

# Industrial fiber optic components and LED solutions

Lighting, Sensing, Imaging

**SCHOTT**  
glass made of ideas





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# Creative new solutions

## Generations of know-how as clear as glass

For more than 40 years, SCHOTT has developed fiber optic products for a diverse range of applications. Our name stands for high quality and innovative solutions in the field of fiber optic lighting, sensing and imaging.

The Fiber Optics Business Segment offers high-tech solutions in markets such as automotive, lighting, medical, industrial and defense.

By mastering glass, fibers and processes for the production of fiber optic components, we develop outstanding, market-oriented products. With our leading technological know-how and innovative ideas we contribute to the success of our customers – around the world, around the clock.

## We work in partnership with you to develop new products:

New fiber optic components for widely differing industrial applications are the outcome of very close cooperation with our customers. Customer ideas generated from knowledge of their product and their industry coupled with SCHOTT's fiber optic know-how result in new products with clear benefits to the market.

We will continue to carry out further research and development in the future to continuously improve our products. We can be your single source fiber optic specialist to support development stages from basic research and prototyping to mass production with competent quality, creativity and support. The earlier we are involved in your project, the more effectively we can help to develop optimum solutions for your special requirement.

We are continuously striving to develop new technologies: latest developments include LEDs (Light Emitting Diodes) for illumination components.



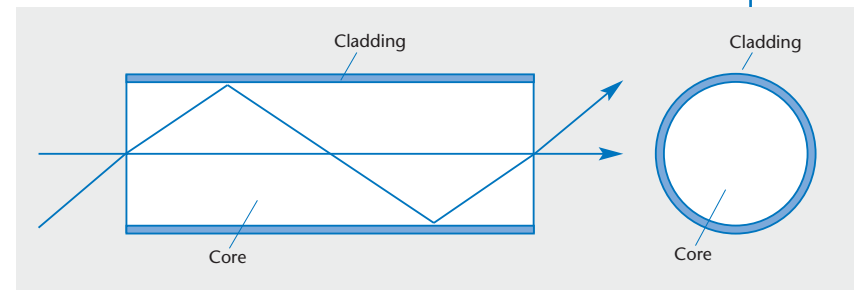
# A highway for light

## The physical principles and properties of optical fibers

Optical fibers are the heart of all fiber optic components. Every optical fiber consists of a core with a high refractive index and a cladding with a low refractive index. Light rays which enter the fiber at one end are guided along the core by total internal reflection at the core/cladding interface. The light rays follow the bends in the fiber and exit the fiber at its other end.

The three most important characteristics of an individual fiber are its:

- Diameter
- Numerical Aperture
- Spectral transmission



The principle of light transmission in an optical fiber

### Diameter

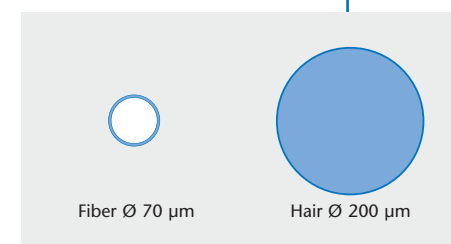
To ensure total internal reflection, the fiber cladding must have a minimum thickness of 2  $\mu\text{m}$  for the visible range of the spectrum. An improvement in the optical efficiency can be achieved by increasing the diameter of the fiber without increasing the thickness of the cladding. This, however, results in a loss of mechanical flexibility. For the majority of applications an optimum relationship between transmission and flexibility is achieved with a fiber diameter between 50 and 70  $\mu\text{m}$ .

### Numerical Aperture

The numerical aperture of an optical fiber depends on the refractive indices of the two types of glass used for the core and the cladding.

The equation:  $NA = n_0 \cdot \sin \alpha_0 = \sqrt{n_1^2 - n_2^2}$  applies to light rays which intersect the optical axis of a fiber. For simplicity it can be used for a light guide where:

- $n_0$  = Refractive index of the surrounding medium
- $n_1$  = Refractive index of the fiber core
- $n_2$  = Refractive index of the fiber cladding
- $\alpha_0$  = Critical angle to the optical axis.



