Study and Analysis of Fresnelized Dome

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Abstract

This paper describes the improved design of a daylight collector using a fresnelized acrylic dome. Surface inside the acrylic arch is framed to have a concentric and variable crystal that permits low-point light into the mirror tube and that reflects high-edge light, to receive a more constant light output through the span of the day. The prism is placed by a series of circular parallel grooves, with grooves closer the zenith of the cover having cross-areas that are unique in relation to the cross-segments of depressions closer the edges of the cover. Dome works for throughout the day in vertical position to illuminate the inside of a room by utilizing a mirror pipe having mirrored surface inside. Design of the collector improve the efficiency when compare with the conventional dome.

Introduction

Before 20th century, daylight used to illuminating the interior of the houses and other places but artificial technique of lighting replaces the use of daylight [1].Now, the non-renewable resources for energy are depleting due to the increased demand. The precious value of city land raises the demand for high-rise,deep plan and compact buildings. This meant that side windows are not the best option for lighting [2]. To fulfil the demand researcher's now focusing to use the daylight as the primary source for lighting purpose which is available in abundance. For better use of natural light first understand the basic terms and advantagesassociated with it.

Visible light is a part of electromagnetic spectrum. Human eye can differentiateonly the visible light in the electromagnetic spectrum.The sun transmits over a scope of wavelengths however its yield serendipitously crests in the unmistakable range on the grounds that the

ISSN: 2229-6913(Print), ISSN: 2320-0332(Online)

temperature of the photosphere or external surface of the sun is around 6000 K which is close to an ideal black body. Sun rays reaches on earth with intensity of 137KW/m^2 known as solar constant.

There are many benefits of natural daylight for example: - Energy saving, Health and well-being,colour rendering and many more.

For the interiors where access to the natural daylight is limited or not available that places requires installation of some light guiding system.Light guiding system consists of mainly three components. A light collector, light transport system and the diffuser to emit the light in all the directions. There are many types of collector are availableboth active and passive. Active collectors are costlier as compare to the passive collector and require more maintenance. So the main focus is on passive collectors. In passive system there are different types of collectors are available like light redirecting panels, Fresnel lens, dome type, parabolic etc [3].

In the list of passive collectors, it is found that very less work is published on the dome type collector but work is available in the form of patents. For that purpose, a collector is required in this case it is a fresnelized dome with varying geometry [5].

Material of the Components

Collector

Material of the collector is PMMA (Poly (methyl methacrylate)). It has refractive index 1.49 approximately, having good optical properties. Polycarbonate also having the same refractive index but its optical properties and material look deteriorate faster as compare to the PMMA. In this work collector diameter is 300mm and height of the dome is equal to its radius.

Transmitting tubes

This system basically a circular pipe made up of same material as of collector but the difference is that pipe is completely mirrored from the inside. Efficiency of the pipe depends upon the percentage of reflectivity of the pipe. Maximum achievable reflective is 95%.

ISSN: 2229-6913(Print), ISSN: 2320-0332(Online)

For deep plan buildings with greater depths, illumination can only be achieved by light transport system. Fibre optic can also be used for transportation of light but in this case light guide pipe of 300mm diameter and 1000mm length is used.

Diffuser

Commercially there are many output devices available. Most commonly used output device is a polycarbonate circular flush or domed diffuser made of prismatic material of diameter same as that of the light guide. Few manufacturers offer a flush toughened glass type diffuser.

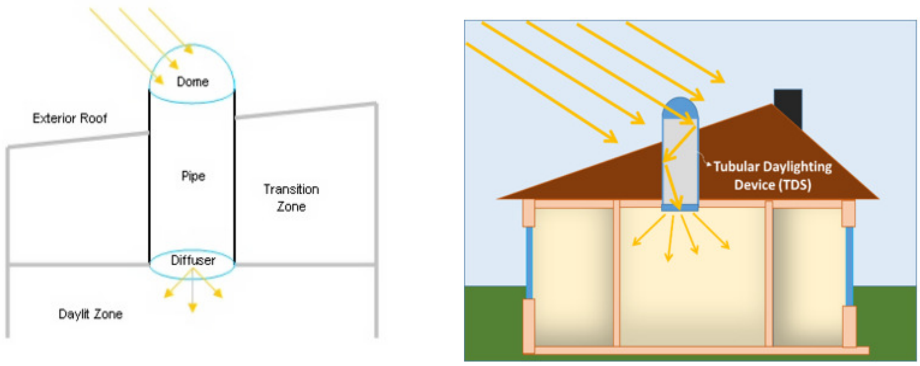


Figure 1: Configuration of light Guiding system

Analysis of the factors affecting the collector performance

Basically, four factors considered for analysis purpose which affects the performance of the collector directly.

