

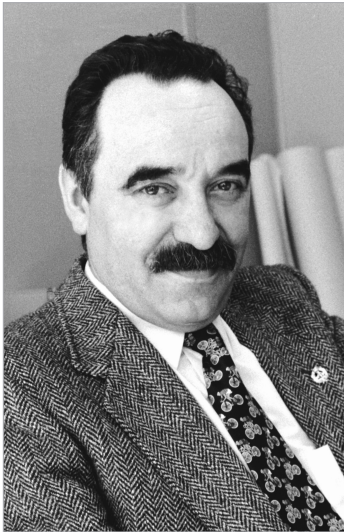
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ADVANCED

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FIBER OPTICS

100 QUESTIONS & ANSWERS



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Depósito Legal: B- 7731- 2000
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Panta Rei

I N T R O D U C T I O N

Fiber optics lighting is not a revolutionary or new technology, in essence is only about carrying light, from one point to another by means of a lens, more or less flexible and long.

The problem is the air of mysticism surrounding the industry*.

The result is a strange industry where it is difficult to know for sure the result of the system being installed and where disappointment, in part due to unfair hopes, is common.

The present work is a collection of the questions most often made by professionals during seminars, consulting, and projects over a quarter of a century. The questions are worded in a short straightforward manner and answered based on objective scientific criteria, without publicity, trademarks, or personal preferences, in an effort to help the general understanding of these systems.

Oslo, May 1.999

* Coupled with the speed of changes and the slippery nature of basic physics.

~~F I B E R S~~

1. What is a fiber optic?

Fiber optics are long lenses. A cylinder or rod of transparent material forming a core surrounded by an external cladding with a slightly different material. Light, when entering the fiber, rebounds on the outer cladding towards the core. This way the light advances through the fiber in bounds or steps, until it exits at the other end.

2. How many kinds of fibers are there?

In truth, there is only one fiber optic. The term "fiber optics" applies really to a branch of light physics dealing with the properties of certain materials that display a phenomenon called "total internal reflection", and not to an object. All optical elements such as lenses, prisms and rods use total internal reflection as a mechanism for light transportation. In the elements described as fiber optics light travels by virtue of this effect but it does so in a number of ways; monomode, multimode, step index, gradient index and so on. For lighting purposes or, to be more exact, to handle visible light, the standard type of fibers are the so-called multimode step index fibers. The use of the other types is confined exclusively to data or signal transmission.

3. What are fiber optics made off?

For lighting purposes or visible light spectrum transmission, several kinds of fibers are used. Glass in very fine strands that have to be bunched together in order to make a sizeable light carrier, PMMA, and polycarbonate in sizes from 0,25 to 3mm and solid core fibers made from special polymers in a Teflon sheath from 3mm to over one-inch thick. Other types of fibers such as liquid core, colored fibers, fluorescent, and scintillating are little used and for specialized applications.

4. Are there different qualities of fiber optics?

Definitely yes. The raw materials used in the manufacture of fibers may be similar in some instances but the process to make finished optics can vary greatly from one manufacturer to another. The greatest differences arise from the level of purity and refinement with which the raw materials are produced, the degree of impurities, contamination and the very technology of the process. Optical properties such as numerical aperture, attenuation and selective spectral absorption are widely different from one fiber to other. This means that some fibers may be suitable for one task and useless for others.

5. What is a light guide?

When a number of single fibers are grouped together to make a larger diameter light conductor the resulting structure is called a light guide. Sometimes large diameter solid core fibers are also termed light guide.

Light guides can come in many forms and finished, clad with a number of different polymers, articulated anaconda type flexible metal coverings, rigid tubes, heat shrink tubes, etc.

6. What are bare fibers?

The term is used mainly with PMMA fibers and refers to the optics that have no external protection sheath.

7. What are sheathed fibers?

The optics that have an external cladding whether opaque or transparent in order to afford a mechanical protection to the optics.

8. Is the sheath color important?

This is a particularly slippery subject and the cause of heated debate. Some scientists affirm that an opaque white or light colored cladding, especially in single core fibers improve, marginally, the transmission properties of the optics. Others say that this is nonsense. In any case, the difference if it exists, must surely be minimal.

9. What is a harness?

The term applied in the industry to describe a group of fibers or light guides, individually terminated and with a common end. Generally, each harness must have its own illuminator.

10. Do fibers have losses?

All things in the universe are inefficient. This means that when a measured amount of something enters a system, less comes out than originally went in. If you pour a liter of water into one end of a pipe, you will always get less than a liter out of the other end. If you apply a voltage to the extreme of one wire, no matter how you do it, you will get a lesser value at the other end.

Fiber optics are no exception, the light entering one end encounters all kinds of obstacles and flaws, resulting in losses; from 2 to 10% for every running meter.

11. Why do some fibers change the color of the light?

In fact, all fibers change the color of the light in one way or another. Due to the physical characteristics of the conductor some frequencies travel with less impediment than others and it is impossible to produce a fiber that would have the same attenuation on the whole of the visible spectrum. To expect a light conductor to transport millions of different wavelengths along with exactly the same attenuation in every one would be quite unreasonable.

Some fibers absorb a little more blue than red and less green than yellow and others just the opposite. Consequently, the hue and tone of the light varies from meter to meter, in some cases very apparently. This phenomenon is referred to as selective spectral absorption.

12. Is low attenuation a sign of good quality fiber?

Generally yes, but in lighting fiber optics the manufacturer's attenuation figures are frequently meaningless. (In order to be reasonable this is the only figure they can quote)

Attenuation is measured using a laser, a light emitting diode or a collimated light source. In all three cases the light used is monochromatic, meaning that only one wavelength or a very narrow set of wavelengths is used.

The figures issued by manufacturers, per example: 150dB/Km refer to that single wavelength and corresponding color which could be yellow or yellow/green. The same fiber may have an attenuation of 750dB/Km on the blue end of the spectrum and 400dB/Km on the red side.

To calculate the average attenuation for white light would involve firstly analyzing the light of the lamp in the illuminator to determine its composition that could vary enormously, even for two identical lamps. Then one would have to measure attenuation in all individual wavelengths taking into account the amount of each present on the lamp's emission. Finally, we would have to compute to obtain a result which would only hold true for that lamp/fiber combination.