All light rays which strike the perpendicular polished end face of the light guide at an angle of  $\alpha \leq \alpha_0$  are transmitted along the fiber. This results in the fact, that the amount of light which can be transmitted through a fiber is proportional to the  $NA^2$ .

### Spectral fiber transmission

As light is transmitted through a fiber its intensity decreases. The relationship between the input intensity and the output intensity defines the spectral transmission  $T(\lambda)$ . The spectral transmission depends on three factors:

- Absorption losses in core glasses. These losses are mainly caused by unavoidable traces of coloring metal oxides. Rayleigh light scattering results from a natural density fluctuation in the glass melt. These losses are proportional to the length of the light guide.
- Losses resulting from less than ideal total reflection at the core/cladding interface depend greatly on the angle at which the light enters the fiber, also impacting the total number of reflections accumulated over the whole length of the fiber. The greater the number of reflections, the higher the loss.
- Fresnel reflection losses – at the input and output surface – amount to approximately 11% combined.

### Transmission of fiber bundles

In addition to the transmission of each individual fiber, the transmission of fiber bundles is influenced by another factor. As a result of round fibers being bundled together, interstitial gaps exist between the fibers. These gaps – usually filled with epoxy material – do not transmit light as well as the glass cladding.

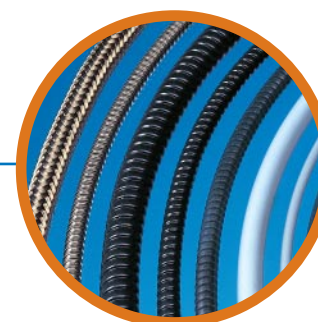
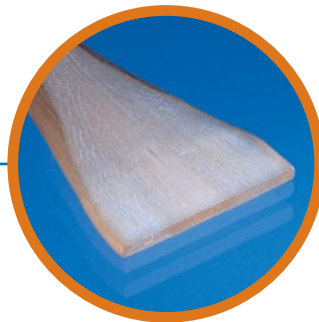
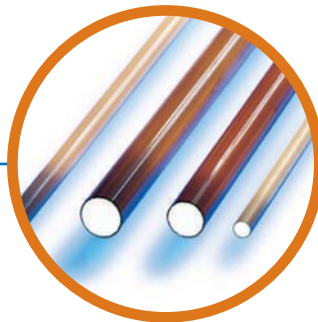
The total amount of light which can be transmitted through a single fiber is the result of length dependent transmission, numerical aperture and active fiber core area. The spectral transmission of a bundled fibers is essentially determined by the type and quality of glass used for the core and cladding, its absorption properties, the packing density of the fiber bundle and the quality of the end terminations.

# SCHOTT's competencies ...

## Manufacturing/Design of light guides

### From single fibers to light guides

Bundles of optical fibers are combined with appropriate end terminations and protective sheathing to form light guides and image guides. Combining well-proven **materials** with in-house developed **technologies** SCHOTT incorporates such fiber bundles into a multitude of engineered components by modifying their properties to suit the particular application.