Following are the factors: -

1. Height of the collector
2. Number of grooves
3. Thickness of the collector
4. Geometry of the grooves/prism

1. Height of the collector

Now the first factor is the height of the collector. For this purpose collector with different height viz. 40mm, 80mm, 120mm, and 150mm with radius 150mm for all the collectors. Since design is for the low elevation light therefore it requires more surface area, which is

ISSN: 2229-6913(Print), ISSN: 2320-0332(Online)

less in the case of collectors with less height than its radius. But the collector with height equal to its radius provides more surface area than the other. Therefore, a collector with height equal to its radius is selected.

Performance of the collector is analysed by simulating the model shown in the graph.From the below graph it is clear that height of the dome helps to collect light at low elevation. It is clear that for better performance collector height should be equal to the height of the radius or can say it should perfect hemi sphere. So to keep this factor in the mind the purposed design of the collector is a perfect hemi sphere.

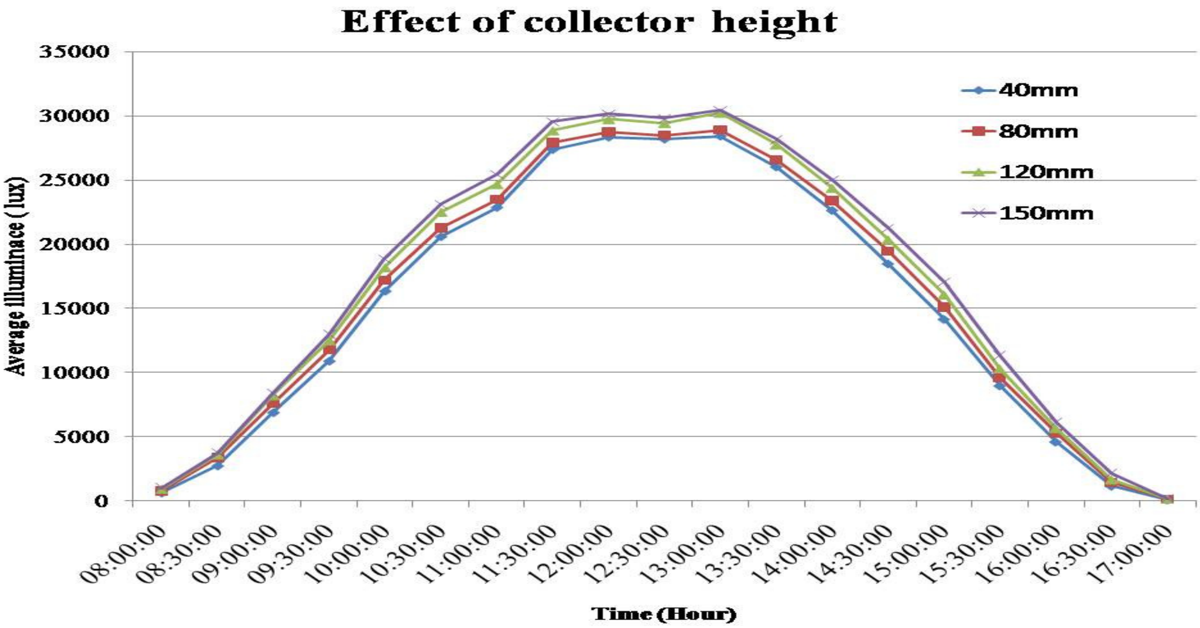


Figure 2:Effect of Collector height

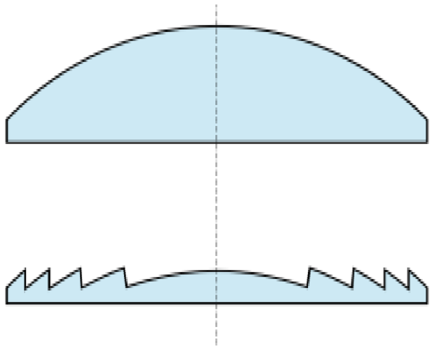
2. Second factor is number of concentric sections.

