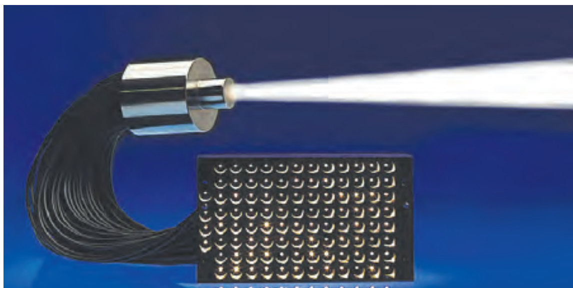
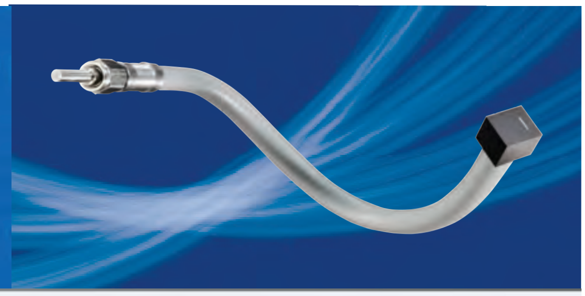
tec5 USA

Technology for Spectroscopy





Light Guide Overview

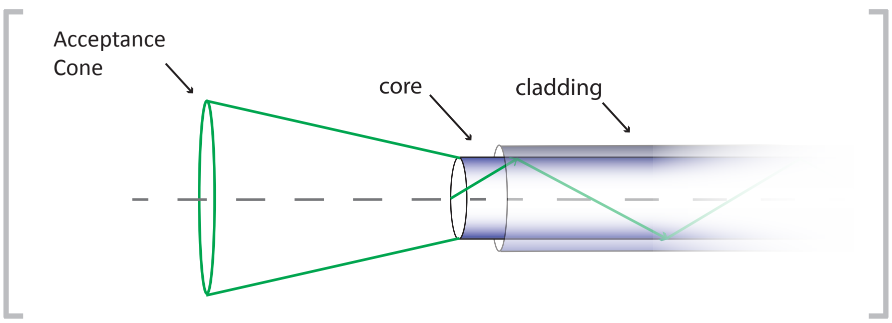
Fiber-Optic Basics

Light guides are an important component in optimizing an optical system as they connect the various functional units such as the light source to a probe or a probe to the spectrometer. Understanding the design and manufacturing of light guides is an important step in creating a high performance optical system. A wide variety of light-guiding components can be created, and the selection of the materials and arrangements define the functionality and performance.

tec5USA offers a wide variety of solutions to guide and distribute light. We work closely with our customers to optimize all fiber-optic components to best suit their application. This brochure gives an overview of the key components and expertise that we offer.

Background

Transparent fibers, rods and other light-guiding media, work on the principle of total internal reflection. The core of a fiber-optic light guide consists of an optically transparent material that is surrounded by air, a mirror, or a media similar to the core but with a lower index of refraction (cladding). The light bounces off the cladding's internal boundaries if the angle of incidence is greater than the critical angle. The critical angle is determined by the difference in the refractive indices of the core and cladding. This critical angle limits the acceptance angle, the Numerical Aperture, of the incoming light.



Numerical Aperture

The numerical aperture is the cone of acceptance, where above a critical angle (α_c) light cannot enter the fiber. The critical angle is defined as:

$$NA = n_{air} \cdot \sin\alpha_c = \sqrt{n^2_{core} - n^2_{cladding}}$$

Typical NA:
- 0.11
- 0.22
- 0.37

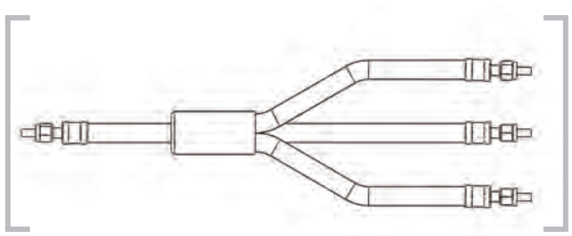
Others upon request

Fiber-Optic Cables

Fiber-optic cables are made up of thin, optically transparent fibers. The fiber is coated to improve the stability due the brittleness of bare fibers. To reduce the external stress on the fiber(s), a sheathing encases the fiber(s). Finally, terminations are added.

