IEEE Access
Multidisciplinary : Rapid Review : Open Access Journal

Received August 3, 2020, accepted August 14, 2020, date of publication August 25, 2020, date of current version September 9, 2020.

*Digital Object Identifier 10.1109/ACCESS.2020.3019314*

# CSP-LEDs Combined With Light Guide Without Reflective Matrix for Antiglare Design

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This work was supported by the MOST under Grant MOST109-2124-M-009-010.

**ABSTRACT** This study proposed a model with different luminous intensity profiles without reflective matrix bar for light fixtures that used asymmetric luminous intensity(ALI) CSP-LEDs (Chip Scale Package-Light emitting diode) combined with light guide as light source module, and analyzed illumination uniformity and unified glare rating (UGR) performance by using a classroom as an example. The study constructed a model of light fixture use in classrooms. Four important parameters affect the comfort of human eye that include UGR, illumination, uniformity of spatial and light distribution of light fixture, in particular, light distribution of light fixture was major affect factor for direct glare. Therefore, light fixture designers previously used many diverse structures to prevent glare, but which will result in a loss of light fixture efficiency about 25%-35% that caused by material absorption and ray loss. This study proposed used ALI CSP-LEDs combined with light guide as light source to optimize different light distribution angles without attached reflective matrix bar or second optical lens on light fixture to simulate a light fixture in a classroom and to evaluate UGR, illumination and uniformity values. We also consider the light fixture tilt angle caused effect of UGR and uniformity. On the basis of the simulation and experimental results, ALI CSP-LEDs beam angle relative to vertical and horizontal axes were 150° and 120°, respectively, the light distribution profile for a beam angle 90° provided the highest illumination uniformity and a UGR of less than 19. Thus, light fixtures with a light distribution angle of beam angle 90° supply human-friendly for anti-glare lighting.

**INDEX TERMS** Anti-glare, asymmetric luminous intensity, light guide, CSP-LEDs, unified glare rating.

## I. INTRODUCTION

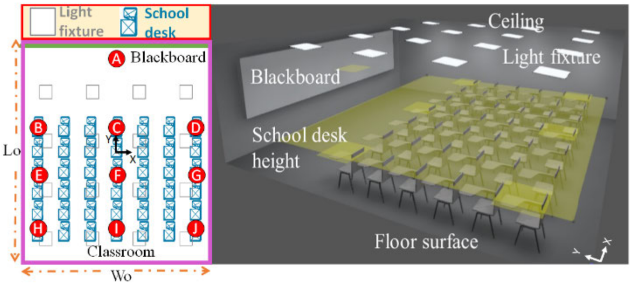
Lighting quality has been identified as a function of the brightness characteristics of unique portions of a visual field [1]. Unified glare rating (UGR) index is an important function for evaluating office, classroom and home lighting that concerning the comfort of the human eye. Over brightness can cause glare, which may impair visual efficiency [2]. International responses to glare are unacceptable; methods adopted in different countries have provided incompatible predictions [3]. UGR value and the individual estimation of glare-related discomfort be discussed [4].

The associate editor coordinating the review of this manuscript and approving it for publication was Jenny Mahoney.

The UGR value is an estimation value for assessing the uncomfortable glare correlative with indoor lighting. Universally, lighting systems have a UGR of 10–25, which a higher UGR representing even more uncomfortable with the human eye. Thereafter, the merits and applications of multiple light sources were recommended [5]. In recent years, many scholars have recommended methods for evaluating a glare index, and UGR is the most frequently applied method [6]–[8]. With the development of artificial light sources, the manufacturers of light fixtures have employed different glare-reducing approaches. There are two modes of glare: direct and reflective glare. Direct glare is caused by light from the light source directly incident into eyes. Therefore, light fixture designers previously used many diverse structures to prevent glare, such as reflective matrix bar to improve illumination [9], decrease UGR and obtain sufficient illuminance simultaneously but which will result in a loss of light fixture efficiency about 25%-35% that caused by material absorption and rays loss [10], so second optical element of reflective matrix bar caused serious energy loss. Traditional fluorescent light is obtained using a linear light source with a reflective matrix bar or louver structure for glare reduction. A louver is used to adjust the light distribution curve [11]–[13]. Light emitting diodes (LEDs) owing to many benefits such as high energy saving, high color rendering index and efficiency, so have become widely used in Lighting applications [14]. Lighting fixtures with LEDs require an evaluation method different from classical lighting fixtures [15]. A LED is a point light source that strengthens glare because, it has the same luminosity as fluorescent light flux in a small unit area. The studies as in have concentrated on using a specific lens and surrounding sidewall to adjust the light distribution [16]. Moreover, optimization of light fixtures layout to achieve anti-glare [17], [18]. Furthermore, some paper describes research to survey discomfort glare caused by LED lights having different spectral distributions [19], [20]. Besides, LED through a freeform lens gives a new light distribution angle that can result in antiglare [21]. In addition, in order to reduce UGR index some researches discussion on how to convert LED from point light source into a widely area light source, in 2015, a hollow air guide with second collimated lens and side-light LED was proposed [22]. In 2019, a tilted light-coupling structure (TLCS) for a panel light with a light coupling design that can achieve light guide plate thinner than the luminescence regional width of a LED source [23]. Equally, an asymmetric light field of CSP-LEDs and a light guide with full printed reflective layer on the bottom surface for an illuminator [24], [25]. Similarly, a hollow cavity makeup comprising LEDs with asymmetric light intensity, that converting LED from point light source into strip surface light sources without solid light guide, so its lighter than that of similarly sized solid light guide model [26]. In summary, these studies proposed antiglare design from design the point light into a widely light source such as linear or planar light source, however, these studies do not mention research on optimizing the light distribution of the light fixture.

