Uniformly illuminated optical fiber-based solar lighting system

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Abstract

There has been a recent problem in achieving smooth sun light at a destination deep inside the building. A system is presented here to achieve smooth and high beam sunlight into the building by using reflectors and optical fibers. Two parabolic reflectors are used; concave reflector concentrates light rays into small area and convex reflector reflects light rays to the fibers. The temperature problem has been solved by distributing light equally in all fibers. Sun tracking system is mounted to get parallel rays all the day time. Comparison between reflectors is also described by using simulation results.

Introduction

There has been a research in providing sun light into buildings[1],[2] using light-pipes. In the sense of implementing the system at low cost it is attractive, however, since the system is bulky, it is difficult for it to be applied to all different kinds of building structures. Therefore, we propose here a optical fiber-based solar lighting system which has advantages like requiring less area, light weighting, and easiness of installing. The cost problem of using optical fibers is eliminated by introducing plastic optical fibers for most of transmitting part. The presented system contains four main modules: 1) light concentrating module, 2) module of making light perpendicular to the surface, 3) transmitting module, and 4) light distributing module to illuminate wide area using reflectors and lenses. There is a problem in all sun collecting systems to achieve smoothness (uniform distribution of light). In order to solve this problem in our proposed system, light should be smooth, normal to the surface, and highly concentrated before hitting the surface of fibers. In reference [3], a low cost solar collector using optical fiber is illustrated, however, since the collector is fixed, sunlight enters into the fibers during day time only.

Hardware design

The presented system is illustrated in Fig. 1. Parabolic reflectors are used to concentrate more light and make light rays perpendicular to the surface of fibers. Reflectors having less f-ratio and large aperture area are used to illuminate large area. In order to reflect light from concave parabolic reflector, f-ratio should be the same of both reflectors; also, focal point of both reflectors should be at the same position as demonstrated in Fig. 2. Silica optical fibers are used at starting point to solve temperature issue. After that plastic optical fibers are mounted having wide core diameter. Index matching jell is also applied to decrease the loss due to the air gap. Equations which are used to design parabolic reflectors are given below.

$$Y = x^2/4 \times f \qquad (1)$$

$$d = D^2/16 \times f \qquad (2)$$

$$A = \pi(f/2N)^2 \qquad (3)$$

where f is the focal length, D is the diameter of the reflector, d is the depth, A is area of the aperture, and N is the focal number (f/D). Fig. 3 shows the mechanism of the working system. 130-mm long silica optical fibers and 10-m long plastic optical fibers are used to verify the proposed system.

Simulation and Results

We have performed the simulation to verify our model. We generated real environment in the simulation by designing every part and considering almost every loss. Source, receiver, reflectors, bent fibers, index matching, and other hardware components are designed in the software. Bent fibers and their loss are considered in the simulation to achieve better outcomes. Silica and plastic optical fibers have diameter 1.8-mm and 2mm. Direction cosines of rays have been determined by ray tracing method. In our case light ray after reflecting from convex reflector becomes perpendicular to the horizontal axis. Therefore, diameter and position of the convex reflector can be

