Selection Parameters While Selecting Optical Fibers For Lighting Purpose

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Abstract- *Daylight simply means bring the sunlight as kind of direct or diffused into the dark rooms through optical fiber and light pipes. Fiber-optic daylighting systems have been shown to be a promising and effective way to transmit sunlight in the interior space whilst reducing electric lighting energy consumption. It helps to reduce the greenhouse gas emission in sustainable developments. This study research emphasize only on daylighting through optical fiber. So selection of optical fiber for transmission of light is very important and one of the crucial part of the whole system of daylighting. Unless selection of optical fiber is proper the transmission loss would affect the diffusing system. So we are primarily emphasizing on selection of the optical fiber on the basis of some parameters which would increase the optical efficiency little bit more.*

Keywords- Daylight, Glass fiber, Numerical aperture, PMMA (poly methyl methacrylate)

List of symbols-

- i – Incidence angle
- Θ_C – Critical angle
- n_0 – Refractive index of medium outside the fiber
- n_1 – Refractive index of core
- n_2 – Refractive index of cladding
- Θ – Refracted angle

I. INTRODUCTION

Light is defined as the visible spectrum of electromagnetic radiation, i.e. radiation with a wavelength between 400 nm and 700 nm. Besides affecting the visual performance, light is important for both our biological and psychological health. It is the most important environmental signal to the circadian system, the “wake and sleep”-clock. Light stimulates this system through, the recently found, third photoreceptor and enables a synchronization of our inner biological time to the external environment [1]. Natural daylight is superior to artificial static light sources in terms of stimulating the circadian system due to its dynamic properties and the high illuminance, which is better matched to the systems spectral sensitivity. Lightning is important and hence there is need of innovative techniques.

The use of electric lighting in our homes and commercial offices and workplaces are major consumer of society’s total energy consumption. According to Ullah and et al. power consumption in buildings is 40-50% of total energy. Daylighting is a part of answer to this issue. Efficient daylight buildings are estimated to reduce energy consumption by 50-80%.

Basically light classified into natural and artificial light. Artificial light has psychological as well as economical effect. The amount of energy demand generated by the use of electric lights is considerable and gives the possibility of significant savings by daylighting. Peak demand for electric lighting occurs at the same time as peak availability of natural light.

The effect of artificial light are as follows:

Economical effect:

In India, as third largest energy consumption after China and USA with 5.3% global share in 2015. In this total energy consumption the renewable power share only 2.21%and other sector has as per given in the Table number1. But it’s very difficult to get this much energy from the nonrenewable sources also it requires plenty of capital investment. India requires a cumulative $2.8 trillion in investment in energy supply in our main scenario, three-quarters of which goes to the power sector, and a further $0.8 trillion to improve energy efficiency. Daylighting can reduce the energy production requirement for commercial and homes also it cannot generate heat and reduce the greenhouse gas emission. So daylighting can definitely help to fuel “Make in India” program by sustainable growth in economy.

Psychological effect:

The information that our brain receive from illuminated environment is an essential element in shaping of our mood and physiological well-being. And that’s why psychological and physiological benefits are reasons to use natural light.

Biological effect:

The research on office buildings shows that failure to provide comfortable indoor environments; use of artificial light instead of natural light is one the reason among other. As mostly office workers spend their workhours under artificial light that's why 78 million have calcium deficiency due to insufficient vitamin D which has primary source as natural light. And 15% of office workers complain of eye strain under artificial light.

So as per the above description of effects the artificial light has on us. Daylighting is solution to deal with this problem. And actually we are trying to develop the system of daylighting mainly using optical fiber. Our project comprise of the three parts as light concentrating device along with solar tracking to get maximum intensity of light, transmission system as optical fiber and diffusing system. In this study research we are trying to focus on selection of optical fiber. Like on what the parameters should have to consider while selecting optical fiber for daylighting purpose? Because after getting the maximum light intensity by concentrating system and uniformity by collimating system. To transmit much of this light through optical fiber, there has to be proper optical fiber system with appropriate selection of optical fiber.

But as we are gone through most of the research paper based on daylighting we conclude that there is lack of study on the selection parameter on which selection would do. But this is the one the crucial part of the design of lighting system because if we won't select the appropriate optical fiber for this purpose there is useless efforts on collection of the sunlight by concentrator on the one end of the optical fiber.

II. BASIC IDEA

In daylighting, we simply bring the outdoor sunlight during day into the indoor places. This is basically done by using optical fiber and light pipes.

Using light pipes, it is simple static structure through which sunlight bring down to the dark places. In this system, there is basically consist glass dome pipe covered by reflective material inside diffuser system.

Also there is another system which is daylighting with optical fiber. This system consist of collection unit, transmission unit, there is solar tracking unit and parabolic concentrator present.