## Materials

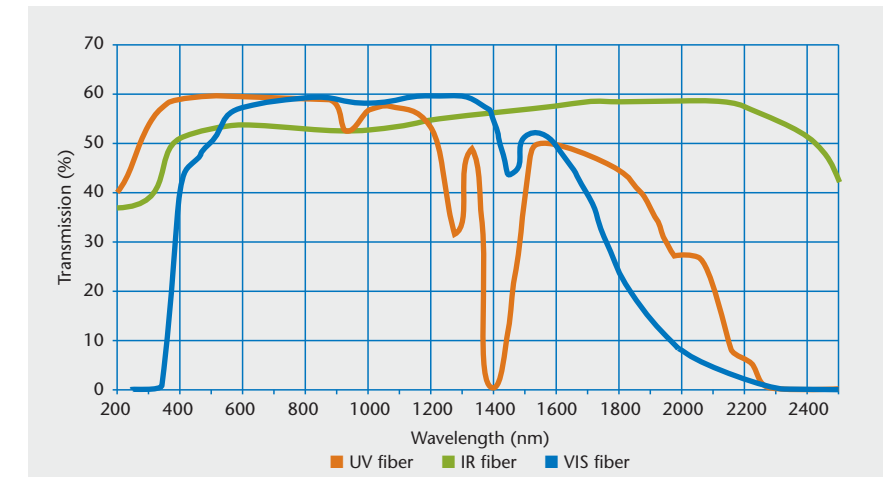
**Flexible or rigid?** The first step in designing a fiber optic light guide is the decision if it needs to be flexible or rigid. Rigid fiber optic rods also referred to as light conducting rods are solid fiber optic elements which can be used to transmit light, image or signals over short distances whenever flexibility is not required. Their advantages over flexible light guides are:

- No packing losses in interstitial gaps and therefore higher transmission
- Excellent temperature resistance because epoxied end ferrules and protective sheathings are not required
- Vacuum or pressure seals are possible

In addition, SCHOTT can also manufacture fiber optic cones respective conical light guides for reducing or increasing the effective optical cross-section and aperture angle ("Light magnification"). Please contact your local sales person for further details.

## Fiber types

The selected fiber type is dependent on the demands of the application. SCHOTT flexible fibers as well as rigid fiber optic rods cover a variety of diameters and optical characteristics like Numerical Aperture and Transmission. Fiber types for the visible and UV spectral range, plus several types to accommodate near IR enable manufacturing of fiber optic components best suited for a variety of different applications. For further details please refer to the actual datasheets.



Spectral Transmission – Different fiber types (fiber Ø 70 µm, length 1000 mm) – Typical values

## Mechanical Protection

### Sheathing

Clearly SCHOTT believes that sheathing is more than simply packaging for fiber bundles; sheathing is an integral structural component used to meet specific applications.

If, and for how long, a light guide operates reliably depends to a large extent on the protective sheathing used. SCHOTT offers many different types of sheathing, so that fiber bundles can be protected in various mechanical, physical and chemical environments.

A standard range of protective sheathing to suit particular applications is available (i.e. metal, polymer, compound). Details see separate datasheet.

### Ferrules

End ferrules for bonded/epoxied light guides are made out of aluminum, brass, stainless steel, nickel silver or other materials. For end ferrules in hot fused components stainless steel is used.

### Housings

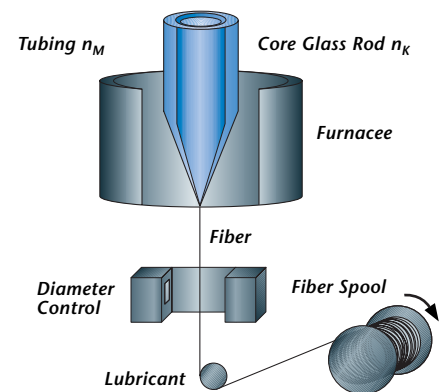
If requested we can manufacture housings to your specifications. Typical housing materials are: nickel, silver aluminum, stainless steel and various plastics.