Arrangements: Functionality

A fiber-optic cable can be manufactured in a variety of layouts. The simplest design is a light-guide extension consisting of a single fiber with sheathing and connectors at each end. Fibers of various thicknesses can be selected to match the demand. A multitude of fibers can be bundled to form a light guide with a larger effective area. Different diameters and materials can be used for the individual fibers within the bundle. A bundle can be split into two or more arms to create a bifurcated or multi-furcated light guide. The splitting allows a fiber-optic cable to distribute light to different positions.



Layout:
- Extension
- Multifurcation

Flexibility: Diameter

Fibers must have an overall diameter of less than 1 mm to be flexible. A thinner diameter allows a smaller bending radius, which increases the flexibility of the overall fiber. However, tight bending of the fiber can cause light leakage and further tightening can cause cracks to occur. Fibers with diameters larger than 1 mm are stiff and classified as rods.

Typical Diameters (in μm):

80	400
105	500
120	800
200	1000

Others upon request

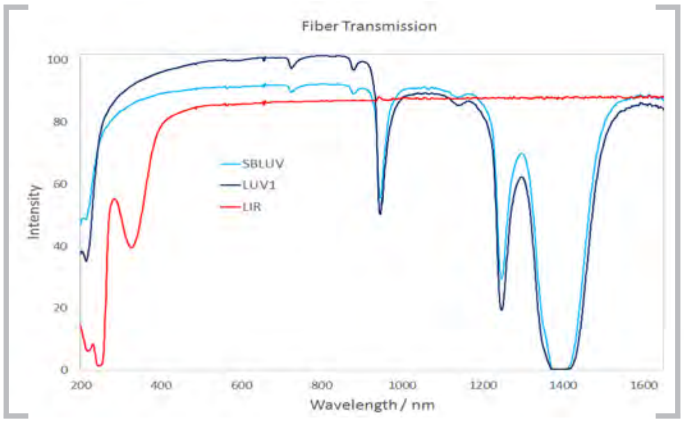
The total fiber diameter is mainly given by the core and cladding, while the coating only adds a few extra microns. Typical core cladding ratios are 1.05-to-1 for UV-VIS and 1.1-to-1 for UV-NIR fibers. NIR fibers have a higher cladding thickness to prevent light from penetrating the outer coating.

Fiber-Optic Cables

Materials: Optical Transmission

The core is generally made from a high grade optical material. Available materials include glass, high quality quartz, and plastics.

Most of our light guides are made out of quartz. Suprasil is used for the UV-VIS range (240 to 960 nm). To avoid absorption in the NIR, quartz with a low-OH content (Infrasil) is used (350 to 2200 nm). For transmission deeper in the UV, the Suprasil is specially treated to reduce the creation of absorption centers in the deep UV. This solarization stabilization allows a transmission range from 200 to 960 nm.



Materials
- Glass
- Plastic
- Quartz

Others upon request

Terminations: Connectors

To allow an easy link to other optical parts, fiber-optic elements are terminated by connectors that are cemented to the ends and then polished. The most common termination is the SMA-905, while an FC and ST connectors provide higher reproducibility. A ferrule offers high flexibility and the option to easily adjust the connection along the optical axis. It can also be angled to create a bent ferrule to fit into tight spaces or avoid addtional optical elements. One specialty of tec5USA are customized terminations to match the demand of the user.

Typical Terminations:
- SMA-905
- FC
- Ferrule

Others upon request

Protection: Jackets

The fragile fibers are inserted into a jacket to provide protection. A multitude of sheathing tubing is available. Our standard is SA quality, which combines an interlocking metal spiral spring covered by a rubber sleeve for high flexibility and protection against pulling forces.

Jackets:
- Silicone
- Polyamide
- PVC

Others upon request

Specialties

Coatings & Cementing: Temperature Stability

The temperature stability is generally limited by the coating and cement as quartz has a very high melting point (~1700°C). The coating is a layer of plastic over the bare fiber (core/cladding) that helps overcome the brittleness and makes the overall light guide more flexible. The other limiting factor is the cementing used to mount the connectors to the fibers. For high temperature (>350°C) applications, the coating is stripped and the fiber is mounted into a tube for mechanical support.