To be honest a close average can be worked out with a few instruments but lamp deterioration due to aging, dust in the system and coloring of the common end due to solvent migration from the potting compounds, if used, soon make nonsense of averaged figures.

13. What are the advantages of glass fiber optics?

Glass fiber optics are very resilient and ideally suited for working in places where the actual conductor will be subject to extreme temperatures or/and radiation, are little affected by most solvents and oils and the spectral transmission is good.

14. And the disadvantages?

It must be borne in mind that the actual nature of the conductor, in lighting systems, represents only one of the elements responsible for system performance. Glass light guides are always sheathed in a polymer tube and the common end encapsulated with epoxy compounds.

The actual element in contact with the environment is the polymer tube. In fact, the characteristics of this element will, for all purposes, determine the resilience of the system. This little considered point makes nonsense of some critics of polymer fiber who complain of the plastic contents. The fact is that if we take a 2mm-polymer fiber and a glass fiber with the same optical diameter we will find out that the latter contains more plastic than the former. Naturally we are talking about a bare PMMA fiber, this is to say without cladding. PMMA fibers can be used bare, glass fibers cannot; must always be cladded. At the common end, the epoxy compounds make up to 17% of the total optical area to receive the light from the lamp. It is a well known fact that these potting adhesives behave erratically in the presence of high temperatures and steep radiation gradients, such as the ones present at the screen or focus of the lamp in the generator, light source or illuminator. This epoxy tends to age very quickly, darken, absorb more radiation, heat up and contribute to the premature failure or deterioration of the system. On the other hand, glass fibers are very brittle. Studies show that vibration affects adversely glass fibers up to the point where shatter may occur. If the external sheath or tube becomes also hard and lose flexibility because of environmental factors then the light guide becomes extremely fragile.

15. What are the advantages of polymer fiber optics?

The spectral transmission of PMMA fibers is difficult to improve upon, the quality of the light transmitted over distances longer than four or five meters is considerably better than the standard glass fibers. Cost is another factor; polymer fibers have a lower cost per optical area unit than glass, in part due to the easier manufacturing process. High quality PMMA systems rely on a fusion process to construct the common end, hence dispensing with the use of epoxy potting compounds. In all instances where the use of many fibers or light points is prescribed polymer systems are a much better option. Another point to bear in mind is the weight factor: glass fibers are heavier than polymer, a fact that may be critical in some applications, such as automotive and aircraft uses.

16. And the disadvantages?

The ends of polymer fibers cannot operate with high temperatures. Light sources or illuminators are needed with a screen temperature lower than 60°C. Although some polymers can work with 100°C and over, the fact is that these constant high temperatures cause changes on the polymer chains, especially at the common end. This results in a hardening and blushing or blooming of the material, causing a deterioration of the system. The use of very powerful and hot illuminators with polymer fibers, in most cases is sheer madness. Although there is very little data on polymer aging, some manufacturers offer a 20-year guarantee on their systems, which is more than adequate in most instances.

Radius of curvature is a delicate matter with large diameter solid core fibers and has to be handled with great care in order not to alter the internal architecture of the fibers, which will result in losses. Bare or unsheathed fibers are very delicate and the external cladding becomes rapidly damaged due to abrasions and scratches.

17. Can I light a house with fiber optics?

A house can be lit with anything, from candles and gas lamps to fiber optics. There is the question, however, of the efficiency of the system. One should never forget that a light source, such as an electric lamp, delivers its maximum output hanging free in mid air, and that anything added, such as a coffer, a louver or an optical system of lenses or reflectors diminishes the performance.

Truth is that in most cases light issuing from a lamp in a spherical fashion is of little use because we want the light pointing towards a given direction, in order to perform a task. Nevertheless, it is also true that anything around or in front of a lamp restricts light to the general output of the system.

With fiber optics, this is no exception. The lamp enclosed in the illuminator would give a greater quantity of light if taken out and hung from a ceiling than pushing the light through fibers.

There is a common misconception amongst the public that if we have a 100 Lm lamp in one place and we run ten fibers to different rooms we would have a 100 Lm light in each room. This sounds very much like the parable of the bread and the fishes and clashes with the laws of thermodynamics, as we know them.

If you have a 100 Lm lamp in a box and run ten fibers out, the total combined output of the fibers will always be considerably less than 100 Lm, now and in the future.

18. Are fiber optics efficient as a means to transport light?

The straight answer is no. If we take any other means of light re-direction or distribution we will find out that are far more efficient.

19. What can justify the use of fiber optics?

In the great majority of tasks, using traditional means, the amount of light used is far in excess to the quantity really needed. Most light goes to illuminate areas that do not need light at all.

With fiber optics, we can distribute minute quantities of light exactly where needed, an impossible feat with conventional lighting because light sources are too large.

The distinct possibilities to put the lamp within easy reach whilst the light is distributed in zones with difficult access is another advantage of fiber optics. The main reasons for the use of fiber optics in lighting are safety, control, miniaturization, cost and ease of maintenance.

20. Are fibers safe?

Fiber optics are passive elements, therefore do not use power to generate light, as is the case with lamps. As light conductors only carry light from one point to another, never electricity.

Fiber optics can be put under, or in direct contact with water, can be cut, handled, broken or hammered and can never be anything but totally safe lighting conductors, with the exception of power conversion.

Because standard lighting fiber optics have a very restricted transmission window most radiation which could be harmful to beings or things is not transmitted. In fact the amount of infrared and ultraviolet issuing from a fiber optic is, in most instances, negligible.

The use of fiber optics in the lighting of museum pieces or radiation sensitive material is one of the main applications of these light conductors.

There is, however, the phenomenon of power to light conversion on the extremes of the fibers: a very high temperature may be present, with the use of high powered illuminators, very close to the tip. If a light guide is cut, abraded or damaged in anyway along its length a very hot spot may ensue which can destroy the fiber and the surrounds. When using systems with high power densities additional precautions should be observed to maintain safety in the system.