## II. UGR DEFINITION AND SPATIAL CHARACTERISTICS

We arranged a classroom spatial layout classroom as illustrated in the floor plan in Figure 1, with a classroom length and width of L0 (Y direction) and W0(X direction), respectively, ceiling of height 3.2 meter and installed light fixtures on a height of 2.99 meter from the floor. A total of 42 sets of school desks and 16 light fixtures were arranged in the classroom. We selected ten positions A-J to evaluate UGR value, the position A indicated a teacher present in front of the classroom and the B to J positions represented students sitting at desks. We set the height of the first surface A from




(a) (b)

**FIGURE 1.** Simulation spatial layout in DIALux Evo. (a) Classroom 2D plan, (b) 3D model design plan.

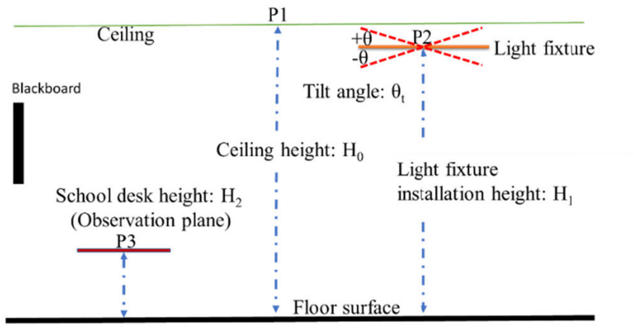



**FIGURE 2.** Illustration side view of ceiling height, light fixture installation height, school desk height and light fixture tilt angle of $H_0$, $H_1$, $H_2$ and $\theta$ respectively.

floor to 1.7 meter to simulate the UGR visual plane of the teacher and surfaces B to J from floor to 1.2 meter to simulate the UGR visual plane of students.

We set up light fixtures on ceiling, as illustrated in Figure 2, the ceiling height H0 from floor are positioned at P1, light fixture installation height H1 from floor at P2, the desk height H2 from floor at P3. We also considered the effect of UGR caused by light fixture tilt, $\theta$ represents the tilt angle of the light fixture. $+\theta$ means rotation towards the blackboard direction.

The light distribution angles of light fixtures were changed without changing the light fixture position to simulate UGR, uniformity and tilt angle of light fixture affected on UGR and uniformity. UGR is defined in Equation (1).

$$UGR = 8\log\left[\frac{0.25}{L_b}\sum\left(\frac{L^2\omega}{p^2}\right)\right] \tag{1}$$

In which 8 gives UGR numeric which optimize in a range from about 5 to 40. Log function is human eyes respond logarithm to brightness. Σ shows the equation comprises all the fittings situated within the area, in which $L_b$ is defined as Equation (2).

$$L_b = \frac{E_{ind}}{\pi} \tag{2}$$

where $L_b$ is background luminance value in cd / $m^2$, that calculated as $E_{ind}/\pi$, in which illuminance $E_{ind}$ is the perpendicular indirect illuminance at the observer's eye and luminance L is defined as Equation (3).

$$L = \frac{I}{A_p} \quad (3)$$

where luminance L is the value of the radiant parts of each light fixture in the direction of the eye of the observer in cd/$m^2$, calculated as I /$A_p$, in which I is the brightness of light fixture and $A_p$ represents the project area and solid angle $\omega$ is defined as Equation (4) [27].

$$\omega = \frac{A_p}{r^2} \quad (4)$$

where solid angle ($\omega$) is the three-dimensional analog of an angle of the luminous parts of each light fixture at the eye of the observer and unit is steradian (sr) on SI unit, in which distance r is from the light fixture to the observer's eyes. Guth position index P is indicator of each glaring luminaire in relation to the direction of observation. Uniformity value is the ratio of minimum illuminance to average illuminance on a surface, as indicated in Equation (5).

$$Uniformity = \frac{minimum(lx)}{average(lx)} \times 100 \quad (5)$$

UGR, Illumination, and uniformity of spatial value should be less than 19, higher than 300, and more than 60%, respectively in the classroom [28].

## III. SIMULATION UGR, ILLUMINATION AND UNIFORMITY OF SPATIAL

Table 1 presents the simulation parameters and setting that include luminous flux, classroom length $L_0$, classroom width $W_0$, correlated color temperature, ceiling height $H_0$, light fixture installation height $H_1$, school desk height $H_2$, reflection factors of classroom ceiling, reflection factors of classroom walls, and reflection factors of classroom floor.