# Technologies

## Fiber Drawing

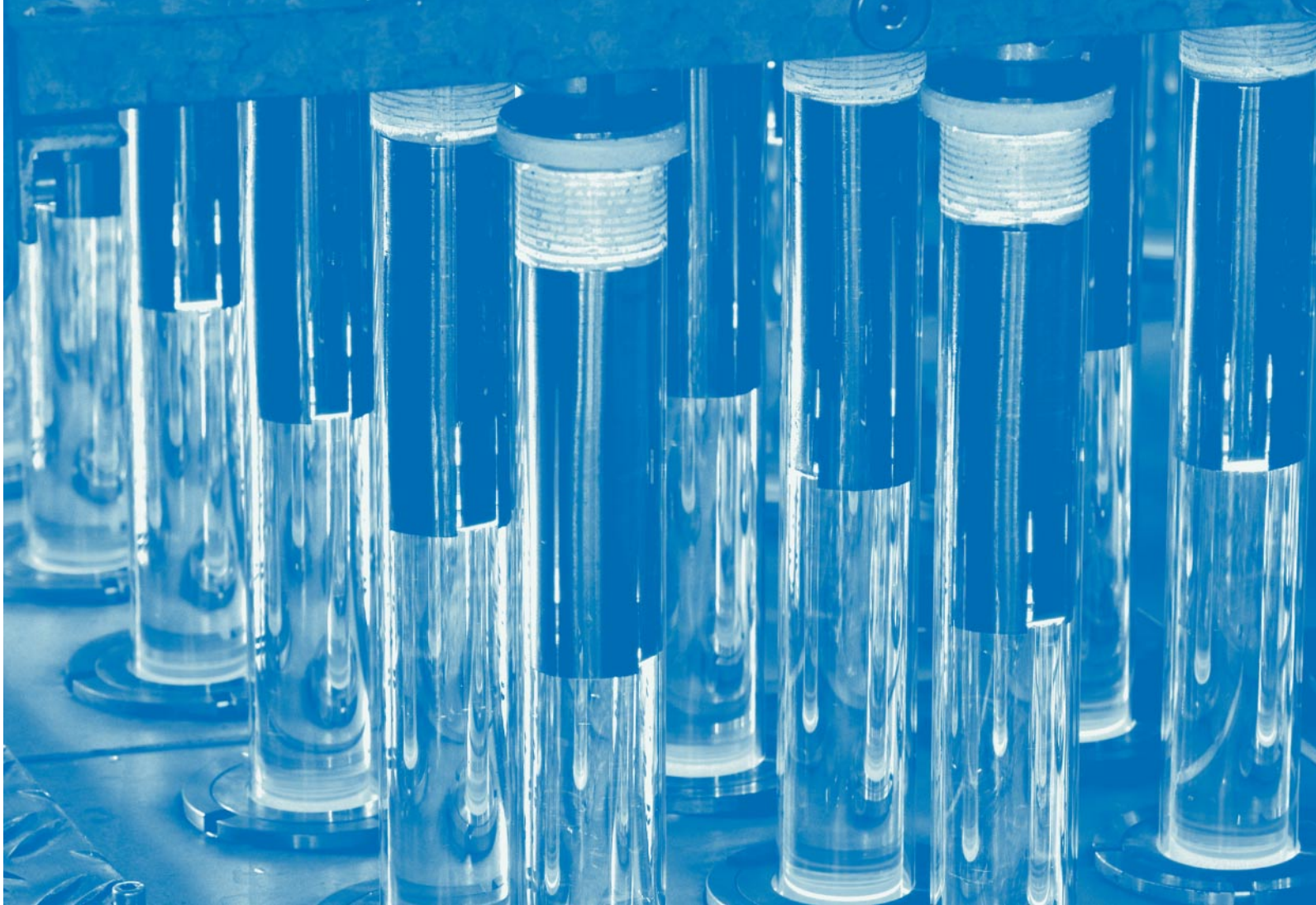
Drawing of glass fibers is a sophisticated process, which requires a tremendous amount of experience, thorough engineering, excellent raw materials and dedicated staff, who just wants to make the difference.



A glass system made up out of core bar and tubing material, both thoroughly cleaned and combined are positioned into a ring furnace. The furnace heats up the system until the glass softens and finally the viscous glass system can be formed to a thin fiber by mechanically pulling. The fiber then is redirected and spooled onto a fiber wheel. The faster the wheel rotates, the thinner the fiber will be. Thus diameters between 30 and 120  $\mu\text{m}$  can be manufactured.

