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Daylight System Using a New Fresnel Lens Design

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Abstract

A Fresnel lens is designed for redirecting the light for further use. Fresnel lens have short focal length, less volume, large acceptance and higher efficiency as compared to ordinary lenses.It is designed for area focus to achieve uniform illumination and less temperature at entrance of optical fiber bundle. The Fresnel lensis made up of polymethyl methacrylate (PMMA). It is a compilation of number of small square blocks, whereeach block is uniquely designed.Their ray trajectory is analyzed by using Trace-Pro software.

Keywords: Fresnel lens, transportation device, Blocks, uniform illumination, Optical fiber

Introduction

By increase in population it is found that their energy demand also increasing by increasing large number of buildings, these buildings required a huge amount of artificial light in day time for business, study and commercial purposes. In USA it is found that the electrical lightning consumption from 2000 to 2013 is increased by 20%[1].Windows contained by these buildings are not sufficient to lighting such area sufficiently. Sun light contain by windows may produce glare or uneven distribution of light.In India mostly non- renewable energy sources are viz. coal & uranium. These sources produce pollution during their use which contributes in global warming effects with 25% [2] Renewable resources are also their as water but energy produced by them are limited and not sufficient. If focus is done toward only lightning purpose, it is found that approximately 41% of total energy is consumed by only lightning in commercial and industrial area and approximately 50% of total electricity cost is dependent on electrical lightning [3]. So, the major problems are these non-renewable energy sources are limited and exhaustible and requires long span of time to reproduce so now the challenges are to save that non renewable energy sources and also to complete that increasing demand by less cost.

So the alternative solution to this problem is day-lightning system. Day light system as its name indicates a system that use to light day time here it uses sun light to illuminates areas to be lighten. As it has many advantage over artificial lightning viz, it is clean in nature and has no

effect over greenhouse effect, it is also found from research that productivity of person is increases up to 16%. Daylight is also beneficial for visual comfort, thermal comfort,[4]natural color rendering, health and ecofriendly. Where artificial light has many disadvantage over day light systems as eye strain, aggravating depression, obesity, aggression, muscle atrophy and diabetes.[5]

Day light can be done by two ways guiding systems or by daylight systems(transportation) and day light systems are mainly divided into two systems that are active systems and passive systems. Guiding systems are for lighten area of 8m to 10m where transportation systems are to lighten at distance more than 10m [6].Active systems are complex then passive systems as they are with trackers to track sun all over the day time. These trackers consist of mechanical parts. So wear and tear of mechanical parts are there and they required maintained time to time. While passive systems are static in nature and are simpler in design. It is also found that static systems are only beneficial for a certain time period. If both the systems are compared to each other it is found that active systems contain higher efficiency as compared to passive systems but they are costlier.

From a comparison between acrylic Fresnel lens, dome and flat sheet. it is found that at higher altitude average illumination is higher for Fresnel lens compared to dome and flat sheet [7].

Here in this paper work is done to design Fresnel lens which is a part of daylight transportation system. A daylight Transportation system consist of a collector may be active or passive, a transportation device (optical fiber), and diffuser. Fresnel lens design in this paper for an active daylight transportation system. Optical fiber is used to illuminate deep spaces and diffuser is used to diffuse light falling over it through optical fiber.

In lens, surface of lens is only part used to bend rays, so only curvature of lens is required to converge or diverge rays. To decrease volume and weight of lens, surface of lens is continuously collapsed and maintained over a flat plane is called Fresnel lens. Fresnel lens basically consist of three parameters i.e. slope angle, finite prism pitch and draft angle Fresnel lens are denoting by their refractive power, which means to the degree of lens by which it can converge or diverge rays. Theoretically zero draft is the best choice for Fresnel lens but some degree of draft angle is required for manufacturing process requirements. slope angle is surface of lens collapsed over plane surface, so it is the only part used to refract rays falling over it [8]Fresnel lens has advantage over conventional lens due to their light weight, cost effective and high optical efficiency.