21. Who makes fiber optics?

Glass manufacturers mainly make Glass fibers. Chemical companies fabricate PMMA fibers. Companies, both public and private, manufacture other types of fiber optics, especially solid core polymer and generally with their own proprietary process.

22. How are fiber optics made?

The actual process varies considerably from one manufacturer to another. In essence, a large cylinder of core is made off high purity material, an element called preform. The preform is later heated or treated and drawn into a filament, which is then coated with the external layer with a different refractive index.

Other systems include co-extrusion, continuous casting, direct co-polymerization, injection, wet drawing and soft extrusion with mercury formers.

These later techniques, and others under research, try to attain a better alignment of polymer chains in order to improve transmission and reduce attenuation. In fact, the fiber stretching and tensioning after drawing to promote molecular alignment is one of the industry secrets.

23. Are optical fibers fragile?

Glass fibers are very brittle, in fact in any glass light guide there is a percentage of fibers broken during the manufacturing process, on the other hand, because these light guides are sheathed, once installed are very resistant to external influences.

Bare PMMA fibers are extremely delicate during manufacture and manipulation, requiring great handling care. Once sheathed are practically impervious to external damage.

Other solid core fibers are very tough because of an external Teflon cladding and can be installed without any problem. The only drawback with this type of optics is the hardening with age, which makes these conductors brittle and prone to shatter.

24. Can fibers be bent at right angles?

No. All fibers must be bent with a radius, which will not alter the internal architecture of the fiber. For every type and size of fiber, there is a minimum radius of curvature, specified and recommended by the manufacturer. Bending fiber optics at right angles will cause the conductor to shatter in the case of glass, and be permanently damaged in all other types

25. Can lighting fiber optics be spliced or joined?

All fibers can be spliced with more or less success and difficulty. The problem is the losses resulting from such a joint.

Fiber splicing is a common practice in the telecommunications industry where is done with sophisticated alignment apparatus and a considerable dose of skill.

Nowadays there are splicing systems for polymer light guides using special fittings and a refraction index equalizing gel capable of low price splices with minimal losses. In glass fibers where one would have to individually splice hundreds or even thousands of single fibers, splicing is not resolved yet.

Solid core fibers can be joined with greater ease but the losses are massive; up to 25% of the available light.

26. Will light go any length along a fiber?

All conductors have losses, and in the case of fiber optics, these are sizeable.

Light losses in the industry average 2 to 5% per meter or over. If we start with, say 100 units of light at the common end we will lose 25% at the end of five meters and over 40% after ten. In fact, most systems have losses greater than 50% over a ten-meter length.

27. How many sizes are there of lighting fiber optics?

Literally hundreds, from a few microns to over an inch in diameter, solid core and multicore, square shaped, ribbons, tapes and sheet.

28. Can you put any amount of light into a fiber optic?

This is one of the standard fallacies of the industry. The system needed to put a sizeable amount of light into a fiber optic is very simple; a lamp, perhaps a lens and something to hold the fiber pointing at the light source. It follows that the bigger and more powerful the lamp the greater amount of light it will issue and the more light that will get into the fiber; at least this is the argument that most people think logical.

The problem is that optics is a subject far from simple. An optical fiber will accept a measure of light and no more, regardless of the power of the lamp: if a light source puts ten units of light through a fiber, another light source, twice as bright will not put double the light into the fiber.

There is one thing called power density acceptance which marks the limit to how much energy can circulate through a system, no matter how much more energy you try to force into it. A copper wire of a given thickness will be happy with five amps, get warm with ten, heat up with twenty and melt with forty.

29. Do fiber optics transmit radiation?

Light is a radiation; therefore, the answer is yes. Some fibers, depending on the nature of the materials from which they are made, transmit one band of radiation more or less wide or restricted.

Generally, the fibers used for lighting transmit little or no ultraviolet, a very small amount of infrared and variable quantities of the visible light frequencies.

Heat is a radiation on the infrared region and does not transmit well on standard lighting fibers. To put an example; the amount of heat that will build up inside a case with a volume of one cubic meter of air, is only one degree in 24 hours, from a 5mm diameter PMMA light guide powered by a 150W metal halide illuminator.

30. Glass or polymer?

There is not an easy answer because it will always depend on the final use and working conditions of the system.

Generally speaking glass fibers are better suited for those environments where high temperatures are constant and for data transmission. Glass fibers are very thin conductors only a few microns in diameter, therefore in order to construct a sizeable light conductor, hundreds or even thousands have to be bunched and sheathed together.

Bending radii are small and the performance is acceptable although glass fibers with comparable spectral characteristics to PMMA are considerably more expensive.

In essence both, glass and polymer systems have advantages and drawbacks, to be individually assessed in view of the actual application and working conditions. In recent times, however, there seems to be a general trend to abandon glass fiber optics in lighting applications in favor of PMMA.

31. Can fibers be made any size?

Theoretically, yes. There are, however, physical constraints because of the materials and utility. Very large fibers have proportional bending radii and are not very economical to produce. Under the all encompassing classification of Remote Source Lighting, tubes made from special polymers and behaving like fiber optics are currently being manufactured, capable of being formed into light conductors over a foot in diameter.

32. How long will fiber optics last?

In the case of glass practically indefinitely due to the inert characteristics of the material. This refers to the actual fiber, and not to the polymer cladding. Also the common ends being an encapsulation of epoxy's will behave less predictably and perform erratically, depending of many factors, such as temperature of operation and level of radiation exposure.

As far as polymer systems are concerned 20 years for the conductors is the standard guarantee in the industry. This also refers to the actual fiber, without reference to the common end whose average life depends on the same factors outlined before.

33. Can several fibers give the same amount of light?

No. If a number of fibers or light guides are coupled to the same illuminator, it is physically impossible that each receives the same amount of light and therefore transmit it. The spot or tack formed by a reflector lamp at the focus point or screen is not completely homogeneous, this is to say that it does not have the same quantity of light in each point of its surface. This problem is sometimes minimized by mixing the fibers at the common end (a process termed "randomizing") but it can never be made totally even.

34. What are side-emitting fibers?

There are no side-emitting fibers. All fiber optics receive the light at one end and transport it to the other. When light enters a fiber and travels through the core it encounters multitude of obstacles: microscopic cracks and fissures, impurities and other elements which obstruct the passage of some light and which, in turn, escapes through the outer cladding.

