Scientific Facts for You

All light sources make photons in specific ways. How each type of luminaire physically works determines how useful it is in any application. The physics controls the output.

Light is not magical no matter what sales literature tells you. It either creates a specific photon content or it doesn't. That content is based solely on how the lamp converts electrons into photons. The spectral output of photons impacts rather or how it should be used for lighting artifacts.

Today the lighting industry is full of marketing half-truths used to sell lighting products to anyone for any use. Over the years the explanations of the science has been muddled to sell stock in ever "newer" innovations with intentional garbled "how it works" information. It is not very exciting to learn all LEDs work identical and have for the past 50 years. So the science gets overly complex. That does not mean there are not improvements. But the very nature of photons limits what is possible.

Fast facts are brief articles designed to arm you with information. For a more complete understanding of photons, Reflected Energy Matching Theory and comparing spectral output start with "What is light?" on the home page by the space shuttle image. Also look to the other published papers.

What Is Fiber Optic Lighting?

Fiber optic lighting is a system. The system is made up of a projector + fiber + luminaires. The projector uses a single lamp (light bulb) to input photons into the fiber. The light travels down the fiber where it exits and is used to illuminate. The fiber can be left bare with nothing at the end. Or the fiber can terminate in a luminaire or head.

Each fiber lights to its end. So the projector is the light source where lamps are changed and there is maintenance. At the projector the fiber is actually fibers like the arms of an octopus or a gathering of spaghetti noddles. Each fiber transmits the light.

Therefore, the end of each fiber is technically a luminaire. It is the "light" that does the work. It is the light that is "mounted".

There are optics at the projector to get light into the fiber. The fiber is "optical", because it is designed to carry light down its length. There are optics at the end of the fiber to shape a beam.

The characteristics or benefits offered are influenced by choices in 1) the projector, 2) the fiber and 3) the luminaires.

Since fiber optic lighting is a system, performance is needed by each part of the system. Pick different components and things work differently. Pick one component poorly, and the whole system performs marginally. Components are picked to match the lighting job. But since no sale is a bad sale, fiber optic systems tend to get sold into jobs they were never intended for and the fiber optic lighting turns into "toy" lighting. It is not very useful for task lighting (the "task" of putting light on a surface or thing) The error was this misapplication. So success is to match a fiber optic system with the work required.

For example a projector using a halogen lamp will work very differently than one using an LED lamp. A fiber optic system using acrylic fiber will have very different characteristics than a system using glass fiber. Even the choices in luminaires dramatically impact performance.

The range of performance is as wide in scope as the range of fiber optic lighting jobs.

An architectural system sold to sidelight a building as a substitution for neon is very different from an instrument system used to light the slide in a microscope. Neither will work very well to light artifacts in an exhibit. “How tings work” becomes a long discussion, because it has to cover 1) the projector, 2) the fiber and 3) the luminaires.

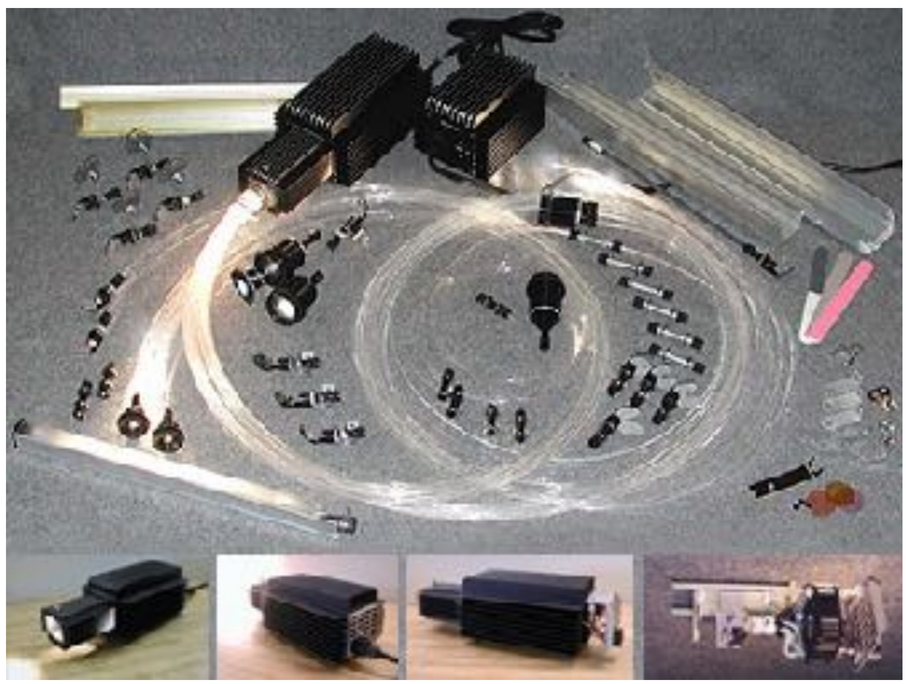
How Fiber Optic Projectors Work?

Fiber optic lighting is a system. The system is made up of a projector + fiber + luminaires. The projector can be as simple as a box with a light bulb inside and a hole to hold the fiber. This is the basic projector for a fiber optic Christmas tree.

The industry today can interchange the word projector and illuminator. But there is a difference. Projectors use **projection** lamps.

They usually have more optics. Projection lamps are designed to be used in focus. If the lamp’s output is focused on the fiber, optics are needed to remove the lamps IR to protect the fiber. Sometimes the optics are there. Sometimes the projector places the lamp in defocus. Sometimes the projector spins a color wheel hoping the wheel cools enough as it rotates to dissipate the heat. Sometimes the projector uses a really low-watt projector lamp. (The Christmas tree example uses a very low-watt, projection lamp with a color wheel.)