**TABLE 1.** Simulation setting parameters in DIALux Evo.

| Specifications | Characteristics |
|---|---|
| luminous flux | 3250 lumens |
| classroom length (L0) | 10 Meter |
| classroom width (W0) | 9 Meter |
| correlated color temperature (CCT) | 4000K |
| ceiling height (H0) | 3.2 Meter |
| light fixture installation height (H1) | 2.99 Meter |
| school desk height (H2) | 0.8 Meter |
| reflection factors of classroom ceiling | 70% |
| reflection factors of classroom walls | 50% |
| reflection factors of classroom floor | 20% |

Table 2 and Table 3 show details UGR relation with the beam angle 70° to 80° and 90° to 120°, respectively. We modulated beam angles without varying the position of the light fixture to compare UGR and uniformity of spatial. According to regulations EN12464-1 2002 for classrooms, the threshold values for UGR, illumination value and illumination uniformity should be less than 19, higher than 300 lx and more than 60%, respectively. Figure 3 presents flow chart of the design methodology for antiglare design.

**TABLE 2.** Relationship between UGR and beam angle 70° to 80°.

| Observer NO., Surface Position (x,y) | Surface height | Min. UGR | Beam angle 70° Max. UGR | Beam angle 80° Max. UGR |
|---|---|---|---|---|
| A, (x0,y4.365) | 1.7M | <10 | 16 | 17.1 |
| B, (x-3.772,y1.242) | 1.2M | <10 | 14.6 | 16 |
| C, (x0,y1.242) | 1.2M | <10 | 14.6 | 15.7 |
| D, (x3.772,y1.242) | 1.2M | <10 | 14.7 | 16.1 |
| E, (x-3.772,y-1.271) | 1.2M | <10 | 14.8 | 16 |
| F, (x0,y-1.271) | 1.2M | <10 | 14.7 | 15.9 |
| G, (x3.772,y-1.271) | 1.2M | <10 | 14.8 | 16.2 |
| H, (x-3.772,y-3.385) | 1.2M | <10 | 14.7 | 16.2 |
| I, (x0,y-3.385) | 1.2M | <10 | 14.8 | 16.2 |
| J, (x3.772,y-3.385) | 1.2M | <10 | 14.8 | 16.2 |

**TABLE 3.** Relationship between UGR and beam angle 90° to 120°.

| Observer NO., Surface Position (x,y) | Beam angle 90° Max. UGR | Beam angle 100° Max. UGR | Beam angle 110° Max. UGR | Beam angle 120° Max. UGR |
|---|---|---|---|---|
| A, (x0,y4.365) | 18.2 | 19.6(fail) | 20.9(fail) | 21.8(fail) |
| B, (x-3.772,y1.242) | 17.5 | 18.7 | 19.8(fail) | 20.5(fail) |
| C, (x0,y1.242) | 16.8 | 17.9 | 18.8 | 19.3(fail) |
| D, (x3.772,y1.242) | 17.5 | 18.7 | 19.8(fail) | 20.5(fail) |
| E, (x-3.772,y-1.271) | 17.3 | 18.6 | 19.7(fail) | 20.5(fail) |
| F, (x0,y-1.271) | 17 | 18 | 18.8 | 19.2(fail) |
| G, (x3.772,y-1.271) | 17.3 | 18.7 | 19.7(fail) | 20.5(fail) |
| H, (x-3.772,y-3.385) | 17.6 | 18.9 | 19.9(fail) | 20.6(fail) |
| I, (x0,y-3.385) | 17.6 | 18.8 | 19.7(fail) | 20.4(fail) |
| J, (x3.772,y-3.385) | 17.6 | 18.9 | 20.0(fail) | 20.7(fail) |