Second factor which affects the collector performance is the number of groves. In the above case dome is plain and worked like an ordinary lens. But the purposed design is fresnelized from the inside.

To understand the second factor,it is necessary to understand the Fresnel lens. Fresnel lens is type of lens which reduces the volume and material of the lens as compared to a conventional lens. This is done by dividing the lens into a set of concentric annular sections [4].

Below figure shows how the Fresnel lens reduces the material as compare to the conventional lens.

ISSN: 2229-6913(Print), ISSN: 2320-0332(Online)



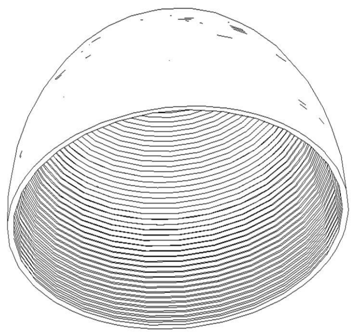


Figure 3: Conventional and Fresnel Lens   Figure 4: Fresnelized dome

In the same way collector is designed by dividing the hemi sphere into a set of concentric triangular section.Now the performance of the lens depends upon the number of concentric sections.To analyse the performance factor three type of dome was considered, having different number of groves. One having 36 number of concentric sections, second having 60 concentric sections and the third one having 89 number of concentric sections.

Analysis of the collector with different number of grooves/prism

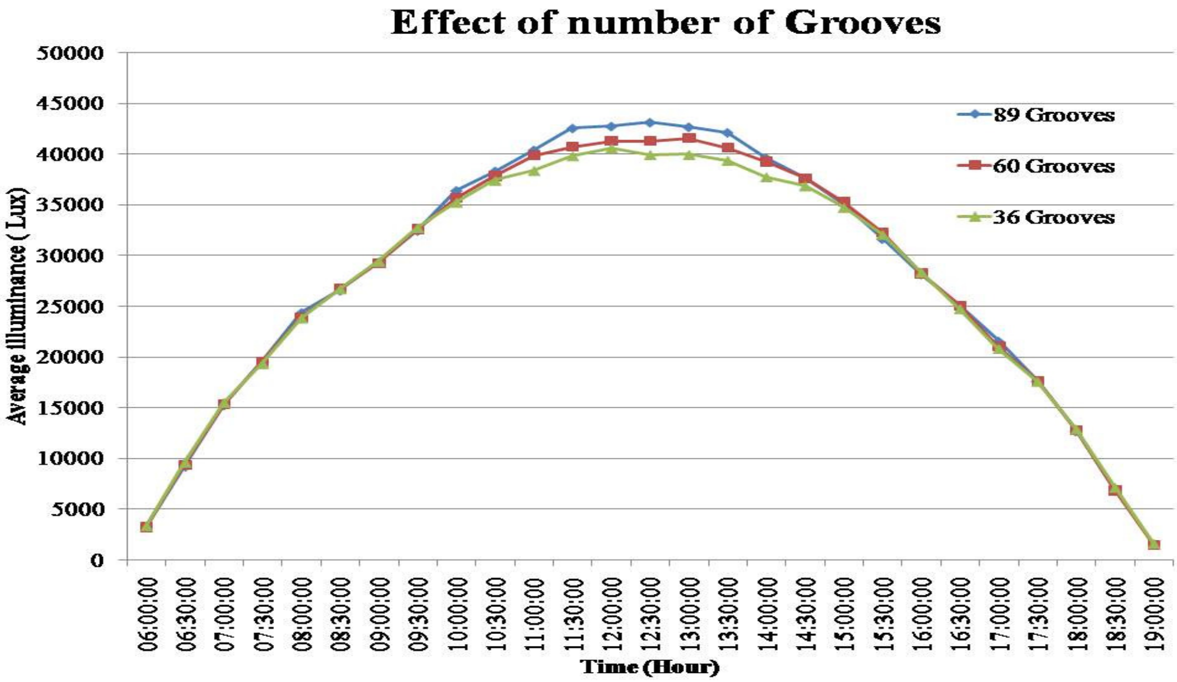


Figure 5: Effect of number of grooves

From the above graph it is clear that collector with more number of concentric sections collects more light.