NoUVIR’s projector uses a powerful, EKE 120-watt halogen MR-16 projector lamp. The lamp is in intense focus. But NoUVIR uses unique COLD-NOSE technology to remove the heat before it reaches the fiber.



NoUVIR also suspends the lamp in a natural airflow, adds a heatsink to the lamp’s pins and includes a quiet box fan to assists the projector’s housing’s heatsink fins. The expensive COLD-NOSE optics stays in the nose of the projector. The lamp, lamp socket, fan, etc. are in a slide-out drawer to make maintenance easy. The projector runs cool enough to touch. It operates around 45°C. Acrylic fiber melts at 90°C.

Fiber optic projectors are always lamp specific.

The optical centerline of the lamp is critical. Change to a different lamp and you will change the performance. Usually you get dramatically dimmer light. Also you can get poor lamp life.

Illuminators may or may not have a filter, but always lack a tight focus. It is still recommended to not substitute, for example, an LED replacement for a low-watt MR-11 lamp. But illuminators are more about effects than lighting things.

Because of the extra design elements, projectors tend to be more efficient and have brighter output. But that is not always true. Some effects illuminators, especially if they change color, can outperform small medical or instrument projectors.

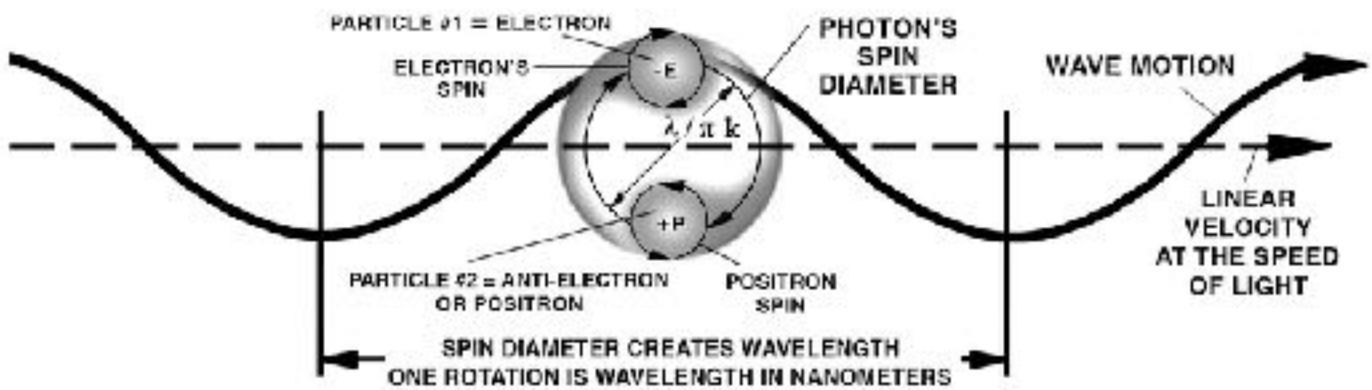
Beware of projectors that talk only about lumen output. Performance is determined by what light makes it out the other end of the fiber. Entrance angles and how the light gets into the fiber greatly impacts performance. It also determines some of the light loss over the length of the fiber. A projector can have high lumens, but poor performance.

Looking Deeper into How Projectors Work

Focus on the lamp and how it creates photons. Electricity flows into the lamp as a rushing line of electrons. Based on quantum physics, the lamp converts those electrons into photons. Each lamp type, tungsten, halogen, LED, fluorescent, HID, etc. make photons. They all combine electrons into photons. The all succeed at generating photon the same way by crowding atoms in a tight molecular structure.

but different atoms as core materials produce different wavelengths as photons. The atoms determine which electron rings throw out what photons. The lamps all create visible light from electricity. But in different amounts of colors (different frequencies) with different balances and biases in color which determine presentation. Also each lamp type has widely different output in UV and iR content.

Light is made up of particles. A single “corpuscle” of light is a photon. A photon acts like a single particle. But it is actually made of two particles with mass.



It is not a wave. The two particles travel in the motion of a wave pattern. But a photon is a two-particle thing. It is not just energy.

Photons of different wavelength are made up of the same two-particle unit. Different light wavelengths have the same energy and speed. Why? Because they are made up of the same two-particle matter.

All light is the same. A visible wavelength in blue is identical in its particle make up to visible wavelength in red. Infrared also has the same construction. So does ultraviolet. The particles never vary or change. We may “see” a difference. But objects are still hit by particles.

It is vital you know light is made up of particles.

The genius physicist, Dr. Richard Feynman, made it very clear to his students. “I want to emphasize that light comes in this form - **particles**. It is very important to know that light behaves like particles, especially for those of you who have gone to school, where you were probably told something about light behaving like waves. I’m telling you the way it does behave - like particles…light is made of particles.” (Feynman, *QED*, 1985, pg 15.)

If you are having trouble with this concept, read the pdf Light and Matter: the Dangerous Romance *and other sections on this website. There are numerous references. Also check out the reference pdf for further reading as the last pdf on the list.*

Therefore, a photon has mass.

Things (particles) are influenced by gravity. Again, a photon is a thing…actually two things with mass. A photon is an electron and its anti-electron. The particles are attracted to each other and spin around each other as they travel forward through space. This makes a wave like motion.

An electron is a negative charged particle.

But when an electron spins backwards, its polarity changes to positive. This “antimatter particle” is today known as a positron. (Science fiction’s loved this breakthrough as an idea that energy as light was speeding through space as a balance between matter and anti-matter.)