All fibers lose some light though the cladding because there are no perfect systems. This unavoidable effect is used to produce elements termed "side emitting fibers" which, in fact are normal fiber optics with a clear protective external cladding which permit to view the escaping light. In fact, some manufacturers induce stresses on the fibers, by means of torsion or bending to bruise the fibers and cause more light to escape along the way.

Some glass fibers are made side emitting, by the expedient method of cladding a bunch into a clear tube and breaking them at intervals. Clearly there comes a point along the tube when there are no more unbroken fibers to continue the process.

35. Are there different types of side emitting fibers?

Nowadays several types of side emitting fibers are marketed. The most common are:
Solid core optics
Multistranded optics
Multistranded roped/coiled and woven/knitted optics.

36. What are solid core fibers?

These optics are cylinders made of diverse polymers and encased on a transparent sheath or tube. As a standard are manufactured in different gauges or calibers from 3 to 25 or more millimeters in diameter.

37. What are multistranded optics?

Multistranded optics are narrow walled tubes of transparent material, housing a number of smaller solid core fibers. The inner fibers are, generally 0,75mm in diameter and numbered from ten or less to several hundred, depending on the final use and diameter of the optic.

38. What are coiled roped and woven/knitted optics?

Simply braided or woven ropes manufactured with thin solid core fiber optics, instead of hemp or nylon. Because of the strain produced on the individual fibers by means of the torsion, coiling or knitting, the fibers have greater losses along the length. This means that more light is available for side viewing purposes.

39. Solid core or multicore?

That will depend on the use to which the optic is put and the actual installation conditions. Solid core optics have generally, a larger bending radius to avoid important losses. Furthermore, because of the transparent quality of the core, unless the contrast with the background is adequate the appearance is that of inferior luminance.

Multicore optics, on the other hand, have a more flexible construction, especially in large diameters. Because of the reduced transparency of the optic, the luminance appears greater.

Solid core fibers can operate in some types with higher screen temperatures and can be connected (at least in theory) to generators that are more powerful without damage to the core. It must be said, however, that the long-term effects, especially those related to the power density of the systems, are as yet undetermined.

40. Can side emitting optics be as bright or brighter than neon?

Fiber optics can be made to be brighter than neon but only for very short distances. We can think of a garden hose as an example: making tiny holes along the hose can cause a sizeable amount of water gushing out of the holes nearer the tap, and for a distance that will depend on the size of the holes. If we make the holes larger a greater amount of water will issue, but only for a shorter distance until it only trickles. There is a limit to the quantity of water that can be made to pass through a hose, a limit given by the material of the pipe and the viscosity of water. We simply cannot increase pressure infinitely. The limit on the quantity of light traveling through a fiber optic is also imposed by physics: the actual material of which the optic is made and the intrinsic qualities of light. There is a power density limit to each material. In some systems, especially with late generation purpose made metal halide illuminators, luminance values greater or equal to that of neon may be obtained for lengths up to few meters. The sizeable cost of these systems when compared to neon makes the proposal impractical in most cases.

41. With all the limitations, what are the uses of side emitting optics?

There is a common misconception about the quantity of light needed for a given task: more light is not necessarily better, and often is worse than the right amount with the correct characteristics. In many instances, small quantities of light to demarcate, decorate or accent are much better than a glaring neon-like line.

A good example that comes to mind is the uses in theatres, cinemas and public buildings to line out corridors, aisles and emergency exits: in these instances the brightness of neon would simply not be acceptable. Coupled with the beauty of color change capabilities side emitting optics are a valuable tool in the hands of the designer for outlining buildings, both externally and internally, pools, spas, cornices, gardens, and all kinds of architectural details.

Another point not to be forgotten is the total safety of fiber optics. There is no electricity in them. This means that in all those instances where high voltage neon simply cannot be contemplated because of danger, maintenance or fragility; side-emitting fibers can be the only sensible alternative.

42. What are the design constraints to side emitting optics?

The actual illuminance of side emitting optics is low, although the luminance is quite acceptable in most cases. This means that if the contrast values are correctly applied the visibility of the optics can be excellent. The actual quantity of ambient illuminance, the colors of backgrounds, distance and line of vision are parameters to be carefully balanced, in order to obtain the best results.

43. Could the light along a side emitting optic be totally homogeneous?

Despite the assurances of some manufacturers, this is a total impossibility because it would clash with the laws of physics, as we know them.

In order for an optic to display the same illuminance along a given length, it would have to be perfect: with no losses.

As soon as light is produced by an emitter starts to decay, in a similar fashion that a bullet starts to lose speed from the moment it issues from the muzzle of a gun.

The light is not the same inch by inch in an optic as it leaves the optical port of the illuminator: the farthest from the light source, less light, due to the attenuation of the optic.

44. Will we always see a difference in brightness along an optic?

Not necessarily so. The human vision system appreciates illuminance grades in a logarithmic fashion and if the transition was smooth would be very difficult to actually notice the difference.

If we observe an optic of, say 30 meters, from one end to the other along the optic it would not matter in which end is situated the illuminator: we would see the optic homogeneously lit, although we know that it is not possible. If we were to look at the same optic sideways, from some distance, then we would notice the difference in luminance, because we could compare both ends.

The judicious use of illuminators, daisy chaining the optics, restricting the length of the fibers to that recommended by manufacturers, the control of the contrast and the angle of vision, are the tools needed for a successful installation.

45. Can light be made to move or chase along a side emitting optic?

With roped or braided multicore fiber and a special process at the common end optics can be made to chase in both directions and display multiple colors at the same time.

46. Are the side-emitting fibers with reflecting core more luminous?

To answer this question honestly is very much like trying to determine the sex of the angels.

If a side emitting light guide has a center reflecting core it would appear that it would issue more light omnidirectionally, this is to say: if the light guide was suspended in mid-air and viewed from any angle.

The problem with that argument is that those optics are, normally attached to a support and viewed from fixed angles. The opaque centerpiece, in this case, would impede the passage of light from behind the core and hence the optic would have less light available to the viewer.