3. Thickness of the Dome.

Third factor which affects the performance of the collector also depends on the thickness of the collector. To analyse the performance collector with different thickness is compared. Thickness for this is taken as 5mm, 7.5mm, 10mm. As the thickness increases denser medium increases which reduces the bending of light.

But as the thickness decreases the denser medium helps in bending of light more inside the light guide tube. Thickness lower than 5mm works better but fabrication with grooves at this thickness is difficult and chances of crack increases. Therefore, the thickness performance taken only between 5mm, 7.5mm and 10mm.

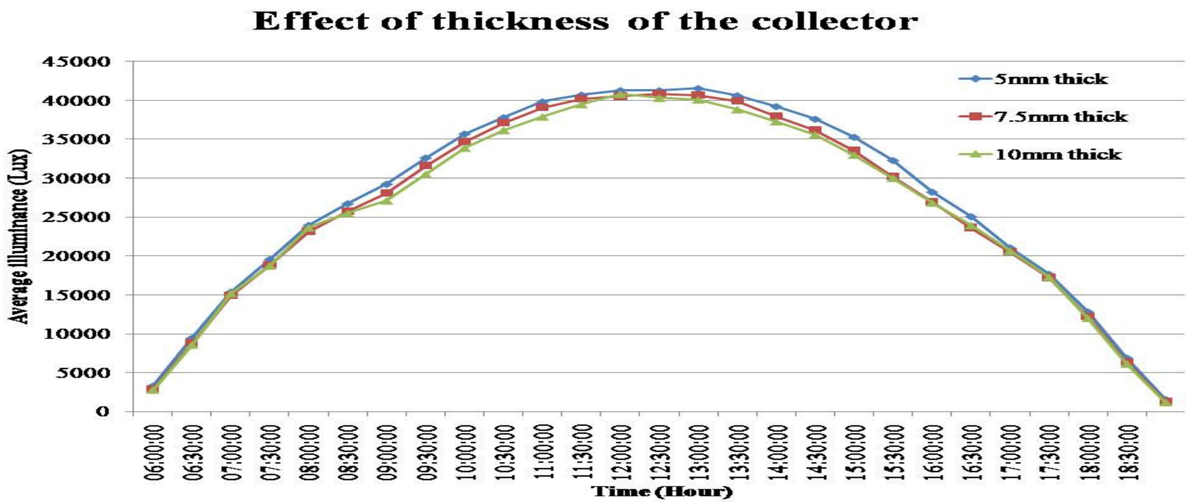


Figure 6: Effect of thickness of the collector

From the above graph it is clear that the performance of the collector depends on the thickness of the collector and collector with lesser thickness collects more light than the other.

4.**Geometry of the groove / Prism**

In the case of dome light enter the light guide pipe through the phenomenon of refraction therefore angle required for the refraction is analysed by doing analysis on different angles of the concentric section placed on the surface of the hemi sphere.

ISSN: 2229-6913(Print), ISSN: 2320-0332(Online)

