Fibre Optic Lighting

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In common with many technological developments in lighting the use of Fibre Optic as a lighting tool has been fuelled by research and developments in other fields, in this instance rapid development in the use of Fibre Optics for Control and Communications in recent years.

From early use in medical instruments including endoscopes, Fibre Optics came into more general use in lighting in the late 1970s when a principal new application was in traffic signs. In this application the facility of a remote light source, simple optical changeover in case of lamp failure and the possibility of multiple graphics in the same sign by using different patterns of harness gave this technology unique advantages. From these beginnings many applications have developed, initially the visible end of the fibre was the useful element, for example advertising signs and theatre star curtains, where the relative simplicity of limited animation provided a new dimension. From these early applications improving lamp technologies have led to the use of optical fibre as a light delivery system for everything from museum display cases to pub ceilings.

The rapid development and heavy marketing of Fibre Optics has led to the common impression that Fibre Optics can provide solutions to almost any tricky lighting problem, however this is not the case! The decision to use fibre optic light delivery systems in a project must be led by a clear understanding of the abilities and shortcomings of the technology. There are many situations where Fibre Optics may be considered as a solution, for example, museum showcases particular;ly where extremely light sensitive objects are to be displayed, also areas where it is impossible to accommodate the volume of a light fitting. Where access is so difficult that removing the lamp to somewhere else enables reasonable maintenance and where temperature control is critical are similarly situations where Fibre Optic Solutions should be considered however it is essential to make a comparison with other means of lighting to be sure that you have selected the correct solution.

The basic operating principals: light from the light source travels in a series of internal reflections along the length of each individual fibre to the end of the tail, where it is emitted directly, or through a lens to gather and focus the light into a beam. Only light entering the fibre end at a specific, narrow range of angles will be reflected along the fibre, light falling on the common end at other angles will either be lost in the common end or reflected from it. Here is the first problem with the design of fibre optic systems, very accurate optics are required to pass light from a lamp effectively into a fibre, there is inevitably a huge waste of light from the lamp which is either not gathered by the optics, or lost from the common end of the harness. It is equally inevitable that the light distribution across the common end will vary resulting in different tails within the same harness having markedly different light output though this effect can be mitigated by use of a randomised harness. The efficiency of transmission from lamp to harness is the reason that not all light sources are equally effective which has produced some interesting comparative results, some 50 W Tungsten Halogen (TH) sources providing more light than some early 150 W metal halide units! Essentially remember that a substantially greater lumen package is required for a given lighting task when using Fibre Optic systems, this effectively translates into a loss of energy efficiency. Fibre Optic systems subdivide the output from a lamp into many small portions which can be a positive benefit in situations where low light levels are required.

Along the length of the fibre run there are also light losses caused by several factors. Firstly the process of internal reflection is not totally efficient as it depends on the difference between the refractive indices of the materials that make up the core and sheath of the fibre. When the fibre forms bends there are further problems of fibre breakage. These are exacerbated by rough handling during installation or subsequent impact and pressure damage, particularly with glass fibre which is a fragile medium!

Finally it must be remembered that fibre is not totally transparent and it also does not transmit all colours equally. Losses along the length of fibre are usually expressed in Decibels this is an exponential measure which expresses the fact that losses and shifts increase far more rapidly than the length of the fibre. As fibre runs get longer colour shift becomes increasingly apparent, it is similar to the green edge seen on sheet glass which seems clear when you look through the face of the sheet. Fibre differs from batch to batch as manufacturers get different qualities of raw material and the fibre extruding machines can run out of the precise tolerances required. When two differing harnesses are adjacent this kind of variation can become extremely visually disconcerting.

Plastics are also used and in general suffer from the same shortcomings as glass fibres with some additional disadvantages, plastic is less transparent and the internal reflection is less efficient. This does render plastic harnesses extremely suitable for applications where light leakage along the length of the fibre is the desired effect such as a replacement for cold cathode lighting in signage or to outline and define edges on buildings.

Below are some specific applications where the advantages of Fibre optic solutions can outweigh the disadvantages outlined so far.

Museum Cases: this is a significant application for fibre optic lighting as it offers some distinct advantages over the direct use of lamps. Glass effectively filters out almost all the damaging Ultra Violet (UV) wavelength and can significantly attenuate Infra Red (IR) energy and therefore reduces heat input to the case, however care has to be taken to ensure the fibre supplied works like this as many communication applications require IR transmission and reject communications fibre has on occasions found its way onto lighting projects. The fundamental idea of breaking a single light source down into many elements is also of use in the museum case where lighting levels in the range of 50 to 200 lux are required at extremely short throws, often less than 600 mm. In this situation fibre is a very useful tool given that a discrete light source, even a 20 W low voltage lamp, is likely to give many hundreds of lux at that distance.

When designing for museum cases care has to be taken to ensure that appropriate lamps are used, only TH can realistically achieve acceptable colour rendering and only providing harness lengths are minimised. Light sources need to be thermally isolated from the case, placing them below the floor of the case can result in significant heat transfer into the body of the case unless precautions are taken to prevent this. Fibre bundles require a lot of space not just to run but also to turn. Tails and associated lens units require facilities to lock them in position as the sheath material around the bundle will resist bending and requires restraint. There should also be provision to insert lenses, filters, diffusers etc. at the output end of the fibre to fine tune lighting to specific levels and objects. Fibre optics give a large number of directional sources which can be useful in providing selective highlighting but need to be carefully set up to avoid confusing multiple shadows. When large areas such as textile panels or graphic walls require even illumination, careful consideration is necessary to achieve good results.