Side-emitting light guides are sheathed in a transparent cover and the viewer, by transparency, has the benefit of the light escaping not only from the individual fibers placed directly in front of his line of vision but also from the ones behind.

If we take a glass tube filled with a colored liquid and light it up from one end, we could view the whole of the mass as a lit-up cylinder. If we then place a concentric opaque core, from a given direction we would have less vision of the cylinder mass. The same would hold true with any transparent cylinder.

To prove this argument is a practical impossibility since it would require two optics, with and without core of the same size and optical properties, placed exactly on the same spot in an illuminator. In my opinion, no matter the patents, the so-called center reflecting cores do not add more light to a guide and probably rests light to the viewer and the system as a whole.

47. Is there any way to improve side-emitting viewing?

A side emitting light guide is viewed optimally when the contrast between the optic and background is maximized. If the light guide is placed on a white track or against a tight opaque white back the light is more apparent.

This does not mean that the optic issues more light, only that the illuminance falling on the background improves the overall luminance of the optic.

I L L U M I N A T O R S

48. What is an illuminator?

An illuminator, light source or generator is a box with a lamp inside, pointing towards an opening where fiber optics are secured. Naturally, this is an over-simplification, although in reality a large number of the illuminators available in the industry are little more than this.

49. What makes a good illuminator?

Illuminators must perform three separate tasks with a degree of efficiency. Firstly must house a lamp and its power source, transformer, ballast, igniter and wiring in a correct and safe manner. Secondly, it must focus the light of the lamp in the most efficient way to ensure an adequate performance. Thirdly, it must create a suitable environment to guarantee the long life of the common end, this being the union with the fiber optics. With this last task in mind, an illuminator must be designed to minimize the thermal load on the screen by all possible means, filters, forced ventilation, air ducting and deflectors.

50. Is bigger better?

It is somehow surprising that manufacturers place great emphasis in the power consumption, stating that a machine is 50, 100 or 400 Watts, when in reality this has little bearing on the overall performance of the illuminator.

In the lighting industry, the performance of a lamp is measured in a number of ways, depending on the comparison standards. The accepted data regarding a lamp's virtues are, usually, efficiency and light output, although the single most important element is the burner size.

Efficiency, determined in Lm/W, states the amount of light that a lamp produces for each unit of energy used. Is very low on incandescent lamps, where most of the energy is transformed in heat and very high in fluorescent and some types of discharge lamps, such as low-pressure sodium. Unfortunately, neither of these last lamps can be used sensibly with fiber optics.

The amount of light that a lamp makes is a useful piece of information when we try to light up a warehouse or an office table but useless when used to project and concentrate light on a given point. In this case the screen of the illuminator or the fiber common end.

The actual quantity and directionality of light reaching the screen, having little to do with the power consumption of the machine, is the only measure of performance in an illuminator.

Many lamps, specially the latest arrivals, have much improved light outputs, better beam control and precision. Paradoxically a last generation 50W-halogen lamp with a dichroic reflector puts more light into a fiber than a 75W lamp with a similar construction and outdated technology.

51. How many types of illuminators are there?

Since there are no standards in the industry, the term "type" is slightly confusing. With regards to power usage, the lamp illuminators vary from as little as 5W to as much as a 1.000W and more. As far as the type of lamp, illuminators are divided into two families: those using incandescent lamps, generally halogen, and the ones equipped with gas discharge lamps. Illuminators can also be typed by use. Some are mainly used for lighting and others to produce effects such as animations, color change or twinkles and sparkles.

52. Halogen or gas discharge?

Again, it will depend on the use of the system. Gas discharge lamps, especially those with a very small plasma area are ideally suited for use with optical systems such as lenses or reflectors. Consequently, the quantity of light aimed in the right direction can be far superior to that of a halogen lamp. Lumen output of these lamps is, usually greater than their incandescent counterparts. Conventional means cannot be used to regulate the output of gas discharge lamps. This means that if regulation is required mechanical irises or complex high frequency oscillators have to be used. Halogen lamps are smaller, less costly, and need simpler power supplies but give less overall light. For lighting and side light applications, gas discharge is used universally, reserving the less powerful halogen light sources for effects and decoration. It must be said, however, that if the correct halogen lamp, with the right projection angle is used, excellent results can be obtained with small diameter harnesses.

53. Must all illuminators have forced ventilation?

Generally yes, the exception being those with a massive construction, which dissipate heat by radiation or transfer.

54. How noisy is an illuminator?

Very noisy, slightly so or totally silent, depending on the power source and the construction. Heat dissipation is something that has to be done by one of two means: radiation or ventilation. If radiation is the method chosen then the housing must have the mass and surface to ensure dissipation of the heat. In ventilated systems, the air is the agent for cooling and must be evacuated and renewed. The problem is that some light sources are so hot that would need an oversized housing to dissipate all the heat build up, clearly not a very practical solution. Silent illuminators use normally small halogen or gas discharge lamps, devoid of mechanical ventilation and relying on radiation to cool the housing and dissipate the heat. Generally, works well only if placed outdoors or in a volume where the ambient temperature is considerable lower than that of the housing. Forced air draught is used in most power illuminators and the noise can range from 20 or so dB to 70 or 80dB. Taking into account that noise in a forced air system is relative to duct size and air speed, in addition to ventilator speed, mounting, vibration and other related aspects is easy to suspect that design can vary the amount of noise that a illuminator produces. This can be brought down to a minimum that can only be further reduced by damping with noise suppression material.

55. Are certifications important?

That will depend on the type of certificate, what is certified and by who is granted. Many certifications refer to the inherent safety of a product, with regards to accidental electrical shock. In fact some certifications attest to the fact that the contraption will not kill you, but say nothing, or very little, as far as the performance of the product. The certificate on a washing machine says nothing to the effect that the thing will wash clothes; only that is unlikely that you will get an electrical shock.

Some other certifications refer to the performance, but unfortunately, these are not compulsory. In the fiber optics industry even these certificates are, very often meaningless because there is little or no control on the interface between illuminator and fiber. A laboratory report will say that a illuminator delivers so many screen lumens but cannot say how many will get into the fiber, because that will depend on a number of factors totally outside their scope.