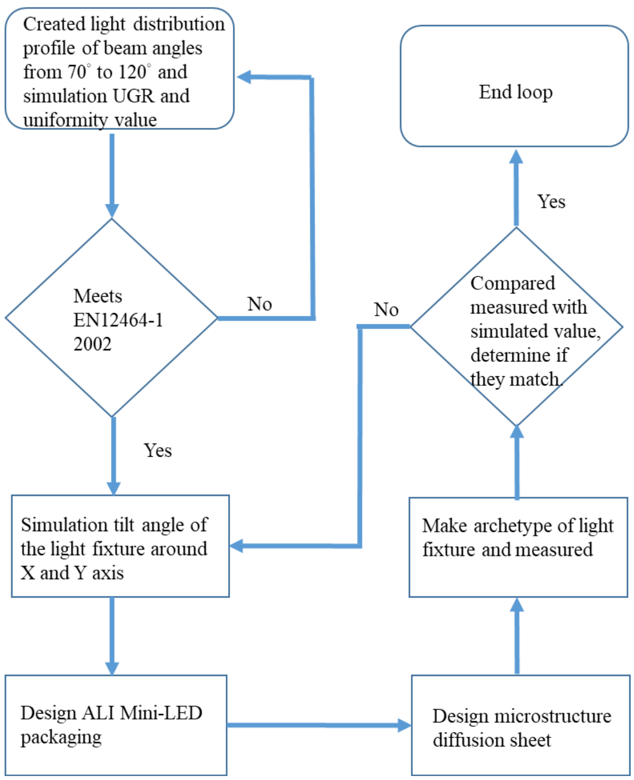



**FIGURE 3.** **Flow chart of the methodology.**

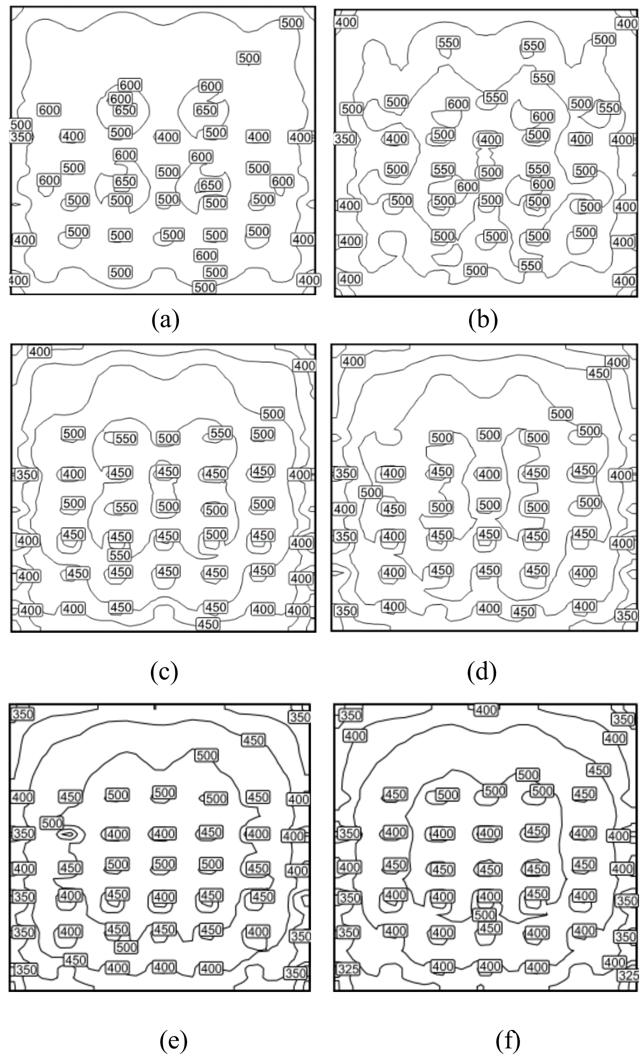



**FIGURE 4.** **Topographic illumination map(lx) with different beam angle conditions. (a) beam angle 70°, (b) beam angle 80°, (c) beam angle 90°, (d) beam angle 100°, (e) beam angle 110°, and (f) beam angle 120°.**

In this article, the simulation has been performed with DIALux Evo.

Figure 4. shows the topographic illumination map on different beam angle as below:

Figure 4(c) presents lx topographic simulated using a light fixture beam angle of 90° and indicates that the 450–550 lx topographic is distributed in majority of the space, the 400 lx topographic is around the edge, and the 350 lx topographic is observed at the edge. The lx topographic changes with a variation in light distribution angle. When the beam angle increases the light irradiated range is wider, so uniformity of spatial distribution becomes more uniform.

Figure 5 shows different beam angle conditions as colors illumination map of uniformity.

Figure 5(c) shows illumination of >405 and 271–405 lx are presented as orange and yellow zones, respectively. On the basis of the simulation result was used to evaluate the illumination uniformity of different light distribution angles. The uniformity values of beam angles of 70°, 80°, 90°, 100°, 110°, and 120° were 64%, 65%, 67%, 67%, 67% and 68%, respectively. Although the beam angle of 120° had the highest uniformity but UGR value at position A-J all over 19.

Table 4 shows illumination and uniformity of spatial value with different beam angles, that indicates beam angle of 90°, 100°, 110°, and 120° of uniformity are approximate.

The average (avg.) and maximum (max.) illumination value of beam angle 90° were 495 and 592 lx, respectively, that more than beam angles 100° to 120°, and minimum (min.) illumination value were 331 lx that more than 300 lx. The uniformity (um.) were 67% that more than 60%, all to conform to regulations for general lighting applications for classrooms.

We using a classroom as an example, in a roomy space, the difference values of illuminance will affect the comfort of the human eye. The illuminance difference values of 283 lx, 261 lx for beam angle 80° and 90°.

Figure 6 presents the light distribution profile of beam angles ranging from 70° to 120°.

The light distribution curve for a beam angle of 70° to 120°. In the judgment of UGR, the smaller beam angle performed more satisfactorily than the larger beam angle. In contrast, in the judgement of illumination uniformity, a larger beam angle was better than a smaller beam angle. Table 2, III and Table 4 present UGR and uniformity values, respectively.

Figure 7 details connection between uniformity and UGR at varied beam angles. The beam angle of 90° corresponds to

