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FACULTY OF ELECTRICAL ENGINEERING

ETIMA 2021

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TECHNICAL SCIENCES APPLIED IN ECONOMY, EDUCATION AND INDUSTRY

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UNIVERSITY „GOCE DELCHEV” - SHTIP
FACULTY OF ELECTRICAL ENGINEERING

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ЕТИМА / ETIMA 2021

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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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Прва меѓународна конференција ЕТИМА
First International Conference ETIMA

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INFLUENCE OF ROTATION ANGLE OF LUMINAIRES WITH ASYMMETRICAL LUMINOUS INTENSITY DISTRIBUTION CURVE ON CALCULATED PHOTOMETRIC PARAMETERS

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Abstract
Lighting systems often use square LED panels or spherical luminaires, which may not always have an exactly symmetrical luminous intensity curve, even if they appear to be symmetrical. A problem with these luminaires can already arise when measuring luminous intensity distribution curves in a photometric laboratory due to incorrect symmetry determination. For design reasons, many times it is very complicated or even impossible to determine the photometric axes of the luminaire in the case of both spherical and square luminaires. This fact may cause a difference in the angle of rotation of the luminaire in light design software and real lighting systems and thus can cause a situation that the lighting system does not meet the requirements of standard STN EN 12464-1. Such a situation is, of course, undesirable and can cause considerable financial losses. Considering the uncertainties of measuring the parameters entering the lighting system calculation and other influences that cause the difference between the calculated and measured parameters, it is necessary to oversize the system to a certain extent, but there is an upper limit defined by Act no. 555/2005 on the energy performance of buildings. This article deals with the problem that can be caused by an incorrect angle of rotation of the luminaire with an asymmetrical luminous intensity curve when installing the lighting system.

Key words
LED, Lighting design software, luminaire.

Introduction

When designing lighting systems, it is necessary to respect valid legislative and normative requirements within a comprehensive set of quantitative and qualitative lighting parameters. The basic parameters include the illumination and the uniformity of illumination, but the same importance is attached to the requirements to prevent glare. From the lighting point of view, spaces with workplaces have a special position in interiors, where it is necessary to create suitable conditions for the working environment. During the building inspection, the photometric parameters of the lighting are verified by measurement and must comply with the requirements of the Decree and the Standard. It is, therefore, necessary to pay increased attention to the design of lighting. Normative requirements for indoor workplaces are prescribed by the standard STN EN 12464-1. The lighting system must be in accordance with Act no. 555/2005 Coll. also efficient and economical. The design and calculation of artificial lighting are associated with a large number of lighting technical calculations. The aim of this process is, on the one hand, to determine the power and the total number of luminaires or light sources and, on the other hand, to verify the required photometric parameters of the illumination. Proper lighting has a significant effect on the overall focus and speed of object recognition. For correct calculation of lighting system parameters, it is necessary to know sufficiently precise parameters entering the calculation. A critical input parameter for square luminaires not only in the calculation of lighting but also in the realization of the lighting system is the luminous intensity curve. An example of a square luminaire that does not have to have a completely symmetrical luminous intensity distribution curve is shown in Figure 1. [1, 2].

Fig.1. An example of a square luminaire with a not completely symmetrical luminous distribution curve

Luminous intensity distribution curve of square luminaires

The luminous intensity curves are a very important input parameter in the lighting calculation, therefore it is very important to measure this photometric parameter of the luminaire as accurately as possible. The basic photometric data of luminaire consist of a set of values of the luminous intensity in different directions, produced by direct photometric measurements. For such photometric measurements involving direction, it is necessary to define a spatial framework around the luminaire. The determination of the intensity distribution of a luminaire in space involves the use of a coordinate system to define the direction in which the intensity measurements are made. The system used is a spherical coordinate system with the centre coincident with the photometric centre of the luminaire. In general, the luminous intensity of luminaire is measured in a number of planes. Square luminaires intended for indoor installation are usually measured in a system of planes C. The system of C-planes (see Fig. 2) is a bundle of planes whose intersection is a vertical line passing through the photometric centre of the luminaire. C - planes are denoted by angles Cx in the range 0 ° - 360 °. In a given plane, the directions are determined by angles γ in the range 0 ° - 180 ° [3] [4].