56. Are machines with the CE mark certified?

The CE mark was a good idea in its inception but it has been so much abused that has become practically meaningless for the end user.

CE is not a certification or a quality mark, moreover is not granted by any official body or controlled in any way, distributors or end users have no right whatsoever to demand a CE certificate from the manufacturer, even if his products bear the stamp.

CE is a declaration from the manufacturer stating that the object complies with CE directives and regulations. Really is the equivalent to taking the words of a used car salesman as Gospel truth.

The market is awash with shoddy products of uncertain origin and parentage bearing the CE mark, products that, obviously, do not conform to any regulation whatsoever.

In a resume: the CE mark does not attest or imply any quality or fitness for use of the object bearing the stamp. It only says that the manufacturer declares that his product is built in accordance with the community directives, under his own responsibility and without effective control by an official body.

57. How then do I recognize a product's quality?

There are a number of ways. The name and status of the company making the product is important and its geographical location. Some countries are famous for making good quality products and others just the opposite.

The stamp of approval of an internationally recognized testing organization is a sure way of knowing that the product has been tested and found built to very high standards. Generally, such institutes or laboratories have follow-up programs that control the manufacturing and quality processes of the manufacturer.

It can be said, with a level of certainty, that a machine bearing one or several such stamps has a traceable pedigree and is well made.

58. What about ISO 9000?

Again there seems to be confusion about the ISO 9000 series of certifications. The ISO in essence is not a guarantee of good quality and is not given to an object but to a company.

ISO 9000 is, in lay terms, a system that removes anarchy from management or production, making sure that things are made always the same and with the same quality, which is not a mean feat.

It does not guarantee that the products are good but with a constant in quality. If a manufacturer makes a good gizmo or widget, the ISO 9000 certificate guarantee that it will always be good. For the same token if someone makes a bad product the ISO will ensure that is always bad. A combination of ISO 9000 and laboratory certificates on a product is the surest way to ascertain that an object, an illuminator in this case, is good and will remain so.

59. How does a color change works?

It consists generally of a small, geared motor with a disc. This can be made of glass, glass segments or a polymer material in a number of colors.

The motor causes the disc to revolve in from of the common end, altering the color of the issuing light. Lower priced systems use colored films or glass whilst most others make use of dichroic filters.

In animation illuminators instead of a disc, there is a turning drum of glass or polycarbonate with color films or varnishes applied in special patterns to create movement and rapid color changes.

60. What is a dichroic filter?

A thin flat piece of glass with a metal deposition in one of the surfaces applied in a high vacuum environment. The metal layer, only a few atoms thick causes interference in the incoming light, letting some frequencies pass whilst stopping others.

This frequency separation has the effect of producing very saturated and vibrant colors.

Depending on the deposition type, all visible light can be allowed to pass through, whilst stopping infrared or ultraviolet radiation. In fact, there is a dichroic or interference filter to separate practically all frequencies in the spectrum.

61. Are heat fuses necessary?

The working temperature range of the fiber optics common end is critical if the performance of the system is to be maintained and the life guaranteed. A heat fuse of thermostat must be installed in such a way as to disconnect the illuminator should there be a heat build up.

Heat can accumulate rapidly for a number of reasons: a failed fan, obstructions on the air passages or poor ventilation. A 50°C thermostat should be the most adequate.

It must be borne in mind that the ambience temperature in which illuminators must operate seldom allow more than 25°C, a very low temperature to maintain in most instances.

62. Can multiple illuminators change colors simultaneously?

Yes. Generally the standard disc rotating motors are of the synchronous type, very reliable, and geared to the most adequate speed. The problem is that, although individually these motors work fine, is difficult to make two or more act in perfect synchronization with each other without additional mechanical or electronic gear.

A simple micro switch and an adequate wiring can make any number of synchronous motors operate at the same time in perfect step.

Some manufacturers offer a variable speed synchronizer to control their illuminators with special motors, zero settings and electronic control gear.

63. Can illuminators be computer controlled?

Practically everything can be computer controlled and illuminators are not an exception. Color discs, lamp voltage and mechanical shutters, in the case of gas discharge lamps, can be programmed and controlled with a computer.

This is normally offered as an option on most illuminators, using step motors and DMX control.

64. What is DMX?

A communications protocol between an electronic circuit and step motors and actuators. A kind of language between elements so that different manufacturers can use compatible components which will work happily understanding the same data.

65. What are end terminations?

Again, we find ourselves in an area where a lot of confusion and controversy are the order of the day. Some American institutions have tried to set standards as to the correct terminology to be applied in fiber optics specification. The problem is that not every manufacturer is American and was not asked their opinion in the matter, hence many people use different names referring to the same part or component.

With Illuminators happens the same as with ends, one can see reflected in manufacturer's literature names such as: light engine, light source, generator, etc. All refers to the same box with lamp inside.

End terminations suffer the same fate: single end, fiber end, single termination, emitting end, tip, end, final, common end, bundle head, head, end ferrule, etc.

In order to set a common ground we will use the term single end and common end.

Terminations therefore are the extremes of a single fiber or a group of fibers.

66. What are single ends?

The extreme of the fiber optics conductor farthest from the illuminator. The bit that emits light or the end that lights up.

67. Are there many types of single ends?

Single ends can be anything from a simple cut with snips or a cutter to a sophisticated polished encapsulation. The actual technique used depends not only on the type of fiber but also on the application of the system.

68. Is the fiber end important?

As far as the actual light output the fiber termination has little influence on the overall light output. It is however, very important, when at the single end will be fixed some lens system. Imperfections, scratches, dig and fractures at the single end termination will show as darker patches on the resulting beam.

The mechanical connection between the single end and the finishing piece, being a board or housing is also dependent on the actual finish and precision of the single end. Ferrules, machined pieces and connectors have to be scrupulously free of adhesives and with even diameters, to ensure a precise fitting.

69. How are glass fibers ended?

Glass fibers are, generally potted or encapsulated at the single end with the help of an epoxy adhesive or compound. This results on a very hard element of fibers and adhesive that, when hardened, is suitable for cutting flush and polishing or buffing.

