Daylight simulation for a typical laboratory using DIALux and Integration of Daylight with artificial lighting for Laboratory Work

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Abstract: Daylight is combination of sunlight, reflected light from the ground and skylight. Daylight is only the natural light available surrounding us which is mostly useful in outdoor use and its advantages of natural light are quietness, softness, calmness, and comfort. However, due to the availability of daylight for a limited time and at times limited luminance levels to perform a certain task, makes use of artificial lighting necessary. Present work reports the simulation of Daylight using simulation tool DIALux for a typical laboratory. This work also reports integration of daylight with artificial lighting to obtain sufficient glare free illumination for laboratory work task.

Key words: DIALux, daylight, glare, task lighting, LED tube.

Introduction:

Daylight is the combination of sunlight, reflected light from the ground and skylight. Skylight is the light which is scattered by molecules of air, aerosols and particles such as water droplets in clouds in the atmosphere, excluding direct beam. Factors affecting the amount of daylight in buildings include latitude and longitude, building form, building location, landscaping, building orientation, building usage, joinery construction materials of interior walls and exterior facades, window size and position and window components (such as glass ratio, glazing materials and shading devices). The amount of daylight in interior spaces can be measured by calculating method of daylight illuminance of space (in Lux and Foot Candle units) and daylight

factor (DF). The sky condition in Pune is clear in most days of the year, but from late June until the end of September is overcast and partially cloudy on most days. Therefore, both computational methods were used in this study. Daylight factor is the ratio of light level inside to the light level outside the structure, which can be measured for a specific point or for an average of a space In more accurate definition, Daylight factor is the "ratio of the illuminance at a point on a given plane due to the light received directly or indirectly from a sky of assumed or known luminance distribution, to the illuminance on a horizontal plane due to an unobstructed hemisphere of this sky, excluding the contribution of direct sunlight to both illuminance". The glazed area of the window, diffuse transmittance of through window material, total area of room surfaces including floors, ceilings, walls and windows, work place area are effective factors in daylight. The standard amount of daylight factor is not the same for all building types and each building has its own value[1,2]. Overall, if rate of daylight factors is below 2%, the space appears to be dark and depressing and often requires use of artificial lighting during daytime and artificial lighting dominates daytime appearance. If value of daylight factor is between 2% and 5%, windows have provided considerable daylight, but sometimes supplementary artificial lighting is still needed; if daylight factor is 5% or more, there would be enough light into the room and daytime electric lighting is rarely needed[3,4,5]. Also, there are standard criteria for the amount of daylight factor based on empirical and mathematical studies. Pune is one of the metropolitan city in state of Maharashtra in India having geographical location 18.516726^0 latitude and 73.856255^0 longitude. The sun track for Pune city is as shown in fig1and day length in different seasons in Pune city is as shown in fig2

(Source http://andrewmarsh.com/apps/staging/sunpath3d.html)[6]