A positron is an electron spinning backwards.

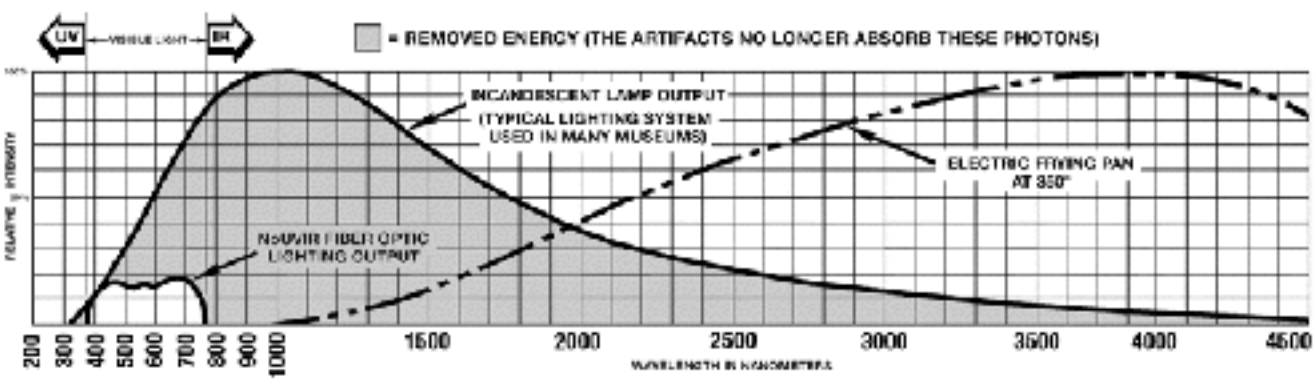
It is the electron’s positive twin. Linked together, an electron and a positron, attract each other, negative spinning around positive. The particles become tightly bonded and are not influenced by fields as together there is no charge. But **photons are influenced by gravity.** They are influenced by the atoms in molecules. They are effected by electron-ring orbits if they come close enough to an atom.

Lamps use tightly bonded metals, metallic gases and phosphors to bump electrons into a backward spin and force a photon pairing (electron and positron) out into space as light. The wavelengths are determined by the flow or pressure of the crowding of the electrons into atoms of dense material. The wavelengths are determined by what electron orbit in the atom gimbaled, bumped and excited. Through the orbital mechanics a photon is thrown out in a wave like motion.

Therefore, the lamp in the projector is a key clue as to performance.

Fiber carries photons. Since the lamp creates the light, the wavelengths the fiber transmits are determined by the lamp. Different lamps produce different amounts of light.

For example, below is the spectral output of a tungsten halogen lamp operating at full voltage. The distribution of the photons show a voluminous amount of infrared. The reason is that the tungsten atom produces photons at its outer rings first. The outer rings are the most unstable. They produce the most light.



As the rush of electricity as electrons are forced further into the atom’s electron orbits, the atom throws off more and more photon pairings from the outer rings. But the atom gets so excited and the inrush of electrons is so great that the atom starts generating photons further in towards the nucleus.

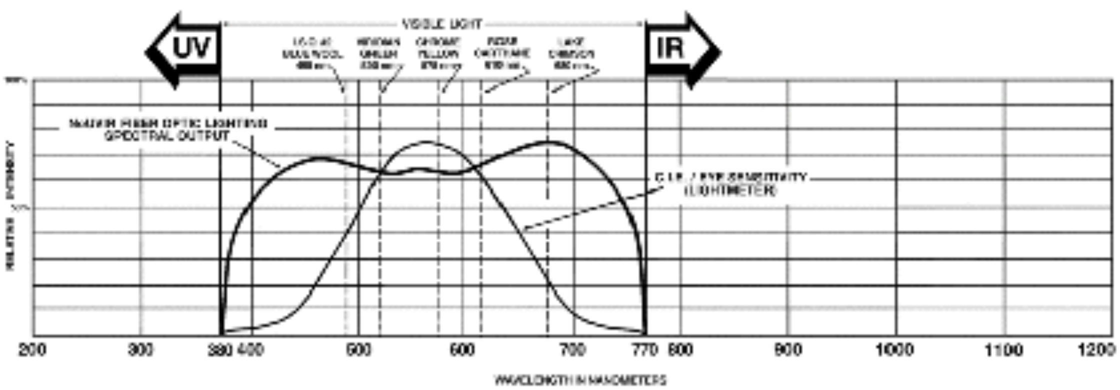
The further in photons have shorter wavelengths. The lamp increases in IR output. The temperature rises. But the lamp starts producing visible light.

At full voltage, photons are coming off of rings close enough to the nucleus that there is a 5% useable visible output. To get to the rings that are generating blue and purple light, some interaction is happening deeper and closer to the nucleus. This generates the small amount of 1/2% to 1% of UV found in a tungsten halogen lamp (with IR filtered reflector) with the rest of the output being around 94% heat.

The heat of the lamp is often credited with the visible output. But IR is a product of the making photo pairs as a process. It is the crowding of electrons into the atoms that increases the heat output and raises the color temperature so the filament glows from red to orange to white.

The UV and the IR do not cause sight. These photons are harmful to artifacts without giving any benefit. So a fiber optic system filters and redirects as much of the UV and IR as possible out of the light of the lamp. A good fiber optic projector will remove some heat. And excellent one will trim out photons so only the white area in the curve is what is transmitted by the fiber.

The white curve shows what is left after NoUVIR's techniques including it's COLD-NOSE technology filtering the lamp's output. The remaining light is only the visible light. This is directed into the fiber.