Due to day lightning system lens used here is non-imaging ones so that these lenses has higher

acceptance angle as compared to imaging one's. In daylight transportation system if temperature at entrance of optical fiber rises it may burn edge of optical fiber so heat provided at entrance should be controlled. When excess light is there to illuminate specified area, solar cell may be used to focused over solar cell by which it can store energy in form of electricity and can help to illuminate day as well as at night time [4]. From research it is found that to achieve uniform output at exit of optical fiber it should be uniformly illuminate at its entrance, for this purpose in earlier days two optical devices were used to uniformly illuminate optical fiber bundle. This system increase efficiency but they glare and shading effect problem was still there at entrance of optical fiber [5].To uniformly illuminate optical fiber bundle, an eight fold Fresnel lens was introduced which used as primary collector. It bends these rays toward secondary optical device octagonal in shape. Each facet of eight fold Fresnel lens bend light toward each face of primary collector octagonal and this octagonal is so designed that each ray falling over it bend towards optical fiber bundle [9].From research it is also found that attenuation increases when incidence angle of incident ray increases. It is found that more than 13% incidence angle of incident ray is not acceptable and maximum attenuation is achieved when incidence ray angle approaches to 22°& when incidence angle reaches more than 30° no TIR is observed in optical fiber[10], [11]. It results lower the attenuation angle higher will be the efficiency.To achieve uniform illumination two optical devices were used to uniformly illuminate optical fiber.

Daylight system using Fresnel lens as shown in figure below. A day light system consists of an artificial light source used to send collimated beam of light towards designed Fresnel lens.This Fresnel lens is used to refract this light rays. Toward an optical fiber of same diameter as same size of block of Fresnel lens. And pattern of light beam after refraction at the entrance and exit of optical fiber are observed and these are found be uniform.

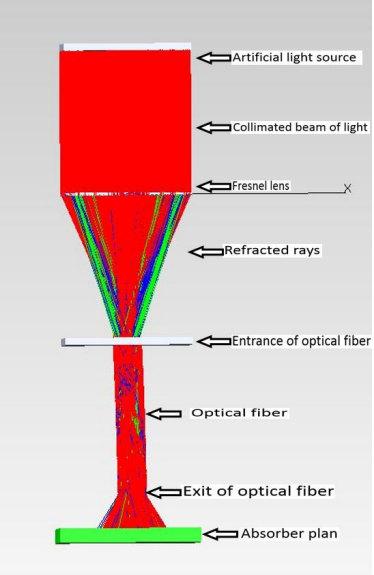

Figure 1. Daylight system using Fresnel lens

While using a circular optical fiber and its pattern at entrance and exit of optical fibers are observed.

Numerical and experimental analysis

As per classification of Fresnel lens. They are described as concentric and linear Fresnel lens[12]which works to focus light on a point and linear to an absorber plane respectively. In this study a new approach of Fresnel lens is designed for the purpose of an area focus instead a point or linear focus.

This design of Fresnel lens consists of number of blocks.Each having width of "w" andcomplete Fresnel lens has width of "W".Only central block of this Fresnel lens is plain i.e. free from any kind of grooves rest others are designed uniquely for their facet angle of groove and facet angle of Fresnel lens. Grooves of these blocks are depending on the position of block in Fresnel lens. Position of these blocks are measured with elements "i" and "j"in x & y axis respectively.

Facet angle of Fresnel lens is denoted by notation α (alpha). Which may be defined as the angle formed between a line from center of Fresnel lens to the x-axis of Fresnel lens. Angle α may also be define mathematically as tan-1(j/i) [13]. Facet of each block should be $\alpha+90^0$ which bend light rays toward absorber plane and by this it looks like a concentric Fresnel lens from top.

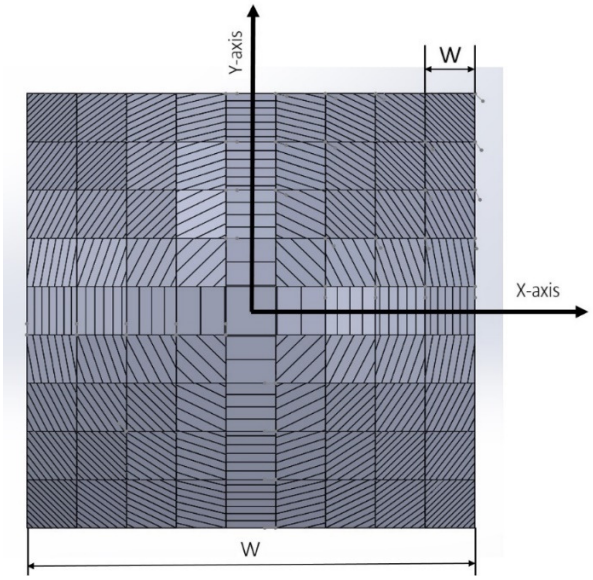

Figure 2. Notation of design Fresnel lens

Beam of light after incidence over Fresnel lens refracted with θ angle. Refraction angle θ for each block is differ it depends on position of block in Fresnel lens. mathematically may be defined as= $\mathbf{arctan}\left(\frac{w}{f}\sqrt{i^2+j^2}\right)$

