Why Use Fiber Optics For Lighting?

Using fiber for remote lighting has many advantages, some of which are more important for special types of applications than others.

Heat-Free Lighting: Since the light source is remote, the fiber transmits the light but isolates the heat from the light source from the illumination point, an important consideration for lighting delicate objects, such as in museum displays, that could be damaged by heat or intense light.

Electrical Safety: Underwater lighting such as used in swimming pools and fountains or illumination in hazardous atmospheres can be done safely with fiber optic lighting, since the fiber is nonconductive and the power for the light source can be placed in a safe location. Even many lights are low voltage.

Precise Spotlighting: Optical fiber can be combined with lenses to provide carefully focused light on extremely small spots, popular for museum exhibits and jewelry displays, or simply light a specified area precisely.

Durability: Using optical fiber for lighting makes for much more durable lighting. Optical fiber, either plastic or glass, is both strong and flexible, much more durable than fragile light bulbs.

The Look of Neon: Fiber that emits light along its length, generally called edge-emitting fiber, has the look of neon tubes for decorative lighting and signs. Fiber is easier to fabricate, and, since it is made of plastic, is less fragile. Since lighting is remote it can be placed at either or both ends of the fiber and sources can be safer since they are low voltage sources.

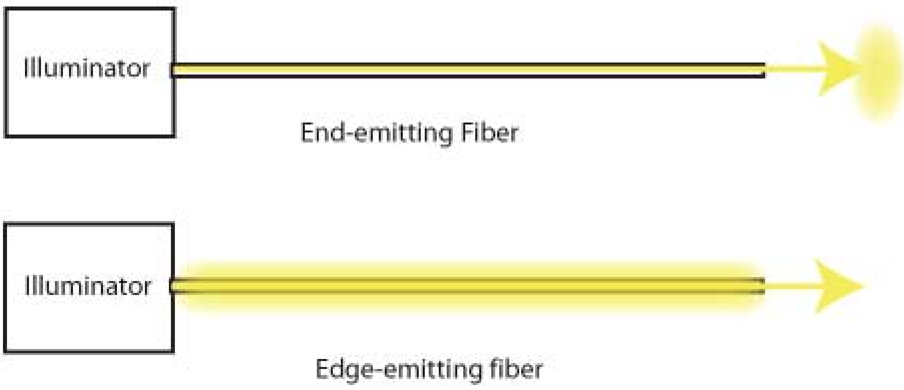
Vary the Color: By using colored filters with white light sources, fiber optic lighting can have many different colors and by automating the filters, vary colors in any preprogrammed sequence.

Simpler Installation: Fiber optic lighting does not require installing electrical cables to the light locator and then installing bulky light fixtures with one or more bulbs on location. Instead, a fiber is installed to the location and fixed in place, perhaps with a small focusing lens fixture, a much simpler process. Often several fibers can use a single light source, simplifying installation even more.

Easy Maintenance: Lighting in hard to access areas like high ceilings or small spaces can make changing light sources difficult. With fiber, the source can be in an easily accessible location and the fiber in any remote place. Changing the source is no longer a problem.

How Fiber Optic Lighting Works

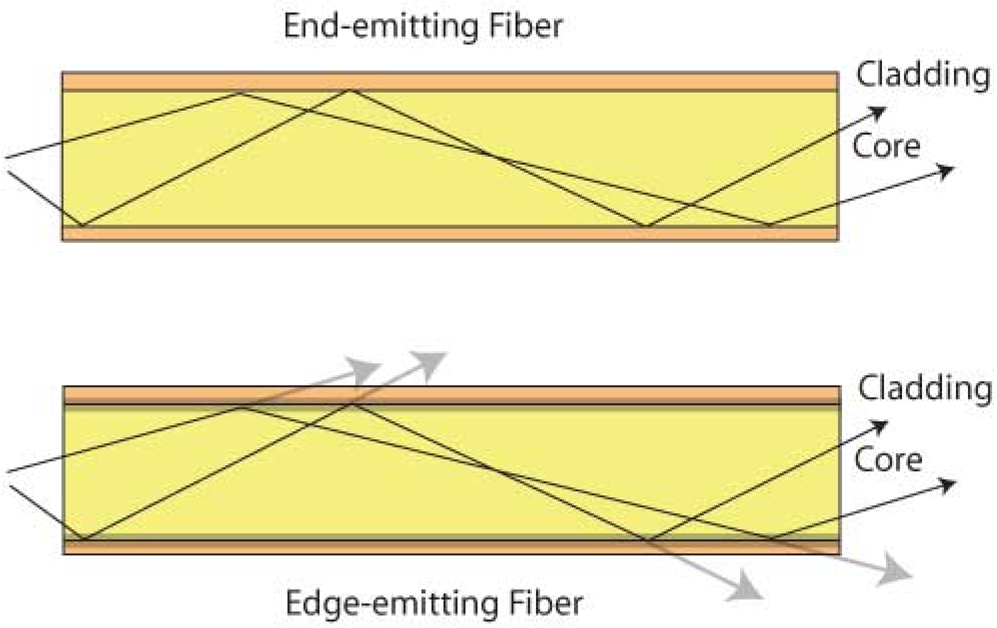
Fiber optic lighting uses optical fiber as a “light pipe,” transmitting light from a source through the fiber to a remote location. The light may be