General Lighting: This has recently become possible with developments in lamps and light sources which allow large quantities of light to be transmitted through a fibre system. Limitations exist however. Significant space is necessary to pass the large diameter bundles that are required to deliver useful amounts of light and a large swept volume is required to accommodate the final turn of the fibre so this is not necessarily a solution for restricted spaces. Some suppliers are selling þdichroic reflector ú fittings to replace MR16 low voltage lamps. This provides a supposed reduced maintenance bonus, however they do not provide the same beam control as a low voltage lamp so will not provide an equal lighting performance. The facility of replacing a single lamp instead of many has the equal problem of a single lamp failure causing a larger loss of lighting in the space. In general considerable care has to be taken in considering Fibre Optics as a general lighting solution as it can bring as many problems as it resolves.

Exterior Lighting: Fibre Optics offer benefits on maintenance and weather resistance and are uniquely suited to some applications such as outlining buildings with potential for colour changing. Care is required to ensure that the materials used are not only weather proof but able to withstand the high UV levels of daylight. Water features and swimming pools are also a good potential use of fibre from the maintenance and safety standpoints as electricity can be kept separate from water, here the main problem is ensuring sufficient light is delivered to the water feature. Minimising the length of harnesses is a key goal in designing systems to deliver light rather than create directly visible glowing effects with little useful light output.

Effects lighting: A simulated starry sky of fibre optics which maybe an architectural cliche remains a good application for the technology as the actual light level required at the fibre end does not have to be exceptionally high for the effect to work. Similar uses include defining nodes and grids on structures and planes, graphic effects based on points of light, route marking and anything else where the apparent source is the key element are potentially successful applications. Control and colour changing for Fibre Optics is relatively simple as this can all be done in one place, at the light source. The development of digitally controlled effects using the common DMX protocol allows a high degree of coordination and potential for expressive moves and changes over large areas.

Project Considerations: Given the problems and potential short comings of Fibre Optics how do lighting designers ensure successful working solutions for projects? In the UK much of continental Europe, the majority of Fibre Optic supply comes through specialist companies who act as distributors for fibre manufacturers and frequently supply their own, proprietary, light sources and lens elements. Frequently Museum Case manufacturers will supply Fibre Optic systems as an integral element of their cases. Given this market structure it is necessary to provide detailed performance specifications for fibre systems to provide assurance that the project requirements are clearly defined and can be enforced in contract. It also allows an element of competition to be developed between different suppliers.

This performance specification must identify the intended use of the system and include necessary technical information derived from manufacturers specifications. It is of prime importance to provide a quantitative specification for the required light levels and sufficient information about the installation provided, to allow the supplier to accurately asses the requirements for the system. It is also important to define the light source requirements including colour rendering, colour temperature, requirement for control and colour change etc. specifically include or exclude lamp types that you know to be appropriate or inappropriate for the project.

Prior to specification it is necessary to have sufficient knowledge to determine the appropriate materials and approximate size of fibre required for a harness suitable for the proposed task. Some of this may be gained through experience, otherwise discussing the proposal with technically competent suppliers should provide guidance. Detail will also be required for the end of the tail, this may be a simple hidden fixing or a complex lensed fitting with provision for filters, beam control and lock off. As fibre optic solutions are normally sought for unusual or difficult situations it is very common that unique details are required to achieve a satisfactory solution so do not necessarily expect that there is an existing detail or fitting that will meet all the design criteria, ensure that the specification is complete enough to design a new fitting for the application if necessary.

Finally it is necessary to determine the installer of the Fibre Optic system. If this is not to be part of a specialist subcontract it is important to include for training of installers who are likely to be unfamiliar with the special nature of the materials and equipment. Treating glass fibres in the same fashion as cable will inevitably result in a high proportion of damaged fibre and poor system performance.

In order to fully and completely assess suppliers proposals it is necessary to examine an existing identical installation or an accurate mock up of the proposal to ensure that it will perform as required, assessing individual elements such as the light source or lens unit in isolation rarely conveys how the entire system will perform when installed.

In conclusion, Fibre Optic Technology is coming of age as a useful tool in the lighting designerÿs kit. With knowledge and consideration in the design and specification and a quality product installed correctly, Fibre Optics can achieve some otherwise apparently impossible lighting results. It is not a universal solution for all our design problems and reliance on suppliers selected on cheapest price basis to provide solutions for complex problems with minimal guidance from lighting designers can result in unsuccessful installations.

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Glossary of Fibre Optic Terms:

Fibre : single strand of glass or plastic drawn from a rod and tube of material with significantly differing refractive index

Bundle: a collection of fibres brought together within a sheath of protective material to create a single light guide

Harness: a group of bundles brought together and fed from a single light source or port

Tail: Output end of a single bundle in a harness

Common End: The collected ends of bundles in a harness brought together at the light source

Light source: lamp holder and optical elements which may include effects or colour changer that feed light into a harness

Randomised: a harness where the individual fibres within the bundles are evenly distributed across the common end. This is required where significant difference of light output between different tails is unacceptable