"w" = width of each individual block with in Fresnel lens

"f" = focal length of Fresnel lens

While facet angle (i, j) derived by Snell's law

$$\phi(i,j) = \mathbf{arcsin}\left(\sqrt{\frac{sin^2\theta(i,j)}{\left(n_{f1}^2 - 2n_{f1}\cos\theta(i,j)+1\right)}}\right) \quad (4)$$

Refractive index of material is denoted as nf1.

Fresnel lens is designed with "w" =10mm and "f" =100mm.

While using a square optical fiber bundle and its pattern at entrance and exit of optical fibers are observed.

Result

By using this newly design Fresnel lens at the entrance of optical fibers uniform pattern is achieved. Which effects to achieve uniform pattern at the exit of optical fiber as well.

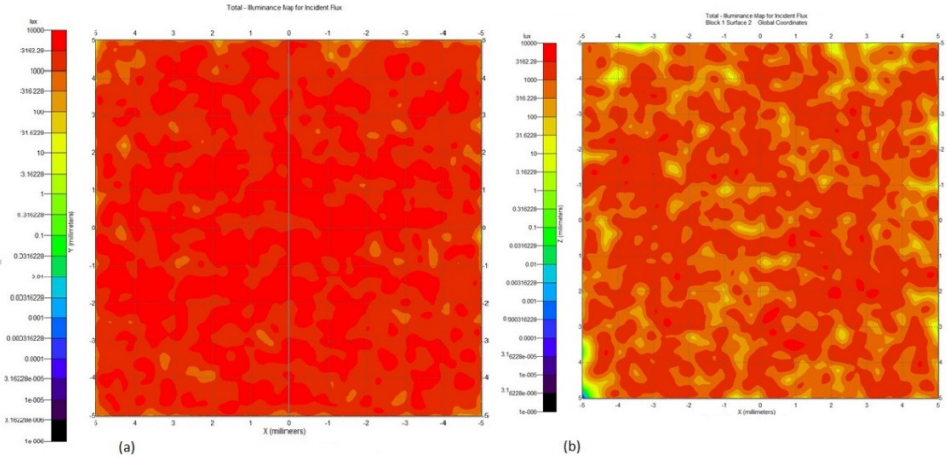

Figure 3. figure (a) entrance of optical fiber, figure (b) exit of optical fiber for square optical fiber section

While using a circular optical fiber and its pattern at entrance and exit of optical fibers are observed.

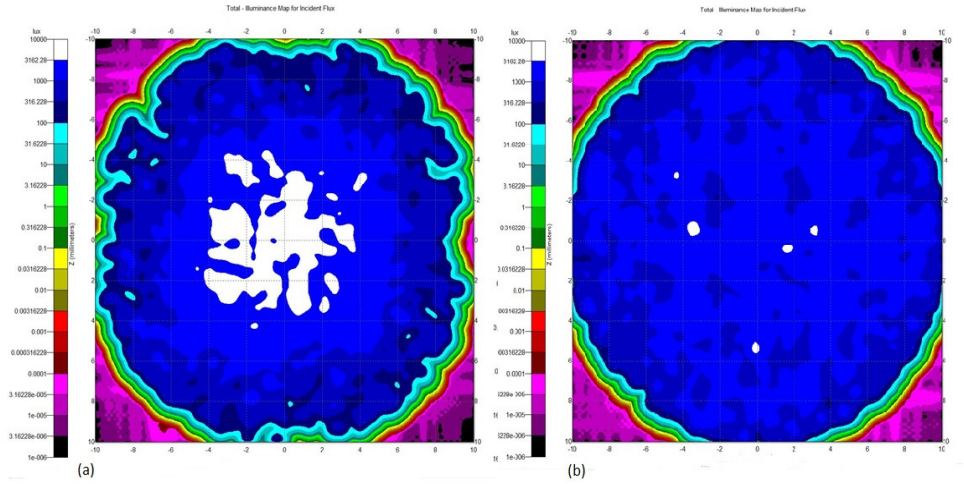

Figure 4.figure (a) entrance of optical fiber, figure (b) exit of optical fiber for circular optical fiber

Conclusion

It is Found that this design should be limited in size because larger the size of this Fresnel lens. The refraction angle from outer blocks of Fresnel lens is also higher which effects to increase the

incidence angle at optical fiber incidence angle more than 13^0effects large attenuation losses. To decrease these losses Fresnel lens of small size are suggested.