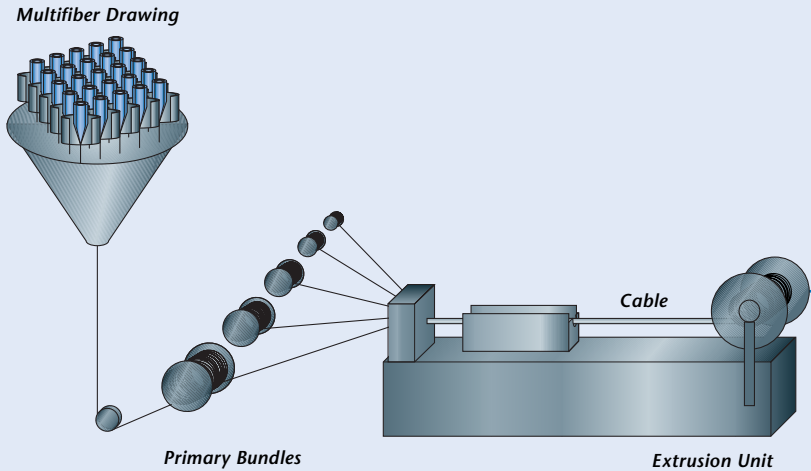
To protect the fibers against breakage the fiber surface will be covered with a lubricant right after the drawing process. Different lubricants are available for specific applications. By combining different core and tube glass materials optical characteristics like transmission and numerical aperture of the fiber can be determined. A large selection of fiber types is available. *See datasheets*

Glass fiber bundles can be extruded with polymer coatings comparable to copper cables for electricity. This enables production of standard cable diameters on spools for subsequent manufacturing steps – a very efficient method for high quantity applications.



## Cable Extrusion

SCHOTT has several extruder lines for continuous manufacturing of optical cables. Several primary bundles generated on the multi fiber drawing tower, are fed into the extruder, where the fiber bundle is covered with a liquid thermoplastic polymer. The extruded cable runs through a cooling bath for polymerization.



- Wide range of cable diameters from a single 250  $\mu\text{m}$  fiber to 8 mm bundles
- Selection of different polymer materials adapted to the specific application
- Economic sheathing for single and multi-branch light guides

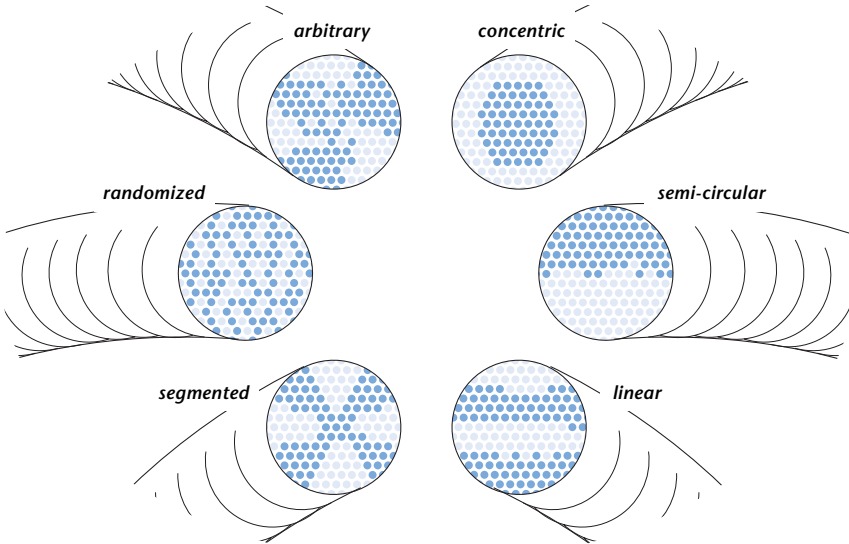


## Fiber Arrangement

The fibers in flexible light guides can be arranged in different shapes, depending on the requirements of the application. This is in particular important for sensing applications, where the size or assembly of certain detectors must be met, often by combining multi-branch assemblies evenly.