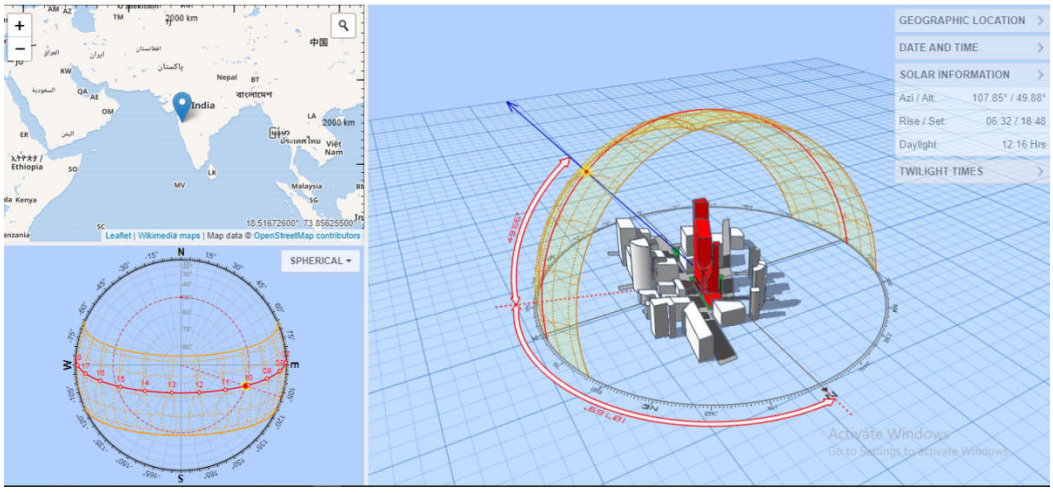


Figure1: Sun track for Pune

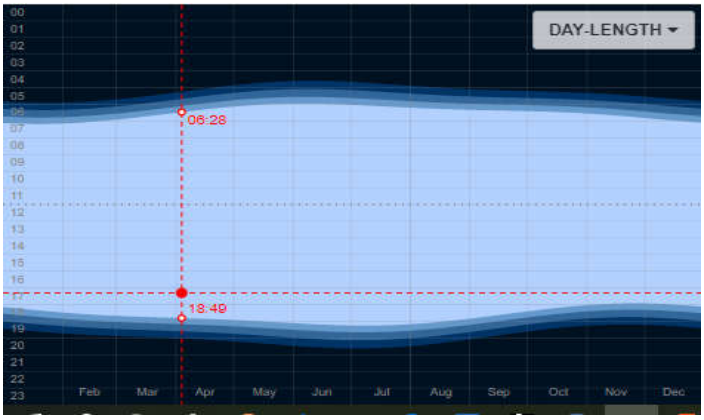


Figure2: Day length in Pune for different seasons

Daylight simulation of Typical Laboratory Using DIALux:

Typical laboratory has dimensions of 20 ft X 23 ft and ceiling height of 10 ft. Lab is rectangular room with regular standard walls and concrete ceiling (Dimensions of optoelectronics lab from the Electronic Science Department are used). Floor has reflectance of 52% ceiling has reflectance `86% and wall has reflectance of 82 %. To north side wall there are four windows two are of size 6.25 ft X 1.25 ft at height 6.92 ft from floor and two of size 6.25 ft X 3.67 ft at height 3 ft from floor. All windows have reflectance of 8 % and transparency of 19 %. A door of size 3.75 ft X 6.5 ft is at corner on west side wall having 56% reflectance and no transparency. There are two trees outside laboratory towards the north side. North alignment of laboratory is 0.5^0. For study of daylight simulation over a year the path of sun and day length in Pune

city are considered and plan for simulation experiment are carried out in three different groups as in table1

Table 1: Day and time Groups for Simulation

Group	Days selected	Time
1 Dec. 2016 to 28 Feb 2017	All days	7 am to 7 pm every one hour
1 March 2017 to 30 June 2017	Alternate days	7 am to 7 pm every one hour
1 July 2017 to 30 Nov. 2017	Random 8 days from each month	7 am to 7 pm every one hour

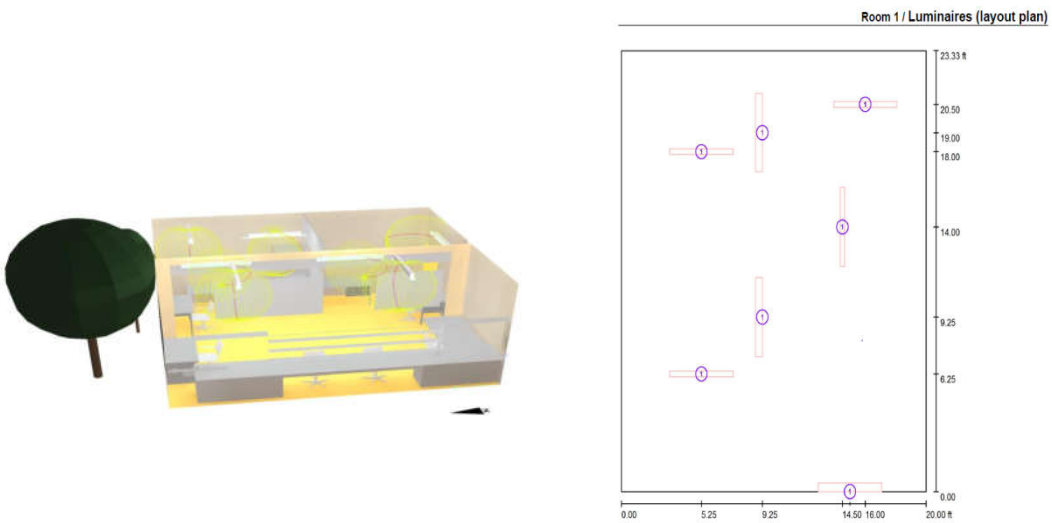


Figure 3: a) RTP laboratory design in DIALux . b) Luminary plan in laboratory.