By using solar tracker we focus the maximum intensity of light on concentrator by single axis trackers or dual axis trackers. After collecting this light on parabolic concentrator, we place the bundle of optical fiber at the focus of the parabola where the light gets concentrate. So transmission of light through optical fiber happens and at the other end we diffuse this light using diffusing system. Diffusing system consist of lenses, reflector etc. We used PMMA optical fiber in our project at the university level for the prototyping the system of daylighting.

By using this system we can minimize the use of artificial light during day. Artificially light is generated at higher expenditure of capital but as per the spending of money we cannot get the maximum light.

III. SELECTION PARAMETERS

To select optical fiber for the lighting purpose, the selection of fiber can be done on the following parameters as:

1. Numerical Aperture
2. Operating Temperature
3. Color Temperature
4. Transmission losses along the distance of optical fiber
5. Flexibility

Numerical aperture: The foremost condition to transmit light through optical fiber is refractive index of core should be greater than refractive index of cladding when light passes through core to cladding. That means from denser to rarer medium. There is possibility to reflect light back to core if 'Θ' exceeds the ΘC critical angle where,

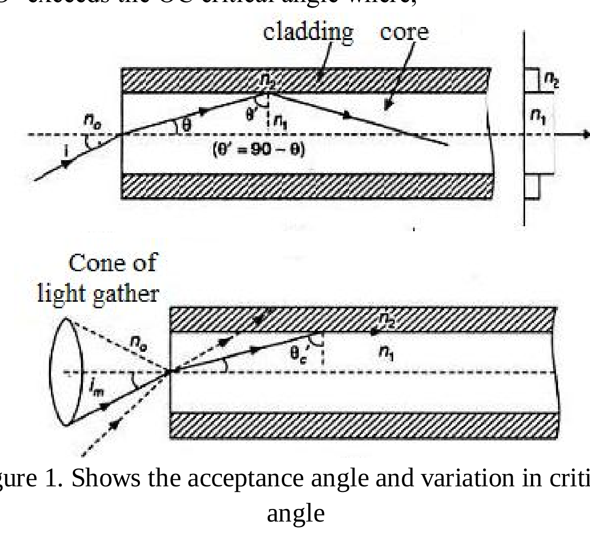

Figure 1. Shows the acceptance angle and variation in critical angle

$$\Theta_C=\sin^{-1}(n_2/n_1) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Θ_C is the angle of incidence in denser medium (n_1) for which angle of refraction becomes 90^0

Using Snell's law of refraction, therefore for light to be propagated through core fully of optical fiber, angle of incident at core-cladding interface should be greater than Θ_C'. As i increases, Θ increases and so Θ' decreases.

Therefore, there is limit to incidence angle at optical fiber beyond which light is refracted to cladding this maximum angle is called maximum angle of acceptance i_{max} and respective,

$$N.A. = n_o \sin(i_m)$$
$$ns_1 \sin(\Theta) = n_1 (90 - \Theta_C)$$
$$= n_1 \cos(\Theta_C')$$
$$= n_1 (1 - \sin^2 \Theta_C)^{1/2}$$

From equation (1)

$$= n_1 [1 - (n_2^2/n_1^2)]^{1/2}$$
$$= (n_1^2 - n_2^2)^{1/2}$$

As fiber tends to preserve the angle of incidence during propagation of light, causing it to exit the fiber at the same angle it entered. Optical fiber with higher N.A. will accept all the light with lower N.A. but at the other end it will give the light with same acceptance as it receives. So it means that low N.A. fiber has low acceptance angle. That means it will transmit less amount of light. So to get high amount of light we should have to select optical fiber with higher N.A.; otherwise use the lens system to gather all the light and change the incident angle in order to match the N.A. of optical fiber.

But as the cost effectiveness matters to the user first recommendation is more suitable that second one. Commercially used optical fiber for light transmission, i.e. glass fiber and PMMA has numerical aperture of 350, 600-750 respectively. A narrow N.A. fiber simply admits less light than wider N.A. fiber, assuming the source is emitting light at wide N.A. So, PMMA has more light gathering capacity than glass fiber.

Operating temperature:

Operating temperature is one of the key factor for selection of the optical fiber. This depends upon the working and melting temperature of the fiber. The working temperature of the glass fiber optics are as follows:

Glass fiber - 600 to 4820c

PMMA - 600 to 850c

Depending upon the type of system and temperature at the collection and focusing area the approximate fiber should be selected.

In most of the collection system the temperature may increases above 850 of the focusing area, therefore glass fiber should be used. To use the PMMA in such systems special cooling arrangements has to be there.

For the purpose of the decorations CFL bulbs or LED are used for lighting and then it is transmitted through fiber. As the LED and CFL produce light of low temperature and at relatively lower operating temperature PMMA can be used there.

Color temp:

Color temperature is measured in Kelvin degrees and they are denoted by a numerical figure followed by letter K. in Kelvin scale lower values actually equates to warmer colors and vice versa.