The point in judging fiber optic lighting systems is that if the photon does not exist in the lamp's output, the system cannot create it.

A projector can filter out UV and IR. It can even color correct by removing some visible light as NoUVIR's projector trims down the visible red light to balance the visible spectrum. But a projector's output is always tied to what its lamp produces.

Fiber optic systems have a spectral output that is tied to the lamp's output. If color is missing, because the lamp is blending or "tuning" the visible light; those colors will be missing. The fiber cannot add them. And those missing colors will become gray and lifeless as presentation.

A favorite lamp for a fiber optic systems used for effects is a LED lamp. See how LEDs work. But the process is still a crowding of electrons from a flow of electricity. An atom is picked that has a loose electron ring that is especially active. As the atom is excited, the same wavelength is generated over and over again. It is a visible blue. (A few manufacturers use violet and the blue can vary slightly from lamp manufacturer to manufacturer.)

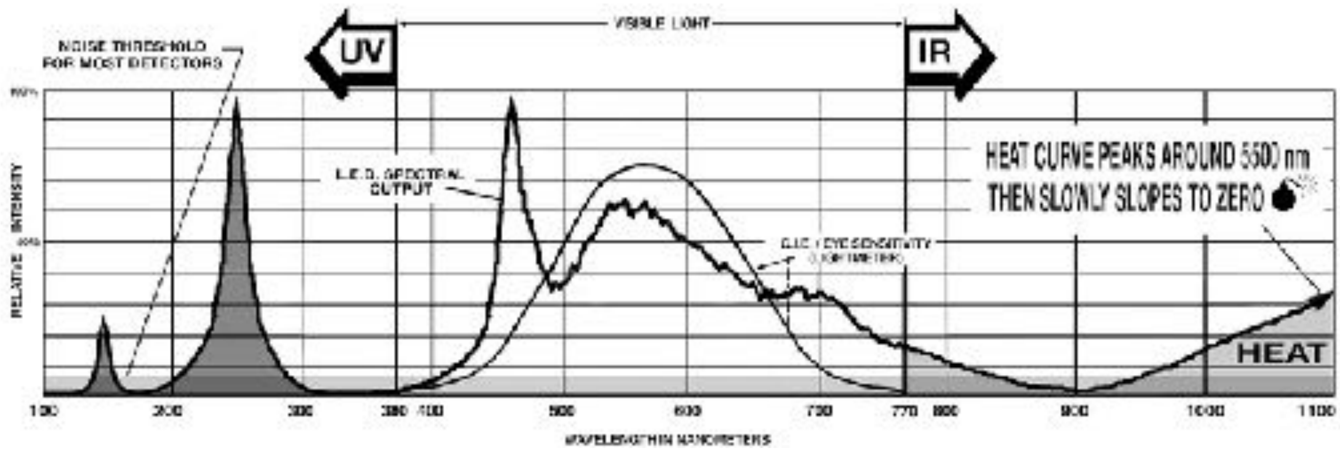
The orbits of the atom have the same pairs of photons in that the distance between the electron and positron is the same. It is blue light. But that is not useful.

So the lamp adds a mixture of phosphors (metallic salts or also called, rare earths) to force the blue photons through to convert part of the blue light into other colors. The blue photon enters, shuffles and the distance changes turning the photon into a green, yellow, orange or red photon. The color and quality of the light is based on the phosphors.

But too much phosphor and the light is absorbed instead of converted to another wavelength. So LEDs have a fine line lamp manufacturers are always juggling. The most energy efficient lamps let more blue light escape through and use thinner coatings. The lamps with the best color rendition use the thickest coating possible while still getting useable light.

Of course these excited atoms also produce UV and IR. Since most of the IR is past 1000nm where it rapidly climbs to 3/4 of the output, most spectral curves stop at 900 nm. Some graphs also fail to show the UV. The good news is that lamps with acrylic lenses filter the UV if the acrylic is thick enough.

Take a look at a top-quality LED lamp's output.



First notice the color spike of visible blue light. Also note that the curve has a lump at green and red. There is overlap. This is a good lamp. But the bias and how the lamp works can be seen in the graph.

LEDs are popular for fiber optic lighting projectors (really illuminators, since the lamp is never well focused), because an LED lamp is less likely to melt acrylic fiber. Its output is 75% IR instead of the 94% heat of a tungsten halogen lamp. A LED lamp will produce more visible light per watt.

(To complete this discussion, LED lamps may or may not produce more visible light at the end of a fiber. The lamp is unfocused. Always. The atoms that create the light are spread out on a surface with a slot or hole. The board emitter is an area and not a point source. It is difficult to focus an area. So much of the visible light does not make it into the fiber. The entrance angles are wrong. Therefore, many of LED-powered systems are dimmer compared to even low-watt halogen sourced systems.)