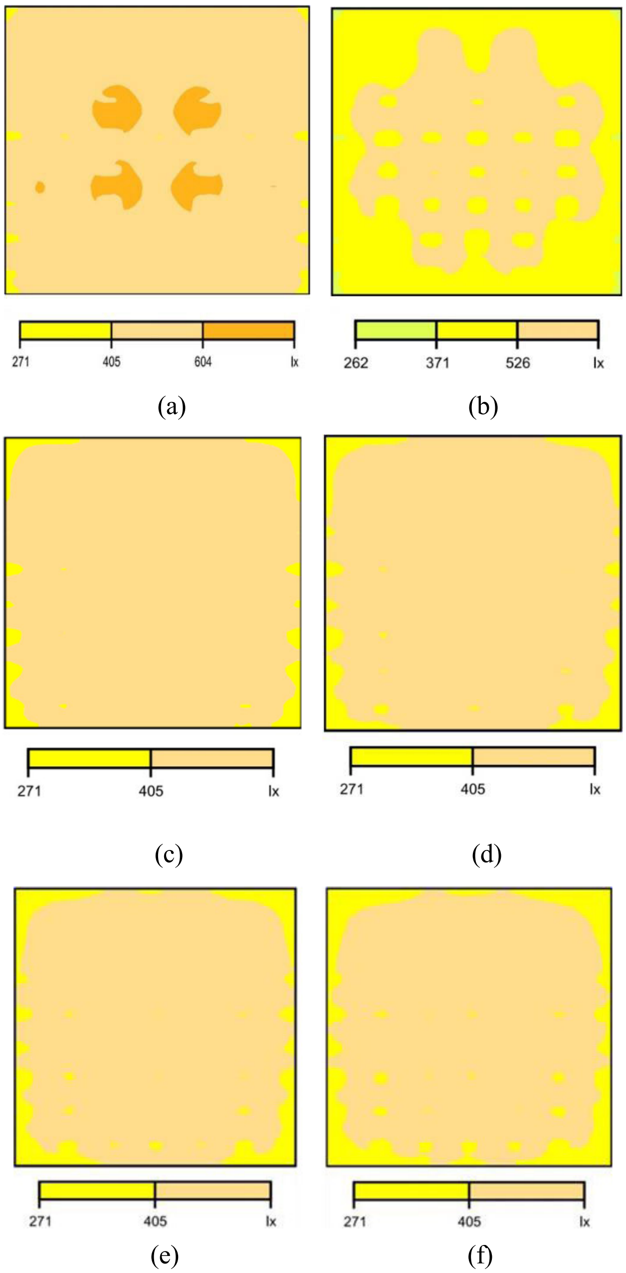



**FIGURE 5.** Colors illumination map of uniformity for different beam angles of (a) beam angle 70°, (b) beam angle 80°, (c) beam angle 90°, (d) beam angle 100°, (e) beam angle 110°, and (f) beam angle 120°.

a UGR of 18 that under 19, which is the critical value, and has a uniformity higher than that exhibited by beam angles of 70° and 80°. That is approximately similar to the uniformity exhibited by beam angles of 100° and 110°. Thence, considering the uniformity and UGR values concurrently, the optimized beam angle is 90 degrees.

Figure 8 shows the $90^0$ beam angle topographic and color illumination map of uniformity.

The center and corner of illumination value were 575, 425 lx, respectively. The classroom 3D illuminance distribution at beam angle of 90° is shown in Figure 9.

**TABLE 4.** Illumination and uniformity value with different beam angles 70° to 120°.

| No. | Beam angle | | | | | |
|---|---|---|---|---|---|---|
| | 70° | 80° | 90° | 100° | 110° | 120° |
| Avg. lx | 534 | 513 | 495 | 478 | 466 | 452 |
| Min. lx | 341 | 336 | 331 | 322 | 312 | 306 |
| Max. lx | 656 | 619 | 592 | 568 | 550 | 530 |
| Δlx (Max-Min) | 315 | 283 | 261 | 246 | 238 | 224 |
| Um % | 64% pass | 65% pass | 67% pass | 67% pass | 67% pass | 68% pass |

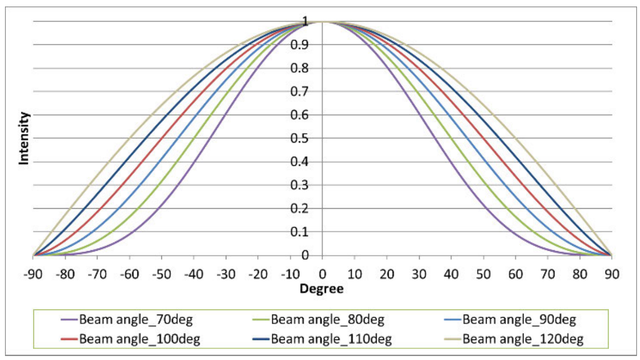



**FIGURE 6.** Light distribution profile of beam angles from 70° to 120°.

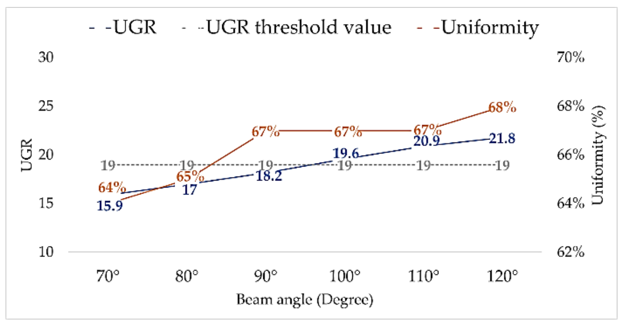



**FIGURE 7.** UGR and uniformity at beam angles from 70° to 120°.

Since the anti-glare light fixture that we proposed without reflective matrix bar, so we also consider the effect of UGR caused by tilt angle of light fixture. Figure 10 illustrates tilt angle of the light fixture around X axis. Figure 11 shows the variation in the uniformity and UGR with the tilt angle of the light fixture. In a tilt angle of 0°, the UGR was less than the threshold value of 19, and had best uniformity by contrast the other tilt angles.