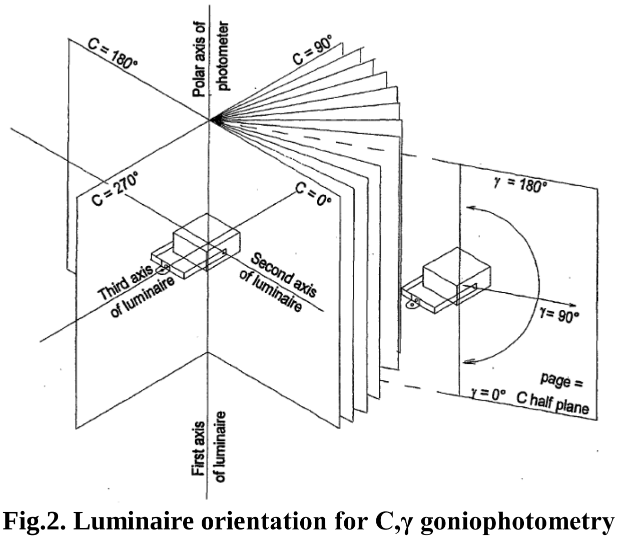

Fig.2. Luminaire orientation for C,γ goniophotometry

The first axis usually going through the photometric centre of luminaire and perpendicular to the light emitting area. The second axis lies within the plane C=0. The third axis is the long axis of the luminaire. According to standard 13032-1 + A1, the axis of the luminaire is determined by the manufacturer or the photometric laboratory to clearly determine the location of the luminaire in the coordinate system for photometric measurements and for lighting calculations. In practice, we often encounter that the luminaire manufacturer does not specify the photometric axes of the luminaire. If specific instructions are not provided, then the plane containing the lower edge of the luminaire canopy should be taken as one reference and the longitudinal axis, determined from the outer edges of the luminaire when viewed in plan, should be taken as the second reference. In the case of square luminaires, there is a problem in determining the photometric axes of the luminaires. The photometric laboratory may identify and mark photometric axes before measuring the luminaire. Without such marking of the photometric axes on the luminaire, it is practically impossible to install the luminaire in a lighting system with the correct rotate. The measurement of photometric parameters is performed on 1 sample and it may happen that based on the marking of the axes of this sample it is not possible to mark other manufactured luminaires of this type. This is due to the use of optical materials whose directional orientation is not visible. Examples of such materials may be microprismatic diffusers or opto-mechanical nanostructures [5, 6].

The measurement accuracy is influenced by several possible sources of errors, which can be caused, for example, by the construction of the measuring instrument (goniophotometer), the conditions in the laboratory and, last but not least, by the accuracy of the lighting technician. The last-mentioned fact is closely related to one of the problems of square and spherical luminaires. The curves of these luminaires may at first glance look like rotationally symmetrical, and the lighting technician can simply erroneously evaluate that it will be sufficient to measure only 1 plane C as allowed by the standard STN 13032-2 and subsequently to make the curve symmetry. Such measurement saves a lot of time but at the cost of measurement accuracy. As shown in Figure 3, these luminaires may not always have a luminous intensity distribution curve symmetrical [7, 8].