Coatings:
- Acrylate (-40° to 85°C)
- Silicone (-40° to 150°C)
- High Temp Acrylate (-40° to 20°C)
- Polyimide (-190° to 385°C)

Others upon request

Cross-Section Converters

Standard fiber inputs have a circular cross-section, or effective area, as an interface. If a bundle is used, then the area can be arranged in different configurations. One common example are circular-to-linear converters that takes the circular input and converts it into a linear, slit-shaped output. This configuration change is often applied to spectrometers to increase the throughput.

Rods & Cones

Rods and cylinders are formed from thick fibers with diameters greater than 1 mm. Rods of almost any diameter can be created and used as functional parts such as homogenizers. Since the thickness reduces the fragility of thinner fibers, the heat-sensitive coating is no longer required, and the fiber-optic element can direct light into extreme environments. The diameter of a rod can be customized.

A cone is created when a rod is tapered so that the cross-sectional interface area is different at the two ends. With the changing diameter, the numerical aperture varies as thinner diameters have larger acceptance angles. Cones can be used for applications such as endoscopes.

Vacuum

Light guides in vacuum environments require certain specifications so that outgassing is avoided. Therefore, special cements and jackets are used to avoid this process. The rubber armor is not included, and the metal coil allows the air molecules to pass through so that all air can be removed from the fiber harness.

Flanges & Feed-through

To pass from normal pressure areas into vacuum, the light guide is fed through the vacuum chamber wall via flanges. There are two principle ways to guide light through such a flange: a feed-through or via potting.

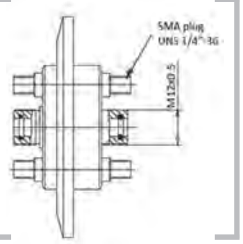
Ratings:
- Pressure: Up to 10^8 Torr
- Temperature: Up to 150°C

With the bulkhead design, a short rod is inserted inside the flange and between two connectors that mount light guides inside and outside the chamber. This part is called a feed-through.

Characteristics:
- Stainless Steel
- Integrated Rods, various diameters
- SMA termination, others upon request

To avoid the losses generated by the two optical interfaces from a feed-through, a light guide can be potted directly into a flange.

Multiple fibers can be fed through a single flange depending on its size.

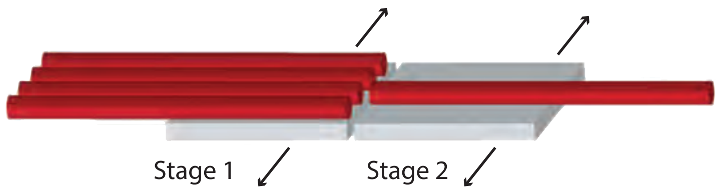


Flange Types:
- CF
- KF

Others upon request

Fiber Optic Switches

A switch moves the ends of the fibers matching it with other fibers allowing a user to direct light into different channels. A common setup includes a single arm that switches between several other arms, or channels.



A basic sketch of an optical multimode switch 1x4

The elements are made from high-precision ceramic parts to achieve high accuracy and reproducibility. These parts are moved by piezo-electric elements to guarantee fast and reliable positioning.

For fibers with diameters greater than 800 μm, imaging mirrors are used to direct light between the individual fibers. The numerical aperture is limited by the mirror diameter and image quality.

Fiber-optic switches easily connect with detector-array spectrometers so that a high number of input channels can be implemented.

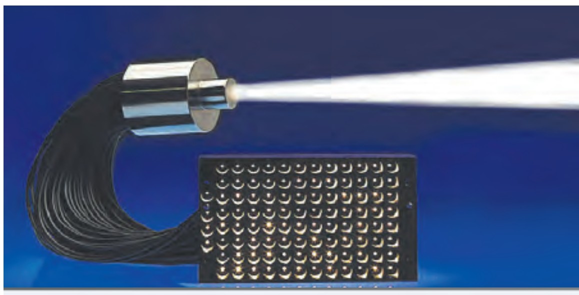
Switches are integrated into compact housings to protect the fiber arms. However, they can be supplied as components with free-ranging fibers if there are restrictive space requirements.

Characteristics:

- Up to 32 channels
- Up to 600 μm fibers
- High reproducibility
- High optical isolation
- Low insertion loss
- Lifetime: 10^8 switches

Interfaces:

- RS-232
- USB
- Parallel (TTL)
- I^2C



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