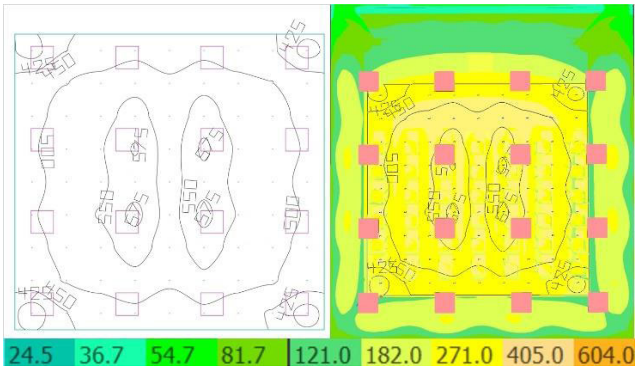



**FIGURE 8.** Topographic illumination map and colours illumination map of beam angle 90o.

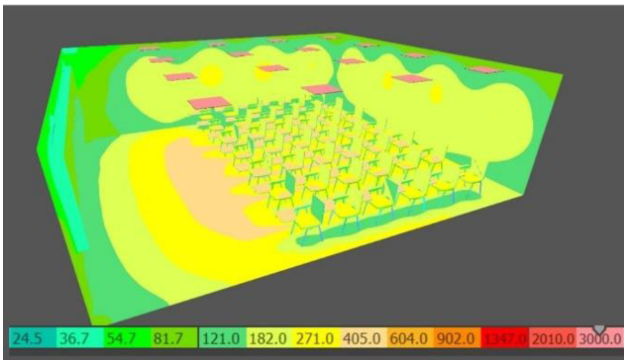



**FIGURE 9.** 3D colours illumination map of beam angle 90°.

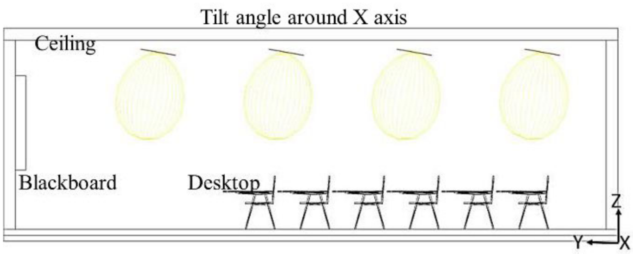



**FIGURE 10.** Illustration tilt angle of the light fixture around X axis.

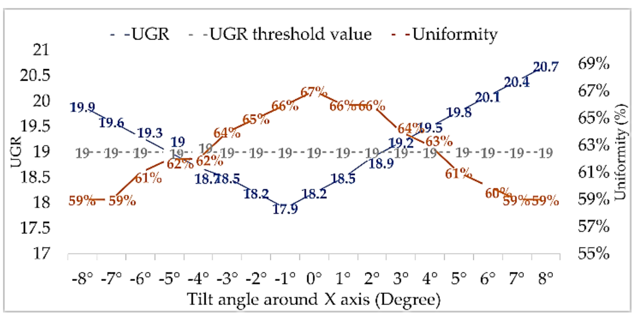



**FIGURE 11.** Simulation results of UGR and uniformity when tilt angle around X-axis.

The simulation results indicate that the tilt angle of the light fixture around X axis +8° to −8°, at +2° to −4° the glare value under the threshold of 19, and the glare value oversteps the threshold of 19 for a tilt angle more than +3° and -5°, and the tilt angle of the light fixture at +6° to −6° the uniformity more than 60%.

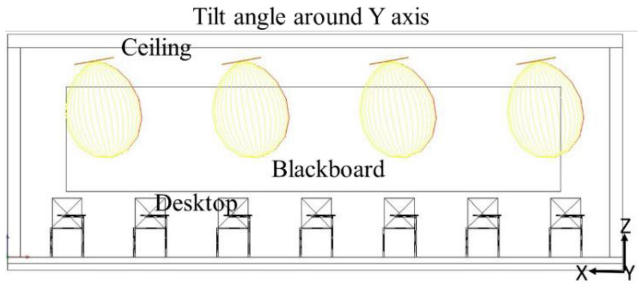



**FIGURE 12.** Illustration tilt angle of the light fixture around Y axis.

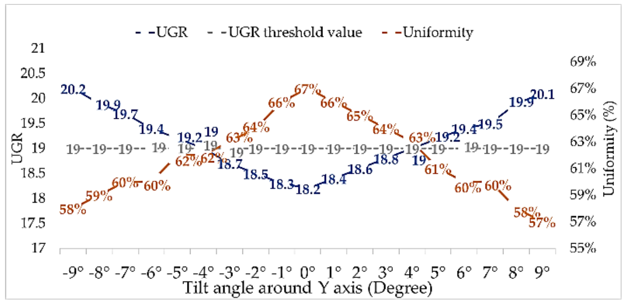
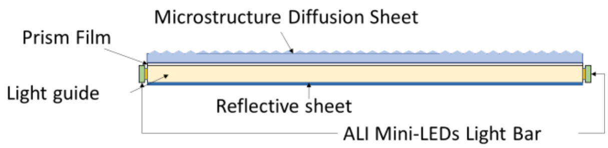
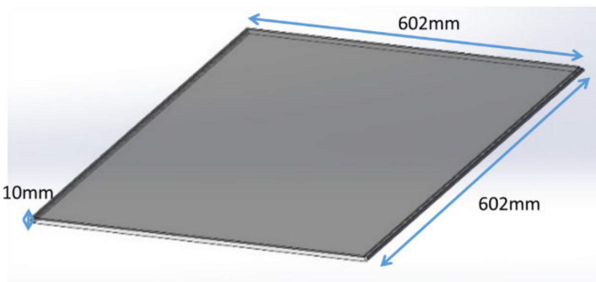