This encapsulation is generally enclosed on a hollow brass tube, rivet or machined piece, which then serves as a fixing, or positioning aid.

Glass fibers permit some sophisticated single end termination to support extreme temperatures or working conditions. Special potting adhesives can be used and ends processed to an operating temperature of 400°C, indicated for oven and burner sensors and controls. In these instances, special thermal bridges have to be built into the fiber to protect the conductor.

Other terminations can be in the shape of wafers, rings, blocks or lines for machine vision, instrument lighting, microscopy and other highly specialized lighting applications.

70. How are polymer fibers terminated?

PMMA fiber single ends can be of several types always depending on the nature of the conductor and the final application. A Simply cut fiber with cutters or snips is a standard for decorative, display and sign uses. The same type of encapsulation as for glass fibers can be used with multiple single conductors and for the same applications with the exception of high temperature work.

For most decorative and lighting uses PMMA fibers are considerably more user friendly than glass fibers. Very simple tools and little skill are, in most instances, sufficient to produce stunning results on site, without having to result to factory custom made and cut components which results in dramatic cost reductions.

PMMA fibers can also be polished to a mirror finish with buffing compounds and machines without encapsulation for single fibers. Common ends must always be fused together, without using adhesives. Some fiber manufacturers specifically render their guarantee void if adhesives of any kind are used at the common end. Fusion produces a solid block , which can the be polished to a very high optical finish.

71. How are solid core fibers terminated?

The very architecture of solid core fibers makes the precise termination a difficult operation, although it must be said that in most applications a precise end is academic.

Solid core fibers are considerably softer than PMMA or glass and hardness is a pre-condition for precise polishing. Additionally if an attempt is made to polishing, the compounds, (whether Cerium based or otherwise) are always in a wax or grease medium and seep in between the Teflon coating and the core, ruining the optic. Standard finishing techniques for the single ends dispense with polishing and resolve to cutting with special tools where the quality and sharpness of the blade determines the accuracy of the cut. Further polishing can be accomplished with thermal treatment but only in factory installations.

Research is under way to polish solid core fibers using very low temperatures or else with water jets and laser cutters with uncertain degree of success.

72. How are coiled, twisted or roped fibers terminated?

In general terms the same techniques as with PMMA apply, since these optics are no more than 0,75mm diameter PMMA fibers bunched together.

In the case of coiled optics the sheath and the internal core (if existing) has to be removed because of the different nature, melting point and physic characteristics with respect to the fibers.

Wherever possible both extremes of a sidelight light guide should be fused and glass polished.

73. What is a common end?

The fiber or fibers have to be connected to the illuminator. Especially in the case of a number of fibers, these have to be bunched together and held securely. The common end is the grouping, fusion or encapsulation where all of the fibers from a bundle come together and are cut flush and even, polished or prepared to connect to the illuminator port.

74. Is the common end important?

Although manufacturers place more attention on fibers and illuminators the common end is a vital piece for the correct operation of an optical fiber system.

A properly engineered common end must pack the fibers tightly without adhesives and be suitable for fine polishing.

Most failures on fiber optics are due to a bad common end design and construction.

The use of potting adhesives is the single cause most commonly found in harness failure, both in glass and PMMA systems and should be avoided at all costs since it only reduces the overall life expectancy of the system.

75. What makes a good common end?

The capacity to hold the fibers even and flush, lack of adhesives, optical polish and absence of packing losses.

76. How many types of common end are there?

Basically two: adhesive encapsulated and state of the art fused, although some manufactures dispense with both and simply fasten the fibers to the illuminator by means of a pressure gland.

77. What is a randomized common end?

When several light guides are bundled together into a single common end it becomes a physical impossibility to attain the same level of light in each light guide because the lamp emission is not totally even on the screen plane. In order to minimize the differences individual fibers are mixed or "randomized" so that each light guide gathers its light from different geometrical points within the screen. Light issuing from individual ends in a randomized system is considerably more even but not perfectly so.

In polymer fiber systems state of the art optical randomizers can achieve greater evenness with little loss.

78. What are end fittings?

Practically the only part of a fiber optic system that the public ever sees. End fittings are the elements for fixing, aiming, supporting and finishing the fiber ends.

79. How many types of end fittings are there?

Literally thousands for every thought or dreamed up application. From small bullet lenses to very large pavers, floor and pool lights. From simple rings and bezels to complex optical trains with several lenses, besides hundreds of custom designed elements for specific applications and uses.

80. Fittings or fixtures?

In the industry, these terms are used indistinctly and often together. Some manufacturers describe fittings as the fixing elements, such as connectors, ferrules, machined ends, tubular rivets and bezel rings, reserving the term fixtures for large elements, swivel rings, pool luminaries and the like. Other manufacturers use the term fitting to describe anything at the end of the fibers.

81. Who manufactures end fittings?

Every system manufacturer produces a range of end fittings designed to be used with their own fiber system.

82. Are end fittings standard?

As a whole no. Each system manufacturer favors a kind of termination for his fibers with pressure glands, threads, rivets or machined pieces as connectors for his own fittings. Due to the absolute lack of standards in the industry, it becomes impossible to use one manufacturer's fittings with the fibers of other.

83. What is an optical port?

In the fiber optics industry, optical port is the element that physically makes the connection or interface between the illuminator and the harness. In its simplest form, an optical port is made of male and female tubes fitting one inside the other with a retaining screw or other fastener. More sophisticated optical ports include filter holders and various devices to adjust, conform and cool the common end.

84. Are there different types of optical ports?

Optical ports can be divided in two types: potting and pressure. Potting optical ports are little more than a hollow tube into which the fibers are introduced and encapsulated with some adhesive, making a block to be later polished.

Pressure optical ports are more sophisticated and include seals to grip tightly, by means of a tool, the harness of fibers.

Glass fibers are always prepared in potting optical ports whilst solid core fibers use pressure optical ports. PMMA fibers can have the common end in either.

85. Who manufactures optical ports?

All system integrator produce a particular type of optical port to connect to their choice of illuminator.

86. Are optical ports compatible?

In general no. Illuminator manufacturers use a particular type of optical port to effect the connection with the common end. As a whole, the harness made by a given manufacturer will not fit into the illuminator made by another without retooling.