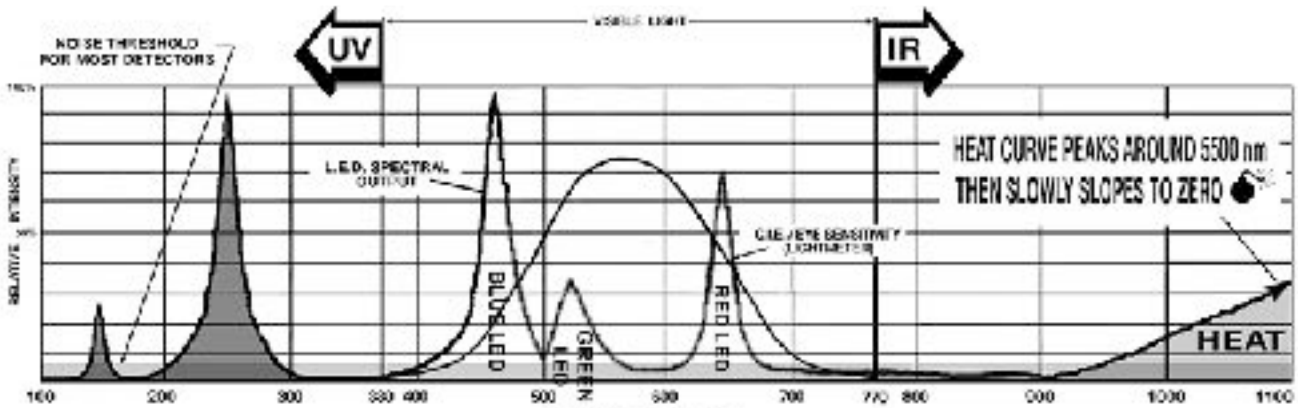
(To further complicate the claims made by LED systems, LED lamp life data do not apply to fiber optic lighting. The industry determines life of a lamp operating in free air. Fiber optic projectors using LEDs by definition enclose the lamp. LED fiber optic systems tend to have premature lamp failure as the enclosure overheats the lamp's temperature specification for the circuitboard. If possible, try to get in-operation lamp life.)

The output shown in the graph is a LED lamp that has an excellent spectral output. This is really good performance from a lamp made by a high-quality manufacturer with tight tolerances and taking no short-cuts in materials to save costs. Poorer quality LED lamps can produce output that is near zero at certain wavelengths with complete colors missing.

But note that even the best in performance from an LED lamp is skewed. A specific blue color is very heavy which will shift the other blues into the more powerfully represented blue monotone. This is why a LED is called in the industry a "blue pump phosphor" lamp (or purple for some manufacturers).

The red light is under represented. To hide this bias, some spectral output curves change the scale as the graph gets taller and longer. Again, others will edit the output.

The jagged stair-stepping is intentional to show the overall curve is not just spiked, but colors next to each other are at different amounts. The curve is almost always shown smooth. But actually colors are stair stepped or, in other words, the materials used to produce the photons favor specific electron rings stimulating certain wavelengths over others. The reason is that the phosphors themselves have an atomic structure that re-corrects towards specific orbits and those orbits determine wavelength (color). The other reason is that the flow of electrons is not perfect. LED lamps show that flow problem whereas other lamps tend to hide it.



Finally some LEDs are tri-stimulus or use a “color fidelity” of individual peaks of color to blend into white light. The white light is a mixture of blue light with the green and red created by the phosphors or in a few cases, purple light with a blue, green and red phosphor. The colors are humps. The eye sees “white” light. Unfortunately, the artifact sees the dominant colors. Presentation is not as good as it should be. And damage rates can be all over the map depending upon what photons are reflected and what photons are mismatched.

The point is that fiber will transmit all the flaws in a color balance.

The spiked blue color of a LED will notch, meaning it is more harmful to mismatched materials like paper documents. And if the fiber transmits UV and IR, the fiber optic system needs to be filtered. Some manufacturers filter. Others do not. The filtering should be visible at the projector in that you can see the optics and it should be more than a single dichroic filter.

Different lamps have different outputs. Those spectral outputs determine presentation and preservation. Knowing what lamp is used in the projector provides clues as the systems acceptability for lighting artifacts.

Different Fibers Produce Different Results

There are three types of fiber material. They are: acrylic, glass and solid-core “light guides”. Fiber is bundled or harnessed in a bushing that holds the fiber at the projector.

To make fiber more complicated, fiber can be solid or mono. Or the fiber can be stranded. All stranded means is that if the fiber is cut apart, instead of one solid piece, the fiber is actually a cluster or bundle of smaller fibers.

(Technically acrylic is a form of solid-core fiber made of polymethyl methacrylate (pMMA). It is solid and not stranded. But decades ago, the definition of solid-core switched to describe various unique blends of plastics with acrylate to try to keep the plastic soft enough to bend and sometimes using a sheathed air-pocket instead of a cladding to contain the light. Pure acrylic fiber bends. But as its diameter grows, it turns into an unbendable rod. About the largest diameter an acrylic fiber can be is 1/8-inch diameter (3 mm) with a 6-inch bend radius. Solid-core can exceed that 1/8-inch diameter, 3 mm, and offer larger diameters for architectural needs.)

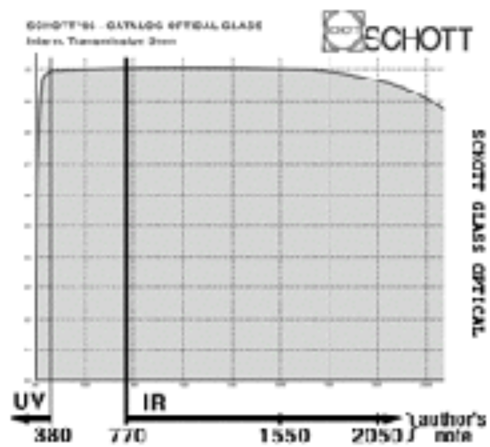
The fibers are held together with a jacketing or sheathing. Fiber made up of bundles of smaller diameter fibers is still flexible, though it can be rather stiff. This cable fiber can be also exceed the 1/8-inch diameter limitation. The idea is that more fibers add light.

This is all under the term - fiber.

Acrylic fiber can be a solid, single fiber. NoUVIR systems use 3 mm diameter, aerospace-grade, 100% acrylic. It is a solid fiber with a .00013 inch cladding. The cladding helps turn the light back into the fiber.