Some of the most common temperature are,

Table 1. Appearance of light through fibers as per variation in color temperature

Temperature (in Kelvin)	Light appearance
2700 K	Extra warm white/warm white(similar to light produced by incandescent bulbs)
3000 K	Warm white (color produced by majority)
3500 K	White (color produced by majority of CFL)
4000 K	Cool white (provides sort of high tech feel)
6000 K	Daylight (similar to natural light)

Most lighting requirements falls between2000 K to 6000 K. But two color temperature dominate around 2700 K is typically denoted as warm white or soft white, this light gives typically orange shade light.

At about 3500 K light becomes cool white or bright white. This color temperature light is more natural and appear to have a slight blue cast. The light at this wavelength is considered ideal for reading and detail oriented task work.

The graphs below shows the color temperature in kelvin at various length of fiber optic. Light source used is halogen light.

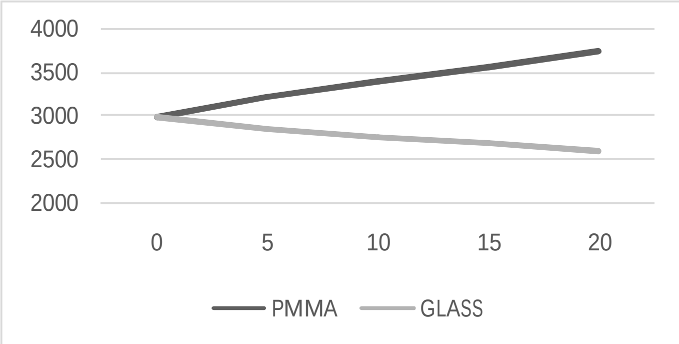

Figure 2. shows the light temperature (Kelvin) at various lengths of the fiber cable

Table 2. Ambiance and applications according to color temperature

Color temperature	Ambience	Application
2000-3000 **K**	Cozy, calm, inviting, intimate	Living room, kitchen, bedroom, bathroom and restaurant.
3100-4500**K**	Bright, vibrant.	Basement, garages, work environment, task lighting, bathroom.
4600-6500**K**	Crisp, invigorating	Display area, security lighting, task lighting, garages, worktables

Transmission:

The ultimate aim of any lighting through optical fiber is that to transmit the maximum amount of light at the diffusing site. So we have to keep the transmission losses as minimum as possible.to keep transmission losses at minimum level we should have to select appropriate type of optical fiber. If we could focus all the light directly into the core (not cladding).

The theoretical efficiency will be about 92%. There are Fresnel losses about 3-4% depending upon type of fiber. When the light strike onto the core surface of the fiber the light will be reflected back by some amount even if it is in the acceptance angle of the fiber this causes because of the difference in refractive index.

Core is the light transmitting part of the optical fiber while cladding is only for the purpose of support and rigidity. We will be focusing the light on the total surface of the fiber (core + cladding). If the area of the cladding is more fiber will accept less amount of light. So we have to select the fiber according to the ratio of area of cladding and core. Lesser will be the cladding area greater will be the transmission.

The table below shows light transmission loss inside the fiber.

Table 3. Light transmission loss inside the fiber

Length (in meters)	PMMA (%)	Glass fiber(%)
0	63	37
3	55	30
6	48	24
9	41	20
12	36	16

Percentage value in the table represents the ratio between the light led towards the fibers from the light source, and the light that emits the fibers.

Flexibility:

Glass optical fiber, just as its name shows, is an optical fiber made of glass. Being a delicate type of optical fiber, it cannot be cut, spliced or repaired, less resistant to flexibility and accidental breakage. Glass fiber optic cables are extremely versatile and robust. Glass optical fiber is generally ideal for hostile environments.

Plastic optical fiber, polymer optical fiber or POF, is an optical fiber which is made out of plastic. Traditionally, it comprises of PMMA (acrylic) as the core (96% of the cross section in a fiber 1mm in diameter) that facilitates the transmission of light, and fluorinated polymers as the cladding material

As fiber technology continues to become more flexible and less expensive, plastic fibers are generally more cost effective than glass fiber optic cables and are ideal for applications that require continuous flexing of the fiber.

IV. CONCLUSION

In this research we do the study of different types of optical fiber which is used for light transmission purpose. We concluded after studying the research papers on this topic by others that after concentrating maximum amount of light on the one end. If we want to transmit this much amount of light at the other end with least transmission losses we should have to select suitable type of optical fiber.

But the selection also depend on the appearance, ambience of light through optical fiber at different place is differ as per the user so this factor also have to considered while selecting the fiber. Along with this parameter length of transmitting fiber also important consideration because transmission losses are increased with increase in length.

So we cannot tell the selection of specific fiber for the light transmission because as per the location where we want to diffuse this transmitted light is differ also it depends on the mood of the user of that light. But we can assure you that if you should follow the above parameters it will definitely increase the ability of fiber to transmit light with maximum amount at the diffusing site. Also if we use PMMA and glass fiber in single bundle we can get different ambience of light at different location.

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