87. What is a fiber optics system?

The term comprises all the necessary elements to install a working unit.

88. What is a fiber optics systems integrator?

A fiber optics system integrator purchases the bulk fibers from a fiber optics manufacturer, and endeavor to manipulate, cut, polish, assemble, pack, produce and market a final product.

89. What is the difference between a fiber optics manufacturer and a fiber optics system manufacturer?

This is a question that would sound silly in other industries but not in this one. Many firms hint, or even affirm in their brochures and catalogues to be fiber optics manufacturers when this is simply not true. A Company that manufactures fiber optics is the one that transforms polymers, monomers or glass raw materials into rods and filaments, cladding those with other elements to, finally create bulk fiber optics.

One can readily see the difference between a glass manufacturer, a glass merchant and a window manufacturer. The first takes sand and melts it into glass the second stores and trades with glass and the third incorporates glass into his final product: a window.

If one looks at the giant chemical and glass corporations it's a fair bet that they are fiber optics manufacturers.

On the other hand, most fiber optics companies are System Integrators. This is to say that they do not make fibers, just like the window producer does not make glass.

90. Who are the best fiber optics manufacturers?

To single out a company would be grossly unfair because in this business the players are, generally, respected industrial corporations with impeccable quality reputations.

State of the art fiber optics cannot be made in a garage shed and huge investments have to be made in plant, equipment and human resources to produce optics of any kind.

The overall quality of fibers in the market is exceptionally high and it must be said that the failures and disasters that may have happened have had nothing to do with the quality of the fibers but with the handling and application of systems.

91. Who are the best systems integrators?

Being quite the opposite to fiber optics manufacturers, system producers are usually small companies. In this case size has the opposite effect on the final product because fiber optics system design require an inordinate amount of ingenuity, talent and technical expertise even for tiny projects. The fast responses, instant drawings, quotations and studies normally demanded are very hard to produce in a corporate environment.

Naturally, this means that some system integrators are little more than a one-man band and some operations are run on a shoestring with more enthusiasm than resources.

On the other hand many system integrators have very little know-how and soon get into trouble with the laws of physics.

Product certification, documentation, information and references are the easiest way to ascertain the professional reputation of a manufactures

In this industry when detailed and precise technical information is not forthcoming and things are shrouded in a veil of secrecy, it usually means that for the manufacturer the thing is also a mystery.

92. How many parts does a fiber optics system have?

Depending on the final use the most common parts to account for in a basic system are: illuminator, fiber bundle, bushing and end fittings. Additional fittings, fixtures, controlling units and power sources may be used harness, optical port.

93. Are fiber optics systems expensive?

To determine whether a system is expensive one would have to establish a comparison with an alternative, which in most cases does not exist.

To compare fiber optics with a standard off the shelf light fitting, lamp or system is an unfair rule of thumb because fiber optics are unique.

Fiber optics systems can carry minute or large amounts of light to, practically any place with precision, without heat or electricity and with the light source far away.

If the fiber optics system is to be used in applications where the above values were of no consequence then one would have to say that there is no need for it.

Fiber optics are not the universal solution to all lighting problems but a tool or a technique to be used in circumstances where other systems would be at a disadvantage or even totally inadequate.

If one compares a one point of conventional light fixture with a one-point fiber optics system then the price difference would weigh heavily in favor of the standard fixture. If we compare several fixtures and one fiber optics system with several light guides and one illuminator, taking into account the maintenance advantages and power savings, then one would have to concede that fiber optics are cheap.

94. Will fiber optics systems be cheaper in the future?

Lighting fiber optics is not a mass-market product and perhaps will never be. Even today most systems are, at least in part, hand crafted or produced in small batches of a few hundred units at most. Very few items are made in the thousands, with the exception of injected parts, which have a very low unit cost.

From a manufacturing point of view short series are very expensive to produce, since the cost advantages of bulk purchase and manufacturing are missing.

Fiber optics groups or harnesses could easily be mass-produced with very important savings, which would reduce unit costs drastically. The problem is that very seldom, harnesses are of the same size or have the same fiber composition. Consequently, they have to be hand tailored, practically one by one, which results on very high production costs.

Another reason for the high unit costs of systems is the technical backup that system manufacturers have to provide. Nearly all of the installations have to be individually assessed, studied and estimated in house, because of the lack of widespread technical expertise elsewhere. This means that expensive technical departments have to be kept in order to provide know-how on a daily basis.

95. Are fiber optics systems difficult to install?

Again, it becomes important to establish a fair comparison with other elements, in this case ordinary light fixtures.

Fiber optics systems, as a whole, are easier to install than electrical fittings.

Sometimes displays, panels, ceilings, effects or projects are made involving thousands or even hundreds of thousands of single optical fiber ends which, to be fair, are a challenge to install.

The problem in these cases is of sheer numbers, size and complexity. In any case to install a point of fiber optics is considerably easier than to install an electrical point.

96. What is a starry sky?

Probably one of the most beautiful lighting effects that can be created, which can be very simple or quite sophisticated.

In its simplest form, a starry sky effect is made with a number of small diameter fibers coupled to a large solid core, which delivers the light from the illuminator. This creates a number of static points of the same diameter, which can be quite effective if a little flat.

More elaborate systems use several fiber caliber's, from 0,25mm to 3mm diameter and run directly to the illuminator. The several sizes of fiber make for different intensities on the point light, giving the effect of distance and perspective creating great depth. Coupled with a twinkle effect wheel the effect can be quite stunning.

97. What is an effect wheel?

A disc of metal or polycarbonate revolving between the lamp and the common end with holes, slits, colors or patterns.

98. What is an animation harness?

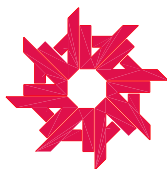
A group of fiber optics arranged in a sequential fashion and numbered. The fibers are then installed in the same order and, with the help of special illuminators, movement can be added to lines or patterns.

99. What are spatial effects?

Representations of comets, nebulas, shooting stars and others, made with often thousands of individual fibers and animation illuminator.

100. How would you describe in one word fiber optics lighting systems?

Magic



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