**FIGURE 13.** Simulation results of UGR and uniformity when tilt angle around Y-axis.




**(a) Side view of the light fixture.**




**(b) 3D model of the planar light module.**

**FIGURE 14.** Archetype structure in 2D and 3D views. (a) Side view and (b) 3D model of the planar light module.

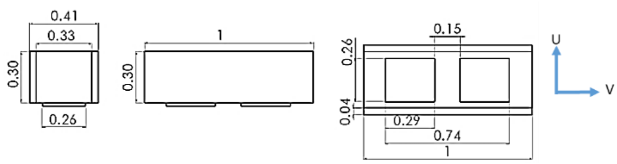



**FIGURE 15.** Two-dimensional view of ALI CSP-LED.

Figure 12 illustrates tilt angle of the light fixture around Y axis. Figure 13 shows the relation in the UGR and the uniformity with the tilt angle of light fixture. For a tilt angle of 0°, the UGR was less than 19, and the uniformity of spatial was higher than other tilt angles.

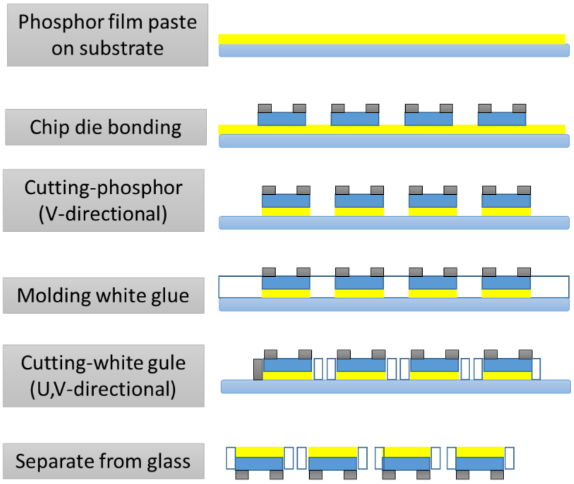



**FIGURE 16.** ALI CSP-LED Packaging Process.

**FIGURE 17.** Prototype of ALI CSP-LED.

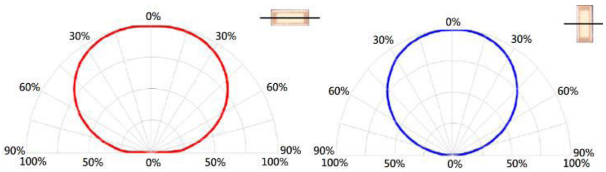
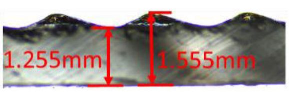
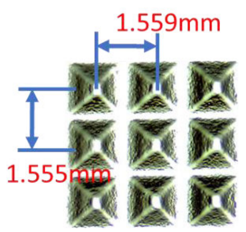



**FIGURE 18.** Asymmetric luminous intensity CSP-LEDs beam angle.




(a)




(b)

(c)

**FIGURE 19.** Shows the prototype of the microstructure diffusion sheet. (a.) side view. (b.) Top view and (c.) unequal view.

The simulation results indicate that the tilt angle of the light fixture around Y axis $+9°$ to $-9°$, at $+3°$ to $-3°$ the glare value under the threshold of 19, and the glare value oversteps

(a) Power shut down

(b) Power in operation

**FIGURE 20.** Archetype of light fixture that power was in operation and shut down.

the threshold of 19 for a tilt angle more than $+4°$ and -4°, and the tilt angle of the light fixture at $+7^0$ to $-7°$ the uniformity more than 60%.

## IV. EXPERIMENTAL RESULT

From the simulation results can know large area light source and controlling light output angle at beam angle 90 degree had better UGR and uniformity of spatial value. We used asymmetric ALI CSP-LEDs combined with light guide as light source module and control light emitting beam angle at 90°. Figure 14(a) illustrates the structure of the planar light viewed from the surface that includes a light guide, a microstructure diffusion sheet, prism film, a reflective sheet at the bottom, and two ALI CSP-LEDs light bar on opposite sides. Figure 14(b) presents the 3D model of the planar light. The light fixture dimension of length, width and thickness is 602mm, 602mm, and 10mm, respectively.

ALI CSP-LED used flip chips as light source that offers many strong points, for instance no wire bonding, a lower thermal resistance, no substrate, and without lead frame, so ability to endure a higher current density, all of which helpful in the design the asymmetric luminous intensity CSP-LED. A chip size of 740 $\mu$m × 260 $\mu$m × 150 $\mu$m and the CSP-LED packaged size was 1000 $\mu$m × 410 $\mu$m, which is illustrated in Figure 15.