emitted from the end of the fiber creating a small spotlight effect (also called “end glow”) or emitted from the outside of the fiber along its length, looking like a neon or fluorescent tube (also called “side glow”).
The light source is usually called a “fiber optic illuminator” and consists of a bright light source and often some optics to efficiently focus light into the fiber. Sources must be bright, so quartz halogen or xenon metal halide lights are commonly used. Smaller fibers may also use LEDs which very efficiently couple light into fibers but do not achieve the light levels of the other lamps.
Optical fibers used for lighting are similar to fibers used in communications, but optimized for transmitting light not high speed signals. The fibers consist of a core that transmits the light and an optical cladding that traps the light in the core of the fiber. Unlike communications fibers that use small cores to maximize bandwidth, lighting fibers use large cores with thin claddings to maximize coupling of the light from the illuminator into the fiber. Side-emitting fibers have a rough interface between the core and the cladding to scatter some of the light out of the core along the length of the fiber to create a consistent lighted look similar to neon light tubes.
Lighting fibers can be made of glass, just like communications fibers, or plastic. If the fibers are glass, they are usually very small diameter and many are bundled together in one jacketed cable to provide enough light transmission. Larger diameter plastic fibers are also used, perhaps more commonly, because they are inexpensive and easier to install, but they have higher light loss and cannot withstand as hot a temperature, sometimes limiting the light input from a source.

Types of fiber

End-emitting Fiber



End-emitting fiber is generally a step-index multimode fiber with a large transparent core that transmits the light and thin transparent cladding that traps the light in the core in an optical process called “total internal reflection.” The core is large in comparison to the thin cladding as that makes it more efficient in coupling light from the illuminator. The cladding does not transmit light, so any light coupled into the cladding will not be transmitted by the fiber.
End-emitting fibers are generally made from plastic as it can be made in larger sizes than glass

and is less expensive and easier to install. Plastic optical fiber (POF) is made in sizes from 0.1 to 20 mm in diameter. Glass fibers are generally made in much smaller sizes (hair thin, about 50-150 microns or 0.05 to 0.15 mm) and bundled together to make larger diameter cables.

The choice of core and cladding materials determines the angle of light rays accepted from sources and transmitted by the fiber (called modes), defined by a specification called numerical aperture(NA). The light will exit the fiber in a cone that shows the size of the NA with larger NA having a wider output cone of illumination. Higher NA fibers also couple light from sources more efficiently, as it will capture light at higher angles emitted by the source. Typical fibers have acceptance cones of 30-60 degrees, corresponding to NAs of 0.3-0.6. When optics are used to focus the light emitted from the fiber, the NA of the fiber must be known to choose appropriate optics.