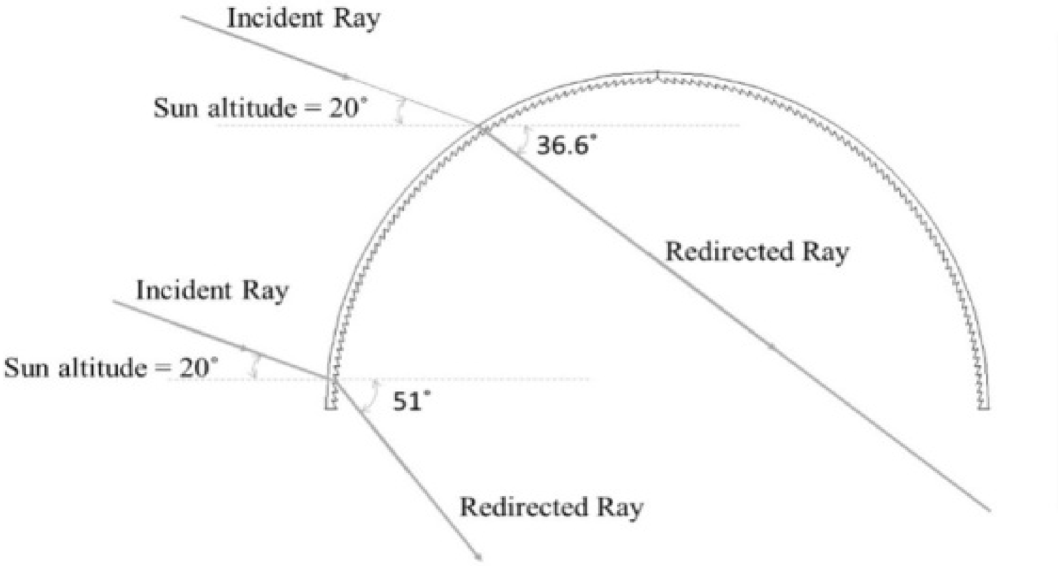


Figure 7 Fresnelized dome bends light at high angle

In the figure 4&5 triangular sections makes zero-degree angle with the horizontal and the hypotenuse side of the triangle makes 70˚with the horizontal. From the figure it is clear that how the triangular section helps the light to bend inside the light guide pipe. Light at low elevation bends more inside the light guide tube but in the case of plain collector light goes almost straight instead of going inside the tube.

ISSN: 2229-6913(Print), ISSN: 2320-0332(Online)