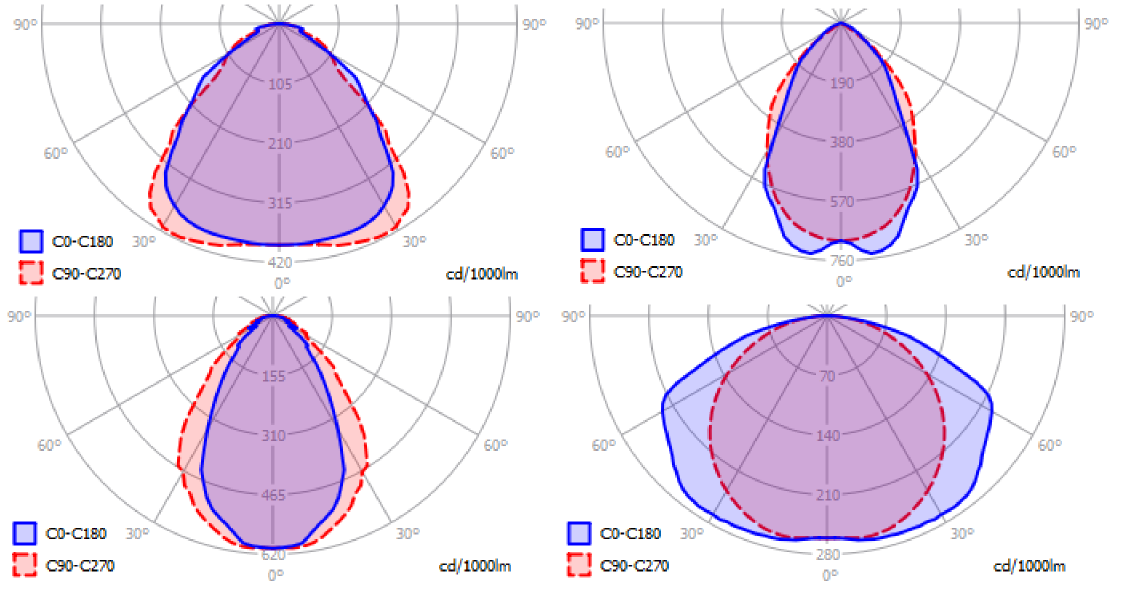

Fig.3. An example of luminous intensity distribution curve of square luminaires 1-4

Design of lighting systems

The procedure for designing the lighting system is clearly given and based on normative requirements. The first step of the design is to model a certain space (interior or exterior) with all the necessary parameters such as the reflectance of surfaces, the positioning of objects and windows, and the determination of the maintenance factor. The second step is usually the placement of computational areas or points, for example at the place of visual activity. In the third step, the luminaires are inserted into the modeled space. Computing software offers various luminaire arrangement options:

- rectangular arrangement
- polygonal arrangement
- circular arrangement
- line arrangement
- place individual luminaire
- automatic arrangement for space

In addition to the "circular arrangement" option, all other types of luminaires insertion add the luminaires to the room so that the angle of rotation about the vertical Z-axis is 0 °. In the case of square luminaires with an asymmetrical luminous intensity curve, the rotation of the luminaire shall be determined according to the luminous intensity curve, for example in a 3D view. This view is shown in Figure 4.

a) b)

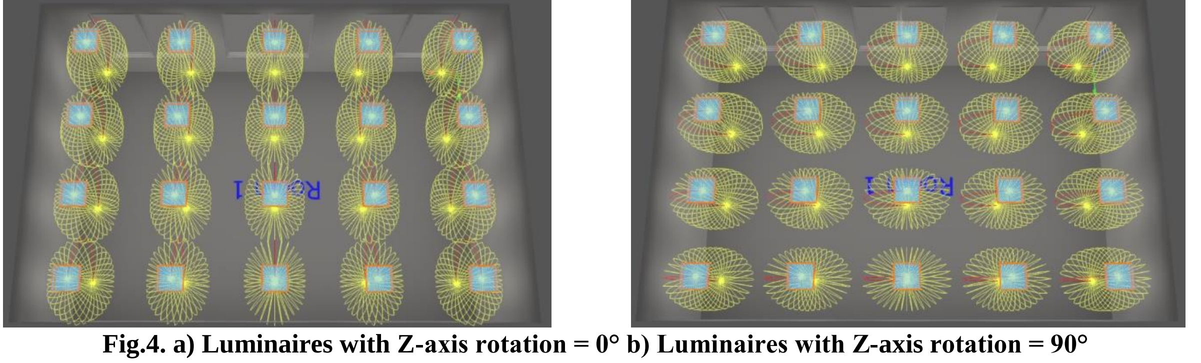

Fig.4. a) Luminaires with Z-axis rotation = 0° b) Luminaires with Z-axis rotation = 90°

The previous figures also show that the designer can turn the luminaires in the calculation software. However, in the case of square luminaires, the resulting rotation cannot be clearly determined from the lighting system documentation. In the documentation, which is generated by the calculation software, the arrangement of the luminaires as well as their rotation is usually mentioned. An example of such output is given in Table 1. The information about the rotation of a square or spherical luminaire has no telling value since it is often not possible to determine its axes with this type of luminaire.

