# Fiber Optic Daylighting System

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***Abstract*— In today's rapidly developing world, the need for energy has risen exponentially. The majority of this energy is used for industrial & commercial use. Energy used for lighting makes up for a sizeable portion of the global energy consumption. Industries, business spaces, commercial buildings etc. all makes use of artificial lighting even during daytime, while abundant sunlight is available. This is one of the major reasons for high levels of energy consumption in these sectors. The solution for this problem is provided by fiber optic solar lighting system. The sunlight is collected and focused by making use of solar collectors on the roof top of a building and then transmitted into the building through optical fibers to interiors of the building. While Solar energy has been used for production of energy, the conversion efficiency of solar pv comes to around 17- 20%. This implies that almost 75-80 of the solar energy is still being wasted. So instead converting the solar energy to electrical energy, which is then used for lighting, the insolation can be directly used for day lighting purposes if the necessary technology can be developed.**

***Keywords*— *Solar daylighting, fiber optics, parabolic collector , luminaires***

## I. Introduction

It is known that buildings consume large amounts of the electricity world and that artificial lighting consume a significant part of this energy. Therefore, it is desirable that the performance of these systems be optimized in order to achieve energy savings. An important innovation that is capable of saving energy is the supply of daylight to a space, as this can reduce the artificial lighting load on the building.

Fiber optic day lighting system serves as one of the brightest innovation in the efforts of using sunlight to light up the interior of a building without affecting the flexibility and ease of application that is usually a trait of artificial lighting. In this system, we collect natural light and transmit it through optical fibers to luminaires within the space. This technology enables us to distribute sunlight evenly to into buildings without disturbing the space layout & is unaffected by issues such as glare, lighting variability and heat gain issues that complicate most day lighting strategies. As products become commercially available and increasingly economically viable, these systems have the potential to conserve significant amounts of energy and improve indoor environmental quality and thereby positively affect the occupant behavior.

## II. Components of Fiber optic day lighting system

### *A. Solar Collectors*

This component of the system is responsible for the collection of direct sunlight and then transmitting it to the fiber optic cable in order to be dispersed to the workspace through the luminaires.

The functionality of a solar collector depends upon how efficiently would it be able to collect sunlight , the quantity of sunlight gathered consistently and the duration over which design light levels can be maintained. Two basic designs of collector have been used most widely for use in day lighting systems, one using Fresnel lenses and other using parabolic reflecting surfaces [1].

#### *1) Fresnel lens design*

A Fresnel lens is a collection of normal lenses so adjusted that it cumulatively provides a short focal length. This property is used in a solar collector which collects the solar radiations one to a single point, where the fiber optic bundle captures this radiations and transmits to the luminaires. The loss of light due to absorption due to thickness is greatly reduced in a Fresnel lens owing to its thinness and flat surface [9].

As different wavelengths have different focal points while passing through an optical lens, we may use this property to filter out unwanted radiations from the sun while using a Fresnel lens collector. The use of filter also is another option to filter out unwanted components of sunlight including UV and Infrared radiations. An IR filter removes infrared radiations and transmits only the visible component of sunlight (i.e. Blocks radiations from 750 nm) and UV filter removes radiations below 350 nm. In total 85 % of IR radiations and 98% of UV radiations are blocked by these filters and transmit almost 90% of the visible radiations [9].

The effective focal length (EFL) of Fresnel lens is given by

$$EFL= r / (n-1) \qquad (1)$$

Where r is the radius of the lens & n is the refractive index of the material used [3].

However the Fresnel lens has problems of spherical and chromatic aberrations [2]. Also, the Fresnel lens with a constant pitch and larger diameter is found to be less effective owing to the light being blocked.

*2) Parabolic mirror design*

The parabolic mirrors have good reflective properties due to their shape. The reason they fit well in to the solar collector design for day lighting system is because for a large diameter, they have good collection efficiency. The material best suited for this application is parabolic reflectors made up of fiber glass owing to their ease of handling and installation.

These mirrors have small F ratio and a larger aperture to capture maximum sunlight with its high concentration ratio. A combination of concave and convex mirrors would produce uniform collimated light at the absorber. The optimum amount of sunlight can be received at the absorber if the bundle of fiber optic cables is arranged in a circular fashion. The arrangement of concave and convex reflector has to be such that

$$F_1 = F_2 \quad (2)$$

Where, $F_1$ & $F_2$ are focal lengths of the concave and convex reflectors respectively. Uniformity in light at the absorber end can be achieved by

$$D_r = D_c \quad (3)$$

Where $D_r$ & $D_c$ is the diameter of the receiver and convex reflector respectively [3].This design, having a primary reflective concave mirror and a secondary cold convex mirror is found to be advantageous when we have the luxury of space, since for greater diameter it has a greater efficiency. The secondary cold mirror reflects only radiations in the visible region (between 360- 750 nm) [9] and transmits IR radiations, which can later be used for power generation using a PV cell.