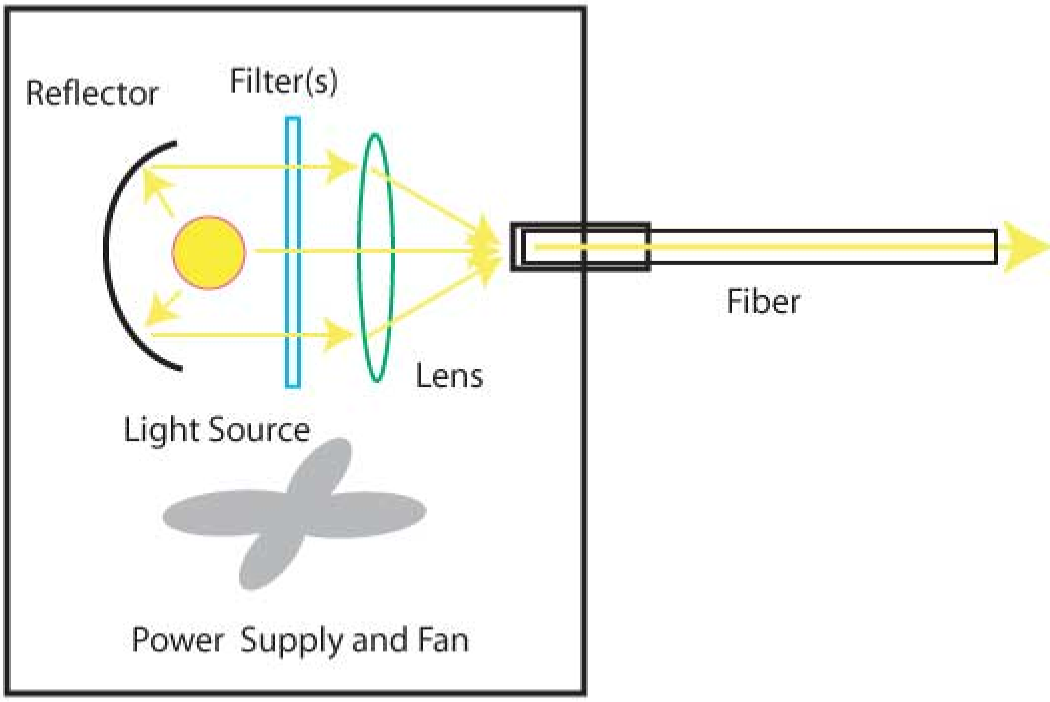
End-emitting fibers transmit light well. Glass fibers are more efficient at transmission because glass is more transparent than plastic, but because of the inefficiencies of packing fibers into bundles, spaces between the fibers in the bundles means much of the illuminator light is not coupled into fiber cores. However, glass fibers may be more tolerant to heat generated by the illuminator, allowing greater illuminator intensity and providing more light from the end of the fiber.

Edge-emitting Fiber

Edge-emitting fiber

Edge-emitting fiber is basically similar to end-emitting fiber except the core/cladding boundary is designed to be slightly inefficient. Instead of trapping all the light in the core, the boundary is rough and some light is scattered into the cladding where it becomes visible. By careful design, the fiber can have a smooth glow that looks much like a neon light tube. Smaller edge-emitting fibers have been woven into tapes that emit light in a band.

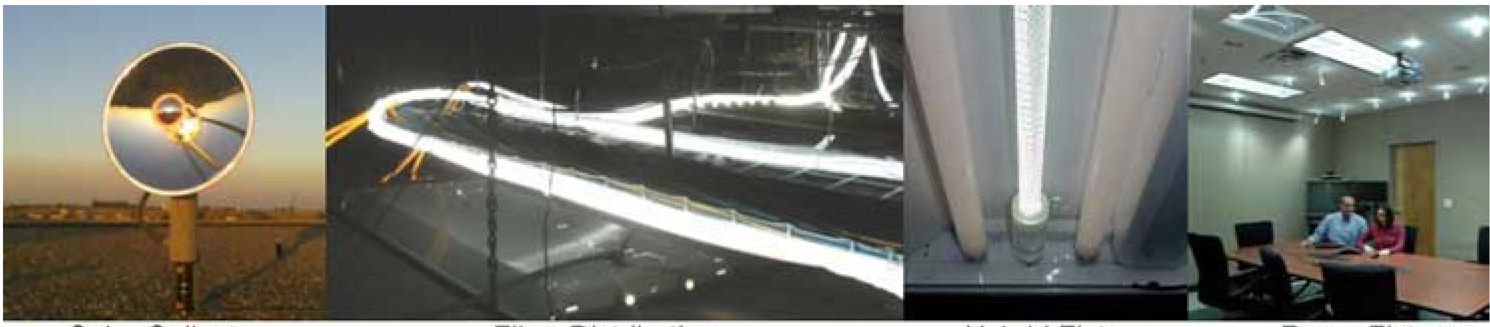
Since much of the light is lost by the edge-emission along the fiber, edge-emitting fiber has high attenuation. This may limit the lengths of edge-emitting fiber that can be used. This can be alleviated by illuminating the fiber from both ends by using two illuminators or looping the fiber back around to the same illuminator, or using reflective end caps to send excess light back up the fiber from the far end.