Extremely important for several sensing and most of the illumination applications is the randomization of fibers. Fibers from one end of the light guide will be thoroughly mixed according to specified procedures to ensure a very homogeneous illumination pattern. Thus, hot-spots of lamps on the illumination end can be evened out over the entire area at the exit.

Special randomization processes have been developed for large lightline with several illumination bundles to ensure that fibers from each bundle are evenly distributed over the entire length of the bundle.





# ... are at the core of our success

## End Termination: Epoxying/Hot-Fusing

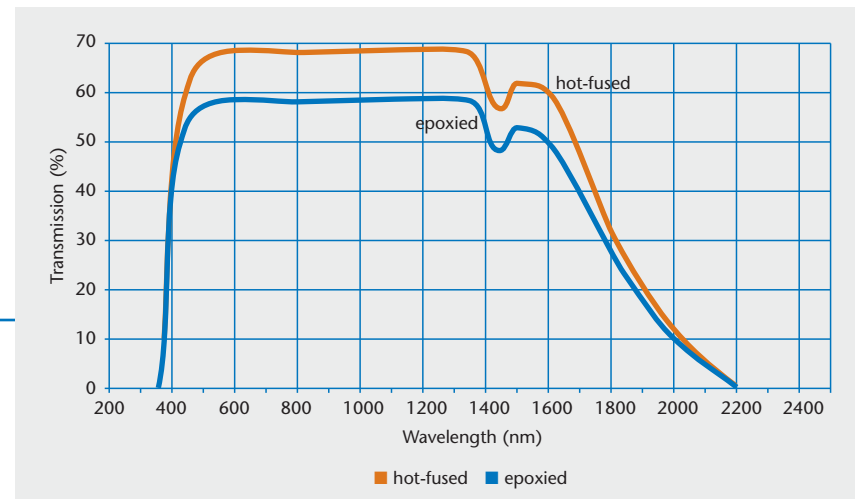
To ensure that fiber ends in light guides can be ground and polished perpendicular to their optical axis thus enabling maximum transmission, the ends need to be terminated. Standard method is epoxying fibers and end ferrule together. Epoxyed light guide ends are temperature stable up to 120 °C. High temperature epoxies up to 200 °C are available upon request.

Where long-term operation in excess of 200 °C is involved, and particularly where additional mechanical loads such as pressure, tension, vibration or acceleration occur at the light guide end, there is a danger of the adhesive disintegrating and the light guide consequently being damaged.

In order to ensure safe operation even at high temperatures, SCHOTT has developed a unique end termination process in which no adhesive is used. Instead, the fiber ends are fused together in a process combining heat with pressure. Fibers made of multi-component glass are embedded at the same time in a stainless steel ferrule.

Light guides with hot-fused ends are particularly suitable for the following applications:

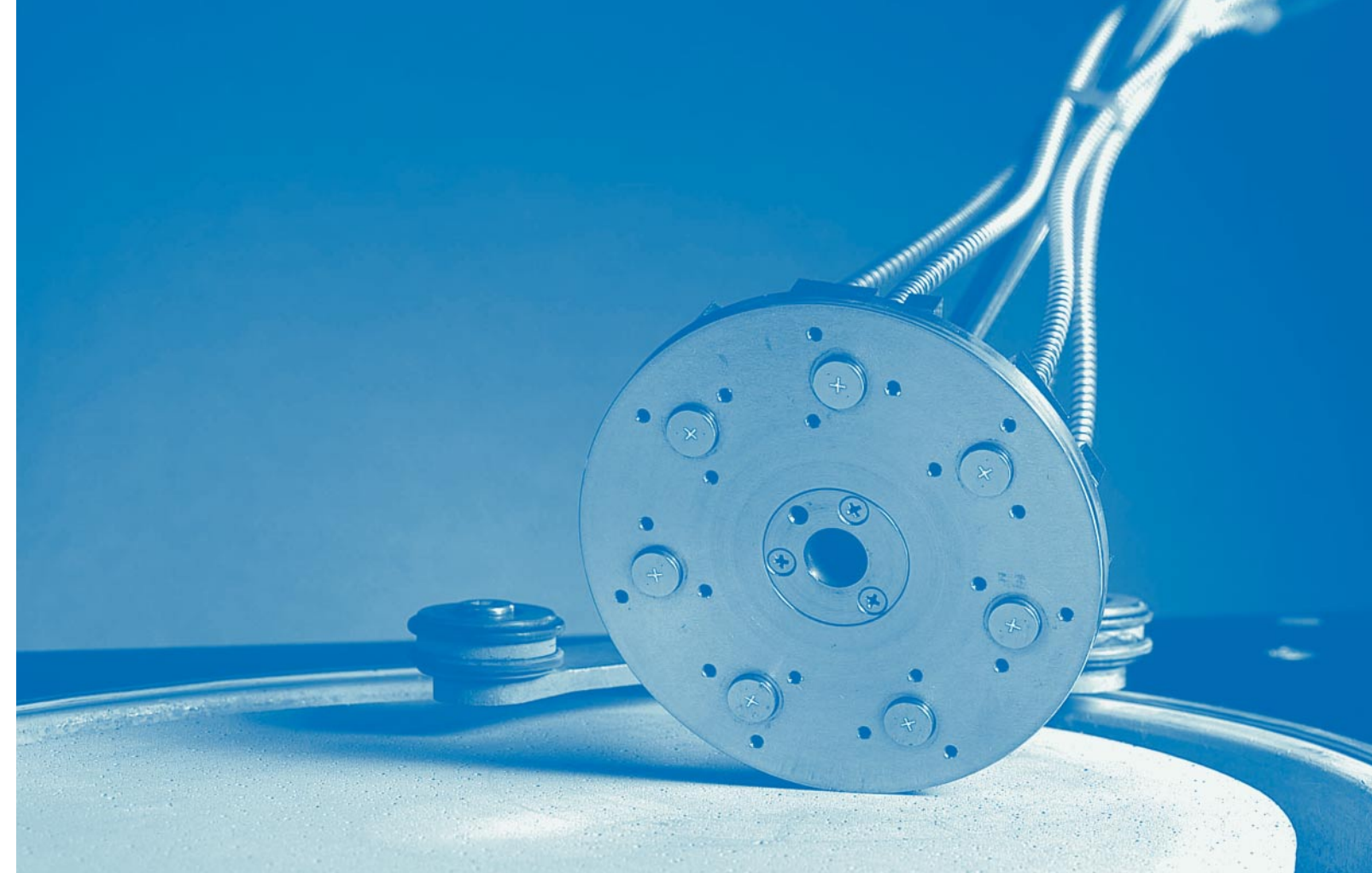
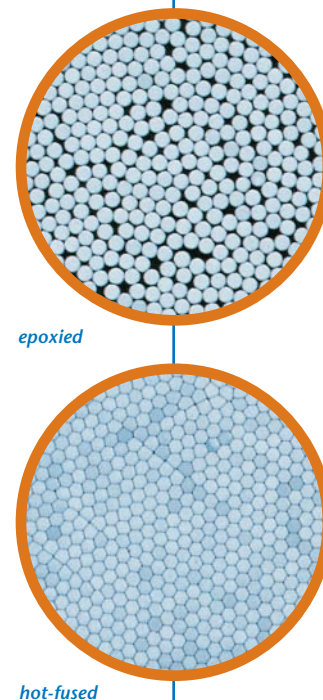
- Pyrometers (radiation and turbine)
- Spark recognition
- High output illumination systems



Spectral Transmission – fiber light guide (fiber Ø 70 mm, length 1000 mm, end tips glued, end tips hot-fused) – Typical values

### Benefits of hot-fused ends:

- High