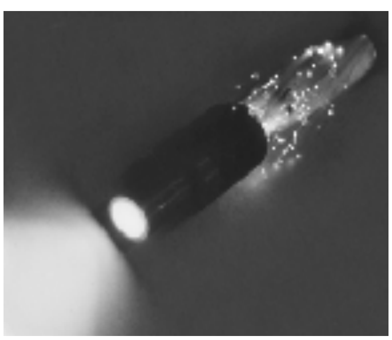
Acrylic fiber can be stranded. Smaller fibers are clustered together, jacketed and turned into a single fiber. The typical stranded fiber uses 1 mm diameter for the strands and is often a 3/8-inch diameter overall.

Glass fiber is always stranded. Cut into the sheathing and you will find dozens, if not hundreds, of fine, thread-like fibers of glass. Glass materials vary.



But almost all glass fiber is designed for communication. Its transmission is designed for peak performance for infrared lasers at 1400 nm. Since it will also transmit visible light and is sold by the mile, this is the most common form of fiber used for fiber optic lighting. The trouble is that is will transmit heat.

Glass fiber is flexible, especially if the jacketing or sheathing is not designed to support the weight of a luminaire. Therefore, glass fiber will break over time if it is stressed by gravity.



The jacketing is usually heavy enough that the breakage in not visible. This fiber simply got dimmer. It was not until it was cut into that the breakage was found where it bent into the luminaire. This means that in a visible fiber optic lighting system the way broken fibers are detect is by light loss.

The break is covered by the sheathing. The weight of the glass fiber pulled the threads and over time the glass broke. The trouble appears as one of the fiber’s lights gets dimmer or eventually just glows.

Solid-core fiber is never made as stranded. Ever increasing diameters are extruded. Some solid-core is durable. Some solid-core needs a replacement plan of every three years.

All fibers except some solid-core fibers are cladded.

How Does Fiber Work?

Fiber is cut into lengths and made into a bundle. Acrylic fiber is cut by a hand tool, polished (by hand or machine) and held as individual fibers in the bushing at the projector. At a later date, a single fiber can be removed and replaced with a longer fiber. Or a fiber already in the bundle can be trimmed to a shorter length. Ready-to-use bundles can be made at the factory.

But anyone can buy a roll of fiber and make a bundle in the field using basic tools.

(NoUVIR has had everyone from a cowboy to an 80-year-old docent cut and polish fiber. It is much like polishing acrylic nails. This is one of the many advantages of using acrylic fiber.)

At the end of the fiber, NoUVIR's luminaires are attached using a collet. Lights can be connected or removed by hand without tools. Other companies use set screws, compression pipe sleeving or glue. Since the fiber is solid, the luminaire can be used in focus and has a zoom.

Stranded acrylic fiber is cut and the jacketing is stripped back with the small fibers all being held in the bushing. Some manufacturers use a hot knife to level the fibers. Some manufacturers polish the fiber ends like NoUVIR recommends. Just like solid acrylic fiber, stranded acrylic fibers can be replaced or trimmed in the field, bundles can be made ready-to-use by the factory or bundles can be made in the field.

Stranded fiber is harder to use with luminaires. It can be tricky to attach the strands and the luminaires' optics have to be slightly out of focus or else the air gaps between the small fibers show up as holes and dark shadows within the beam. Stranded fiber luminaires can usually handle different fiber diameters. Some manufacturers require stripping the jacketing. Some manufacturers require the strands to be epoxied together and cut with a hot knife to flatten or polished. Some manufacturers glue the fiber into the head. One manufacturer attaches the fiber's jacketing to the luminaire using a set screw to pierce the jacketing.

Glass fiber is different.

The bushing needs to be planned. Cutting and polishing is done at the factory. Cutting the fiber, placing it in a ferrule and polishing it takes special skills and machinery. Glass systems are all about forethought and specific specifications. Or the factory bundles end up being longer than necessary (more cost) and extra fiber is coiled up hidden in the installation.

Luminaires for glass installations can have threaded ferrules. The "heads" screw onto the fiber. Other manufacturers glue the luminaires onto the fiber. Because the fiber is stranded, the focus needs to be defocused to get a beam without mottling.

Solid-core fiber is mechanically cut with a special cutter or a hot knife depending upon the manufacturer's recommendation. Like acrylic, the fiber can be made into bundles designed, built and changed in the field. Luminaires can be mounted with set screws, glued in place, attached to ferrules like glass fibers or held by friction squeezing the outer sheathing down for a tight fit. There is no way to polish solid-core fiber. The fiber has a soft surface. So luminaires are defocused.

How Does Fiber Really Work?

Fiber is a crystalline structure. The molecules line up in long chains. The atoms are perfectly spaced with gaps that match the spin diameters of light. Photons enter the fiber material. but are not absorbed. Instead the spinning particle pair weaves through the structure with no interference.

If the light is within Brewster's angle, the light perfectly fits into the crystal gaps and penetrates far down the fiber. As with all molecular structures, there is a lot of space. But the crystals are so perfectly line up that the wavelengths spin through without encountering an atom.

If the light's angle bounces inside the fiber, the cladding will use orbital mechanics and gravity will sling the photon back into the fiber as reflection. The photon will continue to travel to the end of the fiber. If the light's incident angle is not correct, the photon will escape out the side. There is a loss per foot along the fiber.

NoUVIR aerospace-grade acrylic fiber is a 0.7% loss per foot. Most acrylic fiber (because of quality) and mixed-plastic fibers are higher at around 2% to 4%. Some solid-core fibers are 8%. Glass fiber averages about 5% loss per foot for visible light. But for infrared, its loss per foot can be as low as 0.1%.