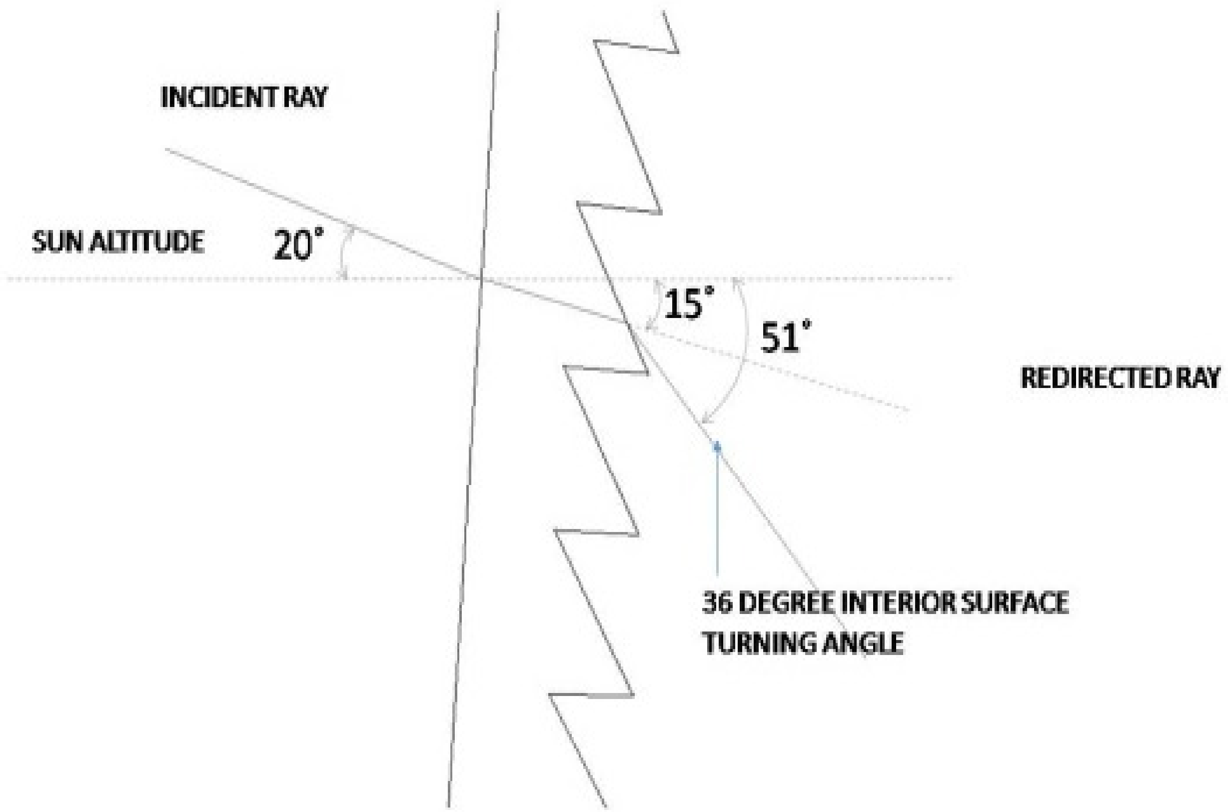


Figure 8: Detail of Grooves inside the dome

In figure 9 Light entering in the dome at 10˚and light entering inside the pipe at 67˚ angle. When light enters the pipe at high angle then the number of reflections also reduces and at diffuser a large amount of light falls and helps to deliver the good amount of light on the target.

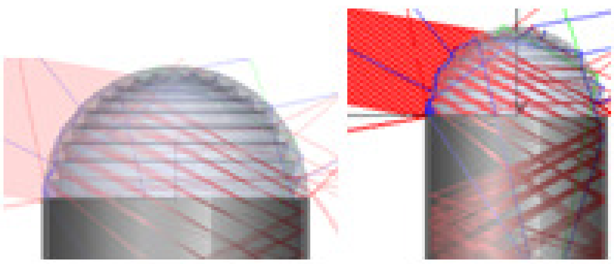


Figure 9 light entering the pipe at high angle from the above graph it is clear that the light collected by the fresnelized dome is more than the light collected by the conventional or plain dome.

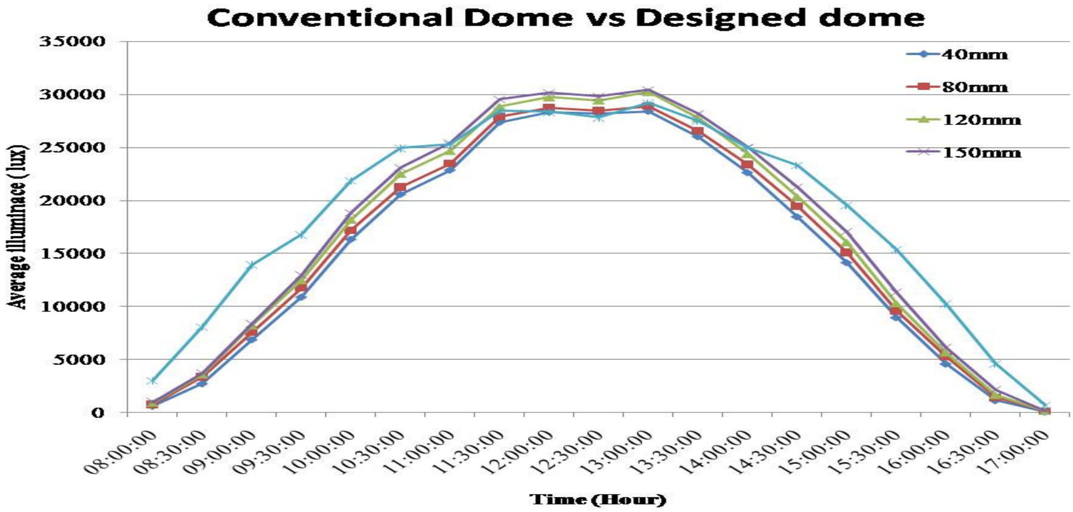


Figure 10: Conventional dome v/s Designed Dome

Conclusion

Conventional dome refracts the light but not at very high angle. fresnelized dome refracts the light entering at very low angle bends at very high angle and as the elevation of entering light at collector increases it bends the light inside the light pipe at low angle. Therefore, a good amount of light is collected by the purposed collector.

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ISSN: 2229-6913(Print), ISSN: 2320-0332(Online)