to meet the lighting requirements of the aforementioned standard. In the next designs, the luminaires were replaced with luminaires with another correlated colour temperature without changed place and number of luminaires. The simulation results are shown in table 4.

Fig. 9. Office visualization in Dialux Evo 8

Table 4. Calculated parameters with Dialux software

Calculated parameters	Correlated colour temperature of luminaire			Required parameters
	3000K	***4000K***	***6000K***	
Vertical illuminance of visual task $\overline{E}_m$ [lx]	457	549	478	> 500
Vertical Illuminance of surrounding area [lx]	457	551	479	> 300
Vertical Illuminance of backround area [lx]	435	526	456	> 100
U_0 [lx]	0,88	0,89	0,88	> 0,6

Conclusion

The main advantage of luminaires with switchable correlated colour temperature is that you do not depend with one colour temperature and you can change it depending on the function of the room. Providing you with the flexibility to make a change whenever you want to. Without needing any electricians and without any additional costs. When designing the lighting system, the designer must consider that during the operation the lamps will changing the correlated colour temperature and thus the other photometric parameters as a luminous flux and colour rendering index. The measurement results show that the change in luminous flux can be more than 20%. The manufacturer of the samples tested gave uniform photometric parameters for all correlated colour temperature however it is necessary to specify the photometric parameters separately for each correlated colour temperature. As figures 6, 7 and 8 show light distribution curves did not change their shape when changing correlated colour temperature. The shape of the light distribution curves does not change due to the use of a microprismatic optical system and a suitable LED lines layout. The simulation results confirmed that the designer must not rely on the photometric parameters declared overall for the luminaire with switchable correlated colour temperature.

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