For stranded fiber systems, entry into the fiber is more of a challenge. The angles can be correct. But if the light hits the gaps between the round fibers or the epoxy holding the fibers, together making the single fiber, the light does not enter the fiber. Some stranded systems can have only a 50% optical efficiency.

The key are the crystal lattice work of the fiber. Crystals will "transmit" specific wavelengths and block others. Acrylic interferes with UV. The photon's spin diameter is absorbed into the atoms as the UV spin is blocked by the lines of crystals and almost immediately broken apart. Therefore, acrylic and certain other plastics will not transmit UV.

But acrylic is perfect for visible light. The spin of the photons avoids the atoms. The photons are ignored. They perfectly fit the lattice.

But grow the spin diameter into infrared, interference and absorption happens are the atoms are spaced in the wrong places. The linked structures of plastic absorb heat. If enough IR at the bushing surface is absorbed, the atoms get into such an excited state the crystal structure starts slipping in its well-ordered pattern. Exceed 90°C and the plastic melts. The crystal structure scrambles, stops excepting light as the open pathways are twisted, more photons are absorbed, the plastic atoms pull the extra electrons into their orbits and the plastic's chemistry changes.

So how does fiber really work? It is always a crystal. But the crystal's structure of lines up ranks of atoms and molecules has to have the spacing ideal for visible photons to slip through the gaps.

Glass fiber is transparent to most IR. The crystals of glass will let photons weave through without interference. But if the bushing is held together with epoxy, the epoxy is a plastic that can scramble and photo-degrade over time. As the epoxy blackens, more photons are absorbed, the chemical damage accelerates and the epoxy eventually breaks up. Without the epoxy holding the fine glass threads, the fiber comes apart.

To solve this, some manufacturers fuse the ends of their glass bundles. With heat, the glass is melted. The round fibers are squished into hex shape filling in the holes and gaps compressing the strands into a solid fiber with cladding honeycombed throughout the bushing. This adds efficiency. It is better than air gaps between the diameters of the fiber. It is better than filing those gaps with epoxy.

But it does scramble the crystalline structures twisting and bending the long molecule chains. More photons are absorbed. A fused end is not as transparent as a polished single fiber.

The key to fiber in a fiber optic lighting system is for the atoms in their long molecule chains to be straight, well-ordered and with the spacing to be consistent with a perfect match to the visible wavelengths.

Different materials have different spacing. For all fiber, as the fiber is longer and longer, more photons escape. But the percentage of escapees is more in the larger spin diameters than the smaller spin diameters. Therefore, fibers with really lone lengths shift from white light to a slight green white to a blue white.

Acrylic fiber is the best for transmission of visible light.

Aerospace-grade has been used with installations with 80-foot long fibers with transmission loss, but a small, usually unnoticeable color shift. NoUVIR recommends 50 feet or less. Fiber at 50 feet has a loss of 72% of the light.

Commercial-grade acrylic fiber will loose light at double the rate. It has more swirls in the crystal chains of molecules, tiny air pockets and impurities like microscopic dirt picked up off the factory floor. A beam that would be 36 footcandles will be 18 footcandles. Lower grades have greater losses per foot.

Solid-core fiber carries more light, because of the much larger diameter of the fiber. But the fiber over 25 feet can be very yellow. Some shift to green. It is the added polymers to keep the fiber flexible that tangle with certain wavelengths and shift the color as not all the colors reach the end of the fiber to produce white light. Again, like acrylic fiber, much depends upon how well the fiber is made.

Glass fiber can have particularly poor performance over length. Though an infrared laser can transmit over phenomenal lengths, several glass fiber manufacturers warn for visible light transmission to limit the fiber length to f9-feet. Some state a 12-foot maximum length.

Glasses structure is less friendly for the wavelengths of the visible spectrum. More visible photons fail to get through the lattice work. The gaps are not as well spaced as acrylic.

Therefore, transmission of light is all tied to the spin frequency of the photons. The visible light wavelengths need to match the lattice work gaps in the fiber's structure. The molecular structure, atom by atom, of the fiber needs to be smooth, straight and in long chains; so the light easily weaves through it. The fiber should to without manufacturing flaws, air bubbles, embedded inclusions or an irregular surface.

The material determines what photons travel through the fiber. But the fiber's quality is important too. Fibers that transmit with higher losses in visible light mean buying and installing more hardware to match footcandle levels.

What About Luminaire?

Once the photons are at the fiber's end, a fiber optic luminaire can be as crude as a cut crystal piece of glass with a hole for the fiber. Or it can be as complex as NoUVIR's luminaires with high-tech, double-surface reflectors designed for fiber, very advanced macro-micro lenses, azimuth-elevation first-surface quartz-overlaid mirrors and collets that lock to the fiber without glue. Or it can be a bar with fibers bonded into the bar. Or it can be a headless track as all the luminaires snap inside a small, enclosed rail.

Luminaires range between these extremes.

When photons exit the fiber's end, the spread is a ragged 72° cone. If the lamp has a beam that is not smooth, the fiber can be unevenly lit. This variance across the surface of the fiber producing a beam that has dim holes inside it, is not round, or has a pattern can also be caused by the fiber or the fiber's end.