Table 1. Information on the position and rotation of luminaires

Luminaire	Position [m]			Rotation [°]		
	X	Y	Z	X	Y	Z
1	9,9	1,04	3,2	0	0	0
2	3,24	1,04	3,2	0	0	0

Figures 5 and 6 show the arrangement of square luminaires. This output is generated by lighting design software. The images are the same, so it is not possible to determine the rotation of the luminaire.

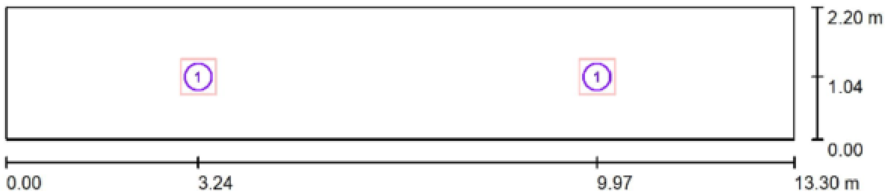

Fig.5. Arrangement of luminaires with rotation about Z-axis = 0 °

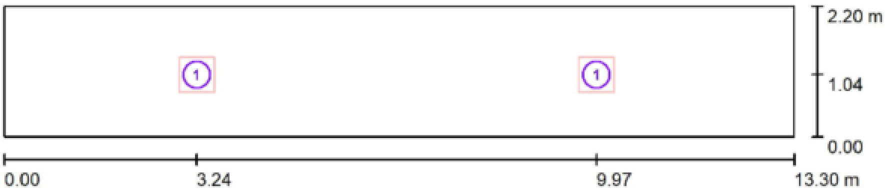

Fig.6. Arrangement of luminaires with rotation about Z-axis = 90 °

Simulation results

To compare the influence of 90° rotation of the luminaires around the Z-axis, simulations were performed in three calculation software. The visualizations of the rooms in each software are shown in Figure 7.