There are seven GE lighting make LED tubes each of 18 watt. The 3D view of laboratory is as shown in fig3 (a) and luminary plan fig 3(b).

Artificial Illumination System Design for Typical laboratory: Initially daylight simulation is carried out using DIALux 4.13 for typical laboratory and daylight factor is determined for period of 1 December 2017 to 31 December 2017. Daylight factor varies from 0% to 1.31% with average daylight factor 0.38%. The outdoor horizontal illuminance is 981 fc while inside laboratory maximum illuminance is 10 fc minimum illuminance is 0.69 fc and average illuminance is 1,91 fc at workplace. Uniformity ratio for daylight is 0.066%. There is no glare at any point in laboratory due to daylight only. Total six unified glare rating (UGR) calculation points and ten UGR

observers are introduce in simulation model[7,8]. Glare rating (GR) is less than 10 for all observers, the positions of observers in the laboratory as shown in fig4 (a), the viewing sector for each observer is from 0^0 to 360^0 with increment of 15^0. The variation of illumination level of daylight at 1 pm is shown in fig.4(b).

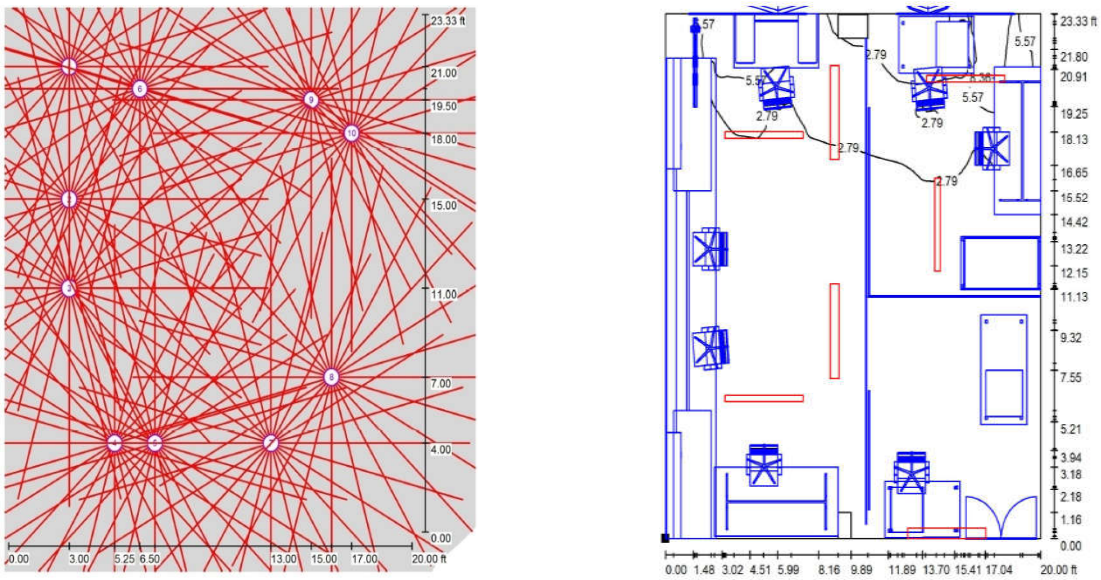


Figure4: a) Locations of GR observes and glare factor for each observer b. Isoline chart due to daylight at 1 pm.

The daylight is not sufficient for working in laboratory so artificial lightning should be design so that there is visual comfort and low power consumption. In this paper we have design the illumination system to achieve visual comfort and energy saving using LED tubes. Initially only two LED tubes are introduce and simulation results are obtained, illumination level increases but not sufficient for working in laboratory. So numbers of LED tubes are increase one by one by studying the value chart for each simulation. Finally laboratory is design with seven LED tubes each of 18 watt their positions are as shown in fig.1b. GELIGHTING 93010933 NL LED MARINER T8SINGLE 1200MM 840 18W are selected for simulation and practical designing of illumination system. Individual luminary have luminous flux of 1319 lm, CIE flux code 42 71 89 90 85 and correction factor 1.000. Total power consumed for seven LED

tubes is 126 watt for producing the light output of 9232 lm. The 3D view of simulated light distribution is as shown in fig 5 (a) and 3D view of false colour rendering as shown in fig 5(b). The GR observers with glare factor is as shown in fig. 6(a), the variation of illumination level with seven LED tubes in laboratory as shown in fig.6(b). Glare rating (GR) is less than 10 for observer no. 6 and 8, it is maximum 18 for observer no.2. GR values lies between 13 and17 for remaining observers. When GR is less than 13 there is no glare, when it is between 13 and19 illuminations is suited for average eye task. Standard illumination levels for different task are mention in table-1 and glare index in Table2[9].