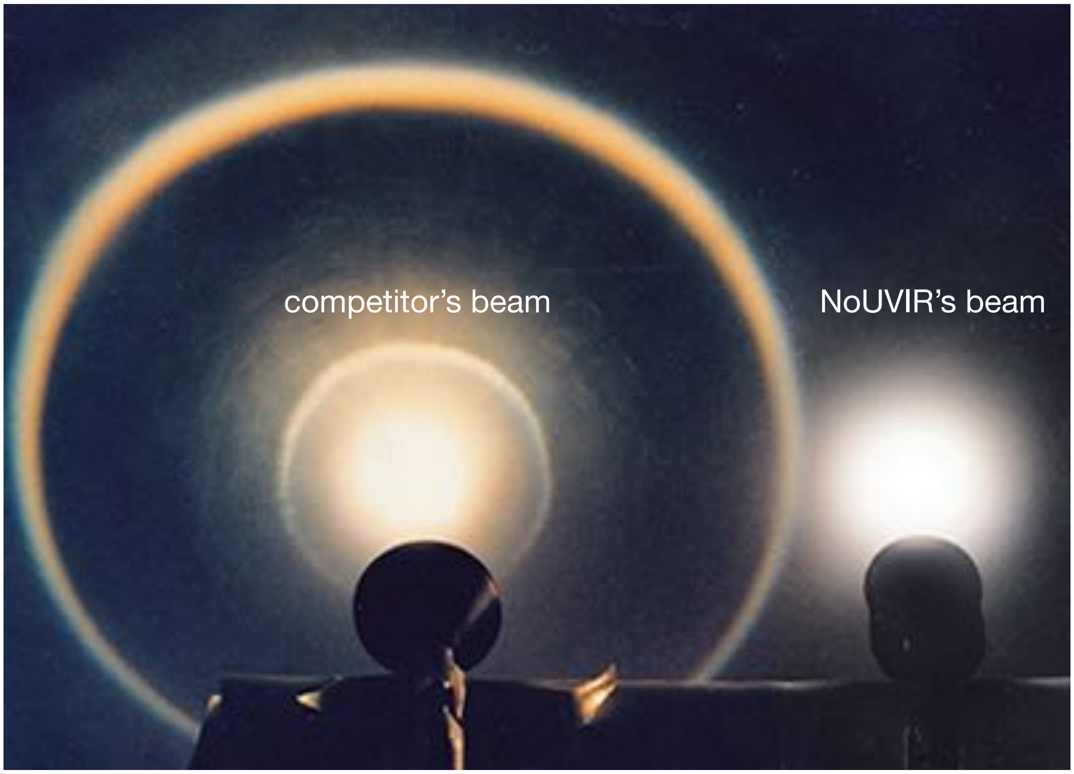
Each photon exits the crystal a little differently as the gravity of the last atoms in the molecules at the end of the fiber pull each the photon spinning out into air. The luminaire's job is to direct the light coming from the fiber.

If you want to make certain the 72° beam has a smooth edge with a soft, but definite cutoff; you add a reflector.

Reflectors in fiber optic lighting can be polar opposites in performance. There are companies that purchase reflector and housing parts made for wheat lamps, MR-11 lamps and even some flashlights. The parts are assembled to make a retrofit of a light light fixture designed for electricity to hold optical fiber. These fiber optic luminaire pick up some strange optical characteristics; because the design is for a filament. The beam tends to be uneven at the edges.

There are also manufacturers that use reflectors made of injection molded plastic. These reflectors are rarely coated with a metallic finish. The reason is the the reflector is short. It does not encounter enough photons to add footcandles. Instead the fiber optic luminaire's design leans on the lens. These lights can have several haloes and even chromatic aberration at the edge of the beam.

Lenses are the most common way to control fiber output. Lenses can be acrylic, styrene or glass. Since exacting dies are expensive, several manufacturers purchase lenses and re-purpose them to fiber optic lighting.



To judge performance, the clue as to the quality of luminaire design and application is found in the photometry. Sometimes further data is backed by photography of beams. But most of the time, fiber optic systems are shown lighting things and in installations. Rarely do manufacturers publish photos of a single beam to show beam quality.

How Do Luminaires Really Work?

In fiber optics, again, the output of the fiber is light. That light is made up of photons. Hopefully all those photons are visible. This means the wavelengths are from 380 nm to 770 nm.

Reflectors usually are made of metal or use metals as coatings. Metals are dense in their molecular structure. Polishing can physically persuade the atoms to tuck in and orient their electron rings in a general plain. This flatland is ideal for reflecting or gimbaling photons without absorbing them and sending the photons on their way in a different direction from the photon's entry into the material. The entrance angle is critical and the surface controls the exit of the photon.

Lenses work like fiber. A lens is a crystal substance with molecules, therefore, atoms, in chains with gaps for passing through photons. The surface atoms of both entry and exit can orbitally bend the photon. Fiber is designed to use these key atoms to kick the spinning photon back into the crystal structure and transmit the photon down the fiber. Lenses are designed to do a flight path course correction and swing the photon into a beam that travels through free space.

A color filter is designed to absorb some of the unwanted photons and let the predominant color (filter color) travel through without interference. The dyes or coatings absorb the opposite colors of the color of choice. Eventually these filters do wear out as photochemical damage fades them. They stop being as effective, because the molecules have dropped bonds and become smaller molecules and even different chemistry.

Applying the Science

In conclusion, enjoy the science. Atomic theory is the “crown jewel” of physics. We know a lot. But photons are still an even deeper puzzle. Are electrons and positrons singular particles or are they complex systems of even smaller particles? What happens to time when a photon tumbles and exceeds light speed? Are there materials that can even more tightly control electricity turned into photons?

But if you want, you can skip the quantum electrodynamics.

NoUVIR has already done the work.

Pick NoUVIR fiber optic lighting for superior performance. It is quantum electrodynamics in action. It is physics at the most challenging level. But it has taken the form of simple-to-use hardware. For most people, you turn it “on”, put in a polished fiber to the projector, add a luminaire on the other end…**and play.**