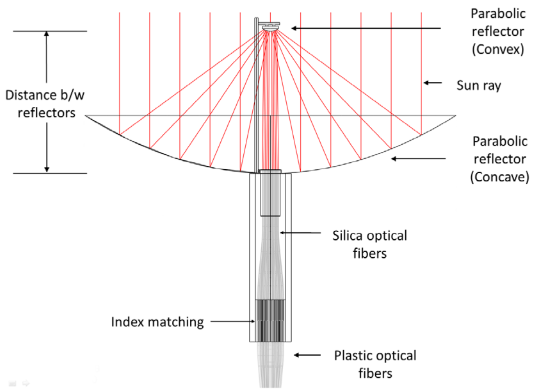

Fig.1. System architecture

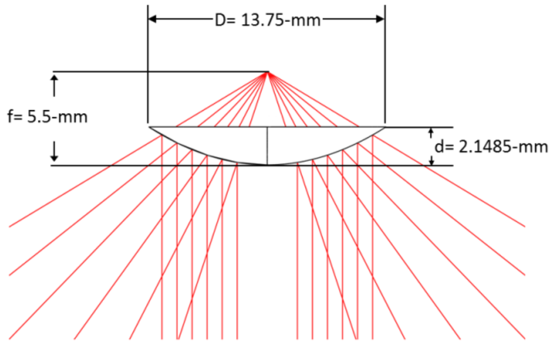

Fig.2. Relation between reflectors

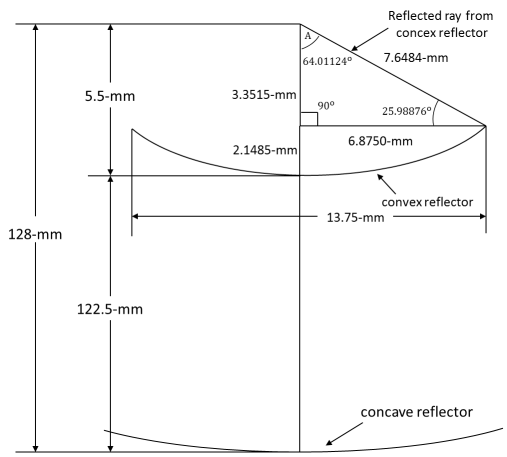

Fig.3. System measurements

easily calculated by performing some calculations on right triangle as shown in Fig. 3. LightTools^{TM} (simulation software) is used for light tracing. Simulation is performed step by step by seeing the difference between results. Firstly, we considered a circular reflector instead to convex parabolic reflector; but, it did not give well and smooth light due to unparalleled rays. Thus, light rays perpendicular to the surface of the fibers can not be achieved by using circular reflector. In order to achieve this goal, a parabolic reflector is the best choice. By transmitting perpendicular light rays from surface of the source onto the concave reflector, illuminance output and attained number of rays are plotted as shown in Fig. 4. The output results considering the reflection in bending optical fibers can be easily seen; due to bending, some light rays are concentrated in a specific area of the core in each fiber and it produces some peak points.

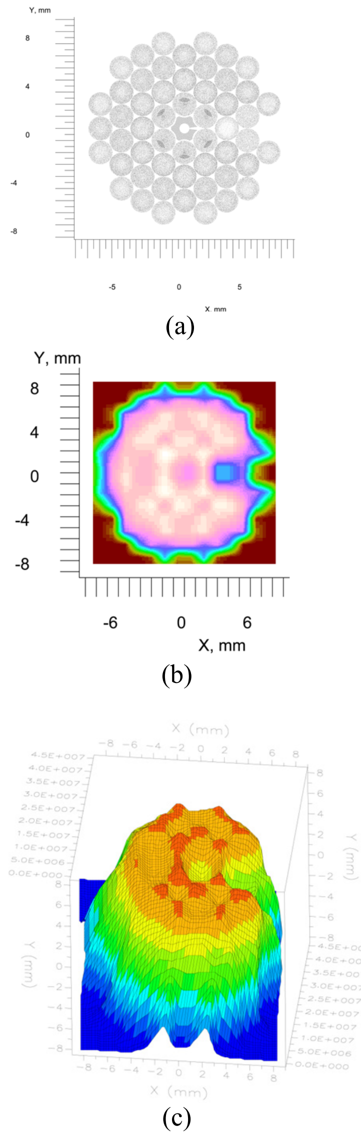

Fig. 4. Simulation Results (a) scatter chart (b), illuminance chart (c), 3D view of illuminance chart.

Conclusion

As a result of the proposed system, a specific area of the room can be completely illuminated with smooth light. The design also demonstrates that more sun light can be guided into the fibers by using a big collector system. Light temperature has been divided to all fibers; so, there is no need to mount an extra cooling system.

Acknowledgement

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References

[1] L. Whitehead et al., ASME 2010, May 2010.

[2] A. Rosemann et al., Solar Energy vol.82, pp.302-310, 2008.

[3] P. Couture et al., IEEE Electrical Power & Energy Conf. 2010, pp.1-4, Aug. 2010.