*B. Solar Tracking*

Solar tracking is required to maintain consistency in quantity of light collected, relative to sun's motion. Two systems, the single axis and double axis systems exist out of which the double axis systems can be considered much more effective since not only does it follows sun's motion from east to west, but also adjust the horizontal position of the collector throughout the year in response to change in sun's position throughout the different seasons [9].The tracking system would have motors in order to move the collector in direction calculated. Two method of tracking is possible. One in which the position of sun is calculated using astronomical clock and the date and time with respect to that particular location. The second option is to have tracking sensors that senses optimum light density and operates the motor to turn the collector in the direction provided by the sensor [4].The computer operated system with a combination of both these would appear as the best possible solution for solar tracking.

*C. Optical Fiber*

Optical fiber for day lighting application is chosen based on their material, ease of drawing it in to continuous strands, the readiness with which it absorbs the required frequencies etc. The most important factor however is the signal attenuation over long distance transmission when it has to be used in day lighting systems [5].

There are three main types of optical fibers that is suitable for day lighting applications.

The first type of optical fiber is core that uses silica based glass material with attenuation to the tune of 0.2 dB/km for wavelength of 1550 nm [4]. The large manufacturing cost, high bending radii and the fragile nature makes it less feasible for day lighting.

The second type is based on core with highly purified liquids, usually water & methanol or ethanol, with attenuation constants of about 2 dB/Km. However splicing and rejoining of these cables is highly difficult and there versatility of application reduces drastically.

The third type is cables that uses Polymethylmethacrylate (PMMA) [4] and is generally called Plastic Optical Fiber (POF). Their low bending radii, high levels of flexibility which is highly suitable for building wiring.

Silica Optical Fiber (SOF) is another option in order to use in fiber optic day lighting solution. However the high cost of silica is the biggest hurdle in its implementation.

Comparing the three options, POF optical fibers can be taken as the most viable option to be used in day lighting system. However the heating effect should be taken in account since after a certain point the fiber beaks down due to IR radiations of sunlight [11]. Proper filtering of sun's radiations is required so that the fiber is not affected by IR and UV radiations [1] [3] [10] [12].

*D. Luminaires*

Passive luminaires are intended to use solely with sunlight and is effective only when there is a cloudless sky and adequate amount of sunlight is collected [7].

Hybrid luminaires on the other hand involves compensating the shortage of day light from the collector using artificial lighting, which involves sensors and controls to seamlessly blend both these lights [8]. Uneven blending of lights would cause severe discomfort to the occupant and would undermine the purpose of the system.

There are two basic designs that are commonly used in day lighting system [4]. The first is luminaire using light dispersing lens and the second being luminaire using light dispersing cylindrical rods.

Fixtures using lenses consists of lenses made of highly purified silica glass or PMMA in order to reduce the transmission losses. Since the light from the fiber is collimated, it is important that the dispersing material be accurately placed and should be so constructed that it disperses light uniformly over the workplace. In this design, each end of the fiber in the bundle is connected to the light dispersing lens.

Light dispersing cylindrical rod is another kind of luminaire that can be implemented in the solar day lighting system. The light dispersing rod which has precision cut grooves would disperse light uniformly when the fibers are connected at their ends [4]. This has a much better efficiency when compared to lenses since loses due to non-dispersion can be negated by placing a mirror at one end of the rod.

For a hybrid system, especially using troffer style lighting frames, cylindrical dispersion rods is ideally suited. The efficiency of the entire system can be improved with control systems involving light sensor [6] and dimmable electronic ballast.

## III. CONCLUSION

Fiber optic day lighting system can be one of the best possible energy conservation measure provided substantial technological advancements can be achieved in the development of its components. In the system discussed, it can be concluded that the parabolic reflector collector, PMMA fiber optic cable and dispersion rod luminaires is the combination best suited for the ideal solar day lighting system. However it needs to be understood that the entire system and all its components is designed based upon illumination requirement and available insolation. So generalization of the system components is not possible since components best suited for such a system would vary for different applications. So optimization of the components should be based upon the requirement and the feasibility with respect to cost and lifetime of the system should be worked out before deciding upon the system design. This is one of the biggest hurdles in the development and installation of this system on a commercial scale. The issue with availability of various components can mitigated if further research is carried out in terms of material used in various components. With advancements in material technology, the overall efficiency of the entire system maybe expected to rise while keeping the cost of the system within reasonable limits. This would make it possible for the large scale application of this system to replace artificial lighting in commercial sector, which would be an ideal sector to start with bring in significant energy savings.

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