Inside laboratory maximum illuminance is 15 fc, minimum illuminance is 1.76 fc, average illuminance is 9.33 fc at workplace and uniformity ratio for daylight is 0.118%.

Table 1: Standard illumination level for different task Index

Task	Illumination level in fc
Public areas with dark surroundings	1.9-4.65
Simple orientation for short visits	4.65-9.3
Working areas where visual tasks are only occasionally performed	9.3-13.95
Warehouses, Homes, Theaters, Archives	13.95
Easy Office Work, Classes	23.25
Normal Office Work, PC Work, Study Library, Groceries, Show Rooms, Laboratories	46.5
Supermarkets, Mechanical Workshops, Office Landscapes	69.7
Normal Drawing Work, Detailed Mechanical Workshops, Operation Theatres	93
Detailed Drawing Work, Very Detailed Mechanical Works	139 - 186
Performance of visual tasks of low contrast and very small size for prolonged periods of time	186 - 465
Performance of very prolonged and exacting visual tasks	465 - 930
Performance of very special visual tasks of extremely low contrast and small size	930 - 1860

Table2: Glare

Glare index	Reaction
0-13	Imperceptible
13-16	Noticeable
16-22	Acceptable
22-28	Uncomfortable
Above 28	Intolerable

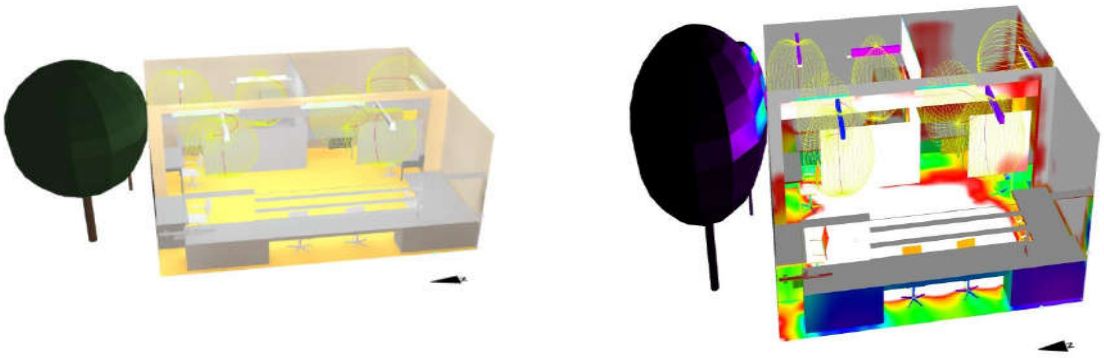


Figure5: a) Simulated light distribution b) Simulated false colour rendring

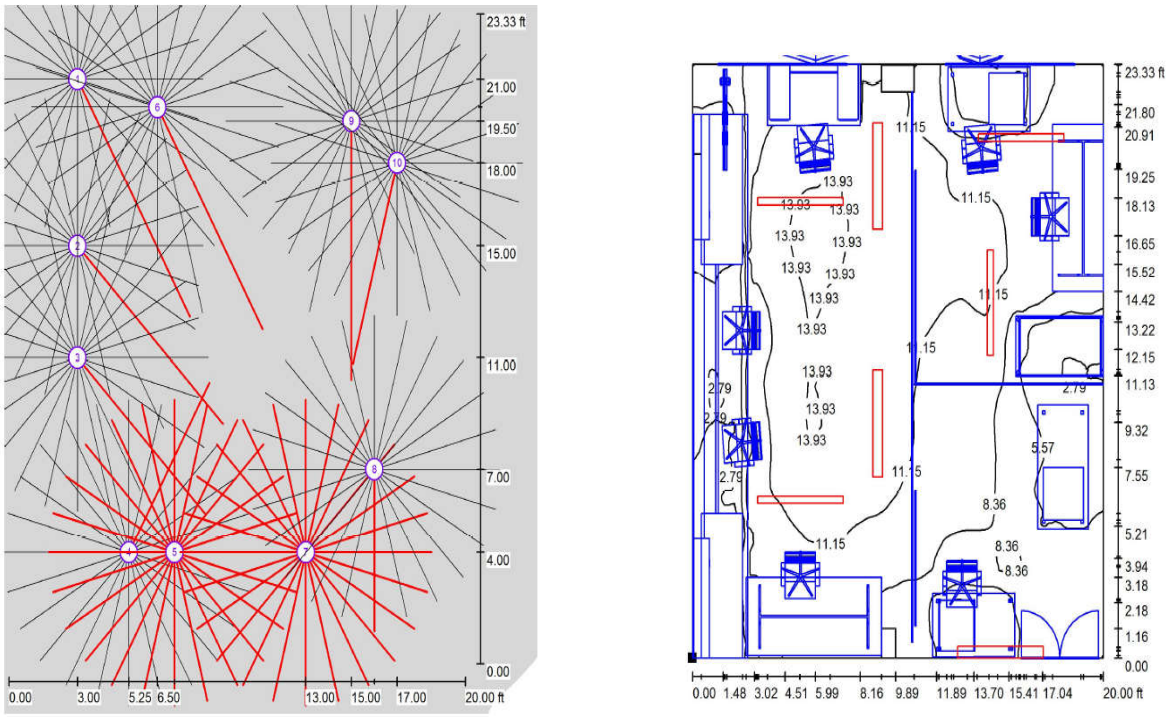
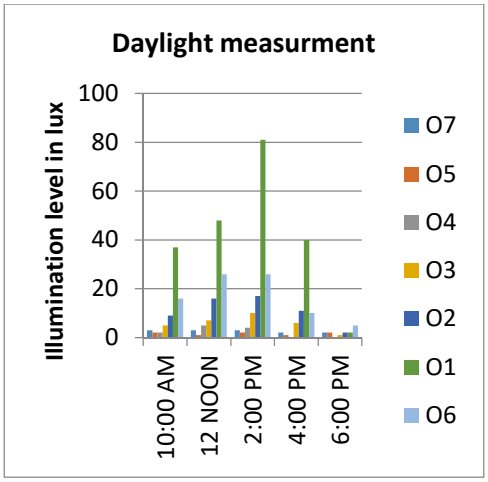