References

1. Ullah, Irfan, Hui Lv, Allen Jong-Woei Whang, and Yuehong Su. "Analysis of a novel design of uniformly illumination for Fresnel lens-based optical fiber daylighting system." Energy and Buildings 154 (2017): 19-29.
2. https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data
3. Singh, Ravinder, GaganBaradia, and Ankur Gupta. "Hybrid Solar Lighting System for Energy Conservation: A Review."
4. Tripanagnostopoulos, Y., ChSiabekou, and J. K. Tonui. "The Fresnel lens concept for solar control of buildings." Solar Energy 81, no. 5 (2007): 661-675.
5. Ullah, Irfan, and Allen Jong-Woei Whang. "Development of optical fiber-based daylighting system and its comparison." Energies 8, no. 7 (2015): 7185-7201
6. Garcia-Hansen, Veronica Ruth. "Innovative daylighting systems for deep-plan commercial buildings." PhD diss., Queensland University of Technology, 2006.

7. Nair, M. G., A. R. Ganesan, and K. Ramamurthy. "Conceptual design and assessment of a profiled Fresnel lens daylight collector." Lighting Research & Technology 47, no. 5 (2015): 533-547.
8. Davis, Arthur, and Frank Kühnlenz. "Optical design using Fresnel lenses." Optik&Photonik 2, no. 4 (2007): 52-55.
9. Song, Jifeng, Zhou Jin, Yong Zhu, Zili Zhou, and Yongping Yang. "Development of a fiber daylighting system based on the parallel mechanism and direct focus detection." Solar Energy 115 (2015): 484-493.
10. Song, Jifeng, Yong Zhu, Kai Tong, Yongping Yang, and M. A. Reyes-Belmonte. "A note on the optic characteristics of daylighting system via PMMA fibers." Solar Energy 136 (2016): 32-34.
11. http://www.genuineholographics.com/
12. Ryu, Kwangsun, Jin-Geun Rhee, Kang-Min Park, and Jeong Kim. "Concept and design of modular Fresnel lenses for concentration solar PV system." Solar energy 80, no. 12 (2006): 1580-1587.
13. Kischkoweit-Lopin, Martin. "An overview of daylighting systems." Solar Energy 73, no. 2 (2002): 77-82.
14. Akisawa, Atsushi, Takayuki Sato, Takahiko Miyazaki, Takao Kashiwagi, and Masao Hiramatsu. "High concentration non-imaging Fresnel lens design with flat upper surface." In High and Low Concentration for Solar Electric Applications II, vol. 6649, p. 66490F. International Society for Optics and Photonics, 2007.
15. Xie, W. T., Y. J. Dai, R. Z. Wang, and K. Sumathy. "Concentrated solar energy applications using Fresnel lenses: A review." Renewable and Sustainable Energy Reviews 15, no. 6 (2011): 2588-2606.
16. Wang, Chen, H. Abdul-Rahman, and S. P. Rao. "Daylighting can be fluorescent: Development of a fiber solar concentrator and test for its indoor illumination." Energy and Buildings 42, no. 5 (2010): 717-727.
17. Mayhoub, M. S., and D. J. Carter. "Towards hybrid lighting systems: A review." Lighting Research & Technology 42, no. 1 (2010): 51-71.

18. Kumar, V., Shrivastava, R.L. and Untawale, S.P., 2015. Fresnel lens: a promising alternative of reflectors in concentrated solar power. Renewable and Sustainable Energy Reviews, 44, pp.376-390.
19. Singh, R., Baradia, G. and Gupta, A., Hybrid Solar Lighting System for Energy Conservation: A Review.
20. Vu, N.H. and Shin, S., 2016. Cost-effective optical fiber daylighting system using modified compound parabolic concentrators. Solar Energy, 136, pp.145-152.
21. Eun-Cheol Kang, Yong-Yeon Choi, Yoon Kwang-Shik and Yi Joon Lee, 2011. A Study on Performance Evaluation of Circular Fresnel Concentrating POF Daylighting System. Journal of the Korean Solar Energy Society, 31 (1), pp.31-35