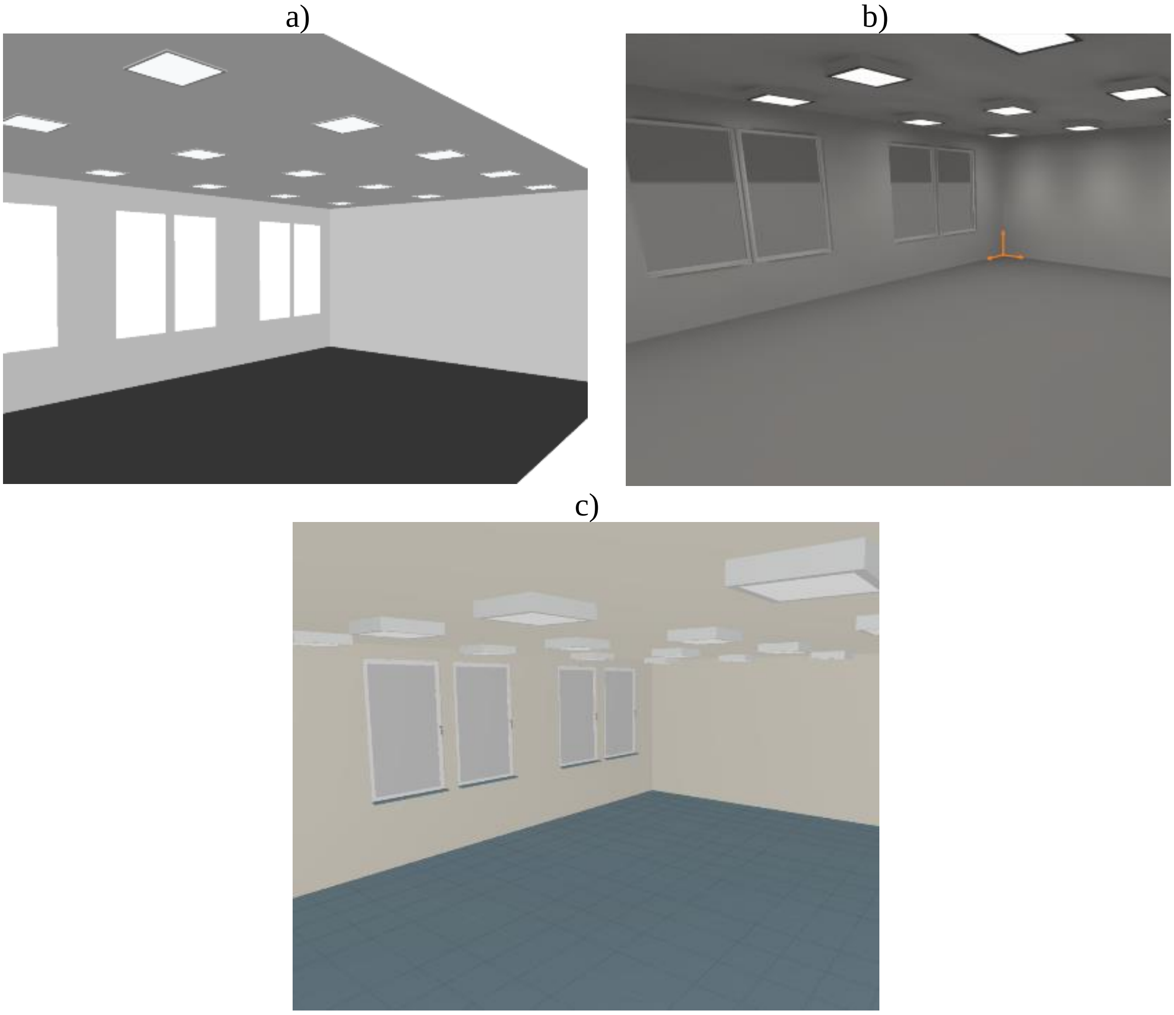

Fig.7. Visualisation of modelled room

A narrow corridor and a wide classroom were modeled in each computational software. The same dimensions, surface reflectivity, maintenance factors, dimensions and position of the windows were set in the rooms. Square luminaires were inserted into each project, the luminous intensity distribution curves of which are shown in Figure 2. A narrow corridor and a wide classroom were modeled in each computational software. The same dimensions, surface reflectivity, maintenance factors, dimensions and position of the windows were set in the rooms. Square luminaires were inserted into each project, the luminous intensity distribution curves of which are shown in Figure 2.

The calculated parameters were:

- average maintained illumination $\bar{E}_m$
- uniformity of illumination U_0
- UGR

Tables 2 to 8 show the results of the simulations.

Table 2. Calculated parameters of the lighting system in the corridor where was used the luminaire no. 1

LUMINAIRE 1									
	Tool 1			Tool 2			Tool 3		
	Z=0°	Z=90°	Δ (%)	Z=0°	Z=90°	Δ (%)	Z=0°	Z=90°	Δ (%)
$\bar{E}_m$ (lx)	132	136	2,9	132	137	3,6	129	133	3
U_0 (-)	0,53	0,56	5,4	0,53	0,57	7	0,51	0,53	3,8
UGR (-)	20	20	0	19,5	19,6	0,5	20,6	20,4	-1

Table 3. Calculated parameters of the lighting system in the corridor where was used the luminaire no. 2

LUMINAIRE 2									
	Tool 1			Tool 2			Tool 3		
	Z=0°	Z=90°	Δ (%)	Z=0°	Z=90°	Δ (%)	Z=0°	Z=90°	Δ (%)
$\bar{E}_m$ (lx)	125	133	6	126	134	6	125	134	6,7
U_0 (-)	0,67	0,69	2,9	0,74	0,75	1,3	0,71	0,71	0
UGR (-)	19	23	17,4	18,7	22,2	15,8	21,1	25,1	15,9

Table 4. Calculated parameters of the lighting system in the corridor where was used the luminaire no. 3