Illuminators , Types of Sources

The illuminator contains the light source for the fiber as well as optics and filters designed to produce the amount

and type of illumination desired. While the amount of light coupled into the fiber is the primary consideration in choosing an illuminator, many other factors are involved, which has driven the market to offer many types of sources.
The power coupled into the fiber or fibers, as many sources will accommodate more than one fiber, will generally determine the type of light source used. Quartz halogen lamps are used in many illuminators. These sources, developed as spotlights or lamps for projectors, come in both low and AC voltage versions, with a wide range of power outputs. Quartz halogen lamps are usually made integral with reflectors that make focusing light into a fiber simpler. New Xenon metal halide lamps that have high power output but require high voltage power have been introduced that offer greater efficiency.
Lower power systems have been able to use LEDs which have higher efficiency but limited power. New LEDs are becoming brighter and even more efficient, making LEDs a viable source for more systems.
Illuminators include more than just lamps or LEDs. Lamps may need reflectors if they are not built into the lamp, as well as lenses to focus light into the fiber. High power sources may have infrared (IR) filters to reduce heating of the fiber and ultraviolet (UV) filters to prevent damaging the fibers during long-term exposure.
Power sources for the lamps or LEDs will be needed, including dimming capability if desired. Since most lamps generate lots of heat, fan-forced ventilation will be designed into many illuminators.
Lamps are easily filtered to provide colored light in the fiber. Using moveable filters, usually in a wheel powered by a small electrical motor, allows the color of the light to be changed in a chosen sequence.
The complexity of illuminators precludes most users making their own, but numerous manufacturers offer various models optimized for various fiber types and applications. Working with these manufacturers is the best way to choose an appropriate illuminator and compatible fibers.
Passive lighting using fiber optics is being done using roof-mounted solar collectors that deliver sunlight over fiber to rooms in a building or below decks for ships.



Solar Collector | Fiber Distribution | Hybrid Fixture | Room Fixtures

End-Emitter Fixtures

Normally, light exits an end-emitter fiber in a cone of light defined by the numerical aperture of the fiber. In some cases, that will be adequate for illumination. However, it is sometimes desirable to focus the light on a smaller spot, create a shaped illuminated spot or diffuse the light to resemble a normal light bulb. End fixtures with lenses are available that can focus the light as needed, but need to be chosen for compatibility with the fiber being used.

Decorative fixtures are also available to create a attractive fixture for the light, not just the end of a fiber. Manufacturers offer many different types of these fixtures, just like with regular light fixtures.

Illumination Levels

Since the illumination of an area or object is the reason for using fiber optics, the illumination levels are most important. Making direct comparisons between various fibers and illuminators can be difficult due to the numerous options available. Even the perception of the human eye, highly sensitive to color, is a factor.

End-emitting fibers are easier to calibrate as the output power can be easily measured at the appropriate distances from the end of the fiber by light meters calibrated in foot-candles. Edge-emitting fibers are harder to calibrate, as they emit in diffuse patterns and their perceived contrast is dependent on ambient lighting.

It is illustrative to look at the factors involved in the illumination provided by the various options.

Coupled Power

The power coupled into the optical fiber is a function of the intensity of the light source, the efficiency of the focusing on the end of the fiber, included filters (IR, UV and/or color), reflectance of the fiber end face and the cross-sectional area of the fiber. Larger fibers, obviously, couple more power. Doubling the diameter of the fiber increases the cross sectional area by four times (2 squared) so the coupled power should be four times higher. Likewise, higher packing density on fiber bundles will increase coupled power. Even the cleanliness of fiber ends is important as dust and dirt absorb considerable light.

Fiber Attenuation

Losses in the fiber due to scattering and absorption will reduce the output power, and since the fiber attenuation is wavelength dependent, the color of the emitted light will change. Longer fibers mean the light will be slightly reddened.

Designing Fiber Optic Lighting Systems

Fiber optic lighting appears to be missing industry standards so every product and application is proprietary.

Since there is so much variety in fiber optic lighting systems, it’s hard to generalize about designing systems. However, every design project will start with some common items: what is being lighted, what kind of light is desired (intensity, illumination pattern, color, variety, etc.), where the light will be presented and where the illuminator will be placed. If the designer is new to fiber optic lighting, consulting with an experienced designer and contractor is highly recommended. They will be able to recommend designs, fiber optic lighting components and manufacturers. They should also be able to help design not only the fiber optic lighting system, but also the power and controller for the system.

If an experienced contractor is not available, one can use manufacturer and distributor websites to help learn more about what applications are possible, what components are available and hot to implement them. One can also see the options regarding buying components and assembling them yourself or buying a complete system ready to install.

Installation of Fiber Optic Lighting Systems

The installation of fiber optic lighting systems involves installing cables, illuminators and fixtures. Most of the applications are custom and many will require specialized practices related to the components being used. Working with manufacturers who have not only developed the components but also the installation fixtures and practices is the best way to ensure the installation is properly done. If the application is a new type, experimenting to determine if it will work properly before committing to the actual work is very important. The advice given above about designing fiber optic lighting systems holds here too, as there is no substitute for experience. It appears that any competent electrician used to installing lighting should be able to install a fiber optic lighting system, especially since they are experienced in installing cable, light fixtures and electrical power and controllers.