Figure 6: a). Locations of GR observes and glare factor for each observer b). Isoline chart with seven LED tubes at 1 pm.

Daylight and daylight with artificial lighting illumination level is measured at seven different observer positions O1, O2, O3, O4, O5, O6, and O7 using lux meter at 2.5 feet height from floor in working time of 10am to 6 pm. The variation of illumination level is as shown in fig.7(a) and (b).



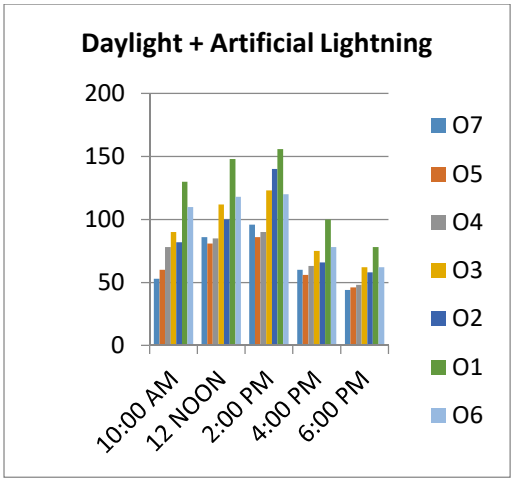


Figure 7: a) Daylight at different positions in Lab illumination level **b) Daylight with artificial lighting**

Result and Conclusion: Daylight is not sufficient in laboratory for all observers, only O1 observer has sufficient light to perform work between 10 am to 4 pm. To improve the illumination level artificial lighting is necessary. Seven LED tubes of 18 watt are mounted at different position to obtain sufficient illumination level in laboratory. The designing is by considering available daylight level so that sufficient light output using minimum artificial light sources. Lightning system is design such that glare rating is tolerable for all observers in laboratory. Lightning system is energy efficient as only 126 watt power is utilize to obtain total 9232 lm. Simulation designing using DIALux4.13 gives close results with actual measured values.

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