Figure 16 illustrates the CSP-LED packaged flow. The first process of the packaged process pasted a phosphor film on a

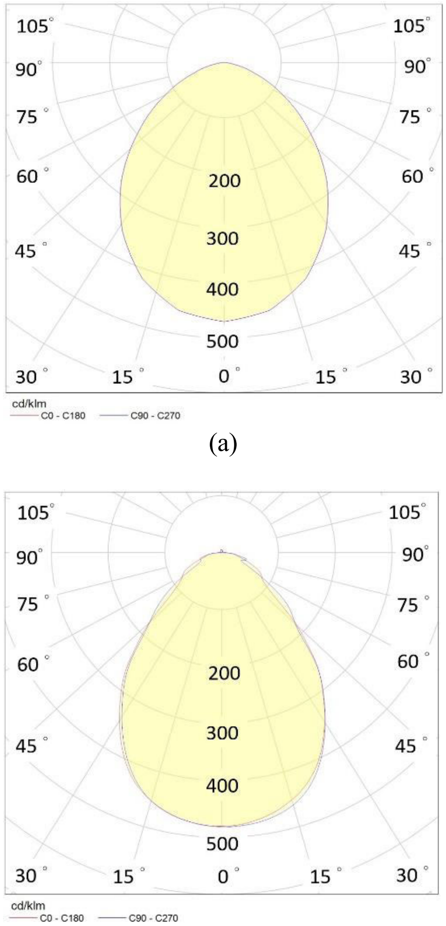



**FIGURE 21. Light distribution of beam angle of 90°. (a) Simulated from DIALux Evo and (b) Measured light distribution curve from the archetype.**

glass substrate. Second, process arranging the chip and die bonding, then cutting film along the chip sidewalk. Third, molding white glue along the long side of the flip chip and then cutting glue along the long all side. Finally, we separate the CSP-LEDs from the glass substrate by baking and UV curing. Figure 17 shows prototype of ALI CSP-LED.

Figure 18 illustrates the ALI CSP-LEDs beam angle relative to vertical and horizontal axes were 150° and 120°, respectively.

Figure 19 shows the prototype of the microstructure diffusion sheet. The dimension of the microstructure shown in Figure 19, in which pitch of 1.55mm, height of 0.3mm and substrate thickness of 1.25mm.

Figure 20 presents the archetype of light fixture that power was (a) power shut down and (b) power in operation.

Figure 21 depicts the light distribution of beam angle. light distribution curve from the simulation and archetype, respectively, beam angle at 90° that light shape is similar.

Base on one set light fixture, the illumination values of height of 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0 meter were 6695, 1674, 744, 418, 283, 268, and 186 lx, respectively as shown in Figure 22. Comparison between simulated and measured

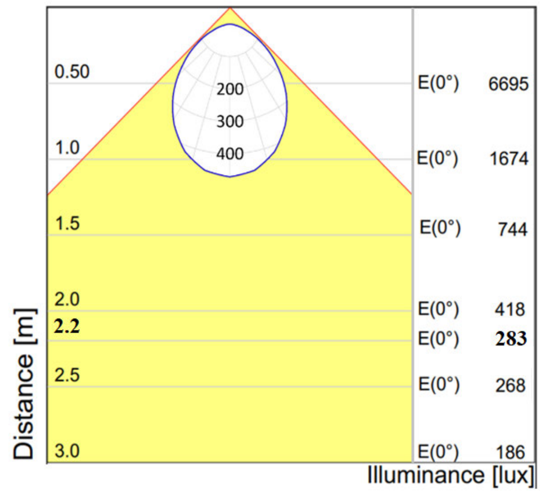



**FIGURE 22. Illumination value simulated from DIALux Evo.**

**TABLE 5. Comparison of measured and simulated illumination values.**

| Measuring distance (m) | Simulated of center illumination value (lx) | Measured of center illumination value (lx) |
|---|---|---|
| 0.5 | 6695 | 6583 |
| 1 | 1674 | 1646 |
| 1.5 | 744 | 732 |
| 2 | 418 | 411 |
| 2.2 | 283 | 279 |
| 2.5 | 268 | 264 |
| 3 | 186 | 184 |

**TABLE 6. Compare simulated with measured illumination values at the corners of the observe area with a classroom height of 2.2 m.**

| Measured height at 2.2m, Coordinates distance form center x,y (m) | Simulated illumination value (lx) | Measured illumination value (lx) |
|---|---|---|
| x:-1.025, y:-1.025 | 116 | 114 |
| x:+1.025, y:-1.025 | 116 | 113 |
| x:-1.025, y:+1.025 | 118 | 115 |
| x:+1.025, y:+1.025 | 118 | 115 |

illumination value is listed in Table 5. The result indicates a good matching between simulation and experiment.

Table 6 shows a compared measured with simulated illumination value, that measured illumination of 113 to 115 lx at the corners on the observe area.

## V. CONCLUSION

We proposed design of light distribution without attached reflective matrix bar, louver structure or second optical element on light fixture with ALI CSP-LEDs combined with light guide as light source module to decrease the glare effects and achieve high efficiency and meet uniformity requirements of space that considers for human factors in Lighting.

The simulation results indicate that a light fixture in a classroom at a beam angle of 90° has a UGR of less than 19 and uniformity value of higher than 60% in the classroom. The experiments revealed that the archetype results were similar to the simulation results. The light fixture can be used to design a classroom lighting plan with uniformity of 67%, a UGR of 18 and achieve average illumination of 495 lx to comply with EN12464-1 2002 for general lighting applications for classrooms and other architectures.

## ACKNOWLEDGMENT

The authors thank the anonymous reviewers for their valuable suggestions. This research was funded by the (MOST109-2124-M-009-010).

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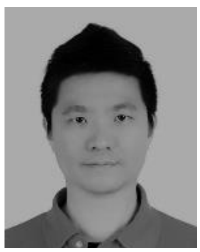

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