LUMINAIRE 3									
	Tool 1			Tool 2			Tool 3		
	Z=0°	Z=90°	Δ (%)	Z=0°	Z=90°	Δ (%)	Z=0°	Z=90°	Δ (%)
$\bar{E}_m$ (lx)	148	145	-2,1	149	146	-2,1	145	142	-2,1
U_0 (-)	0,4	0,34	-17,6	0,4	0,33	-21,2	0,39	0,32	-21,9
UGR (-)	20	18	-11,1	19,7	17,8	-10,7	20,6	18,3	-12,6

Table 5. Calculated parameters of the lighting system in the corridor where was used the luminaire no. 4

LUMINAIRE 4									
	Tool 1			Tool 2			Tool 3		
	Z=0°	Z=90°	Δ (%)	Z=0°	Z=90°	Δ (%)	Z=0°	Z=90°	Δ (%)
$\bar{E}_m$ (lx)	139	126	-10,3	140	126	-11,1	135	122	-10,7
U_0 (-)	0,43	0,34	-26,5	0,43	0,33	-30,3	0,43	0,33	-30,3
UGR (-)	21	17	-23,5	20,1	16,4	-22,6	20,8	18,1	-14,9

Table 6. Calculated parameters of the lighting system in the classroom where was used the luminaire no. 1

LUMINAIRE 1									
	Tool 1			Tool 2			Tool 3		
	Z=0°	Z=90°	Δ (%)	Z=0°	Z=90°	Δ (%)	Z=0°	Z=90°	Δ (%)
$\bar{E}_m$ (lx)	527	525	-0,4	517	515	-0,4	522	523	0,2
U_0 (-)	0,67	0,67	0	0,64	0,64	0	0,82	0,85	3,5
UGR (-)	19	19	0	18,7	19,5	4,1	20,2	20,9	3,3

Table 7. Calculated parameters of the lighting system in the classroom where was used the luminaire no. 3

LUMINAIRE 3									
	Tool 1			Tool 2			Tool 3		
	Z=0°	Z=90°	Δ (%)	Z=0°	Z=90°	Δ (%)	Z=0°	Z=90°	Δ (%)
$\bar{E}_m$ (lx)	524	521	-0,6	515	517	0,4	553	550	-0,5
U_0 (-)	0,63	0,66	4,5	0,65	0,62	-4,8	0,81	0,72	-12,5
UGR (-)	16	17	5,9	16,7	16,9	1,2	19,9	22,3	10,8

Table 8. Calculated parameters of the lighting system in the classroom where was used the luminaire no. 4

LUMINAIRE 4									
	Tool 1			Tool 2			Tool 3		
	Z=0°	Z=90°	Δ (%)	Z=0°	Z=90°	Δ (%)	Z=0°	Z=90°	Δ (%)
$\bar{E}_m$ (lx)	605	608	0,5	593	597	0,7	580	588	1,4
U_0 (-)	0,71	0,65	-9,2	0,69	0,59	-16,9	0,79	0,89	11,2
UGR (-)	18	19	5,3	18,5	18,5	0	19,4	19,3	-0,5

Conclusion

From the calculated values it follows that the rotation of the square luminaire by 90 degrees has a significant influence on the calculated parameters of the lighting system. The biggest change in average maintained illumination was achieved with the luminaire no. 4 which was used in the corridor. This change was -11,4%. Changes of the average maintained illumination in the classroom were minimal. The significant influence of luminaire rotation was on parameter U0 too. In the corridor, there was the biggest difference of this parameter after turning the luminaire by 90 degrees - 30.3% and in the classroom -16.9%. The UGR parameter was also influenced by changing the rotation of the luminaires around the Z-axis. The biggest change in UGR was recorded in a narrow corridor where there was a difference 23,5%. The results show that the designer must also consider the possibility that the lighting system will be realized with luminaires turned 90 degrees. Especially for square and spherical luminaires where it is not possible to determine the longitudinal axis of the luminaire, the designer should verify the effect of the rotation of these luminaires. The consequent financial costs associated with rotating the luminaires in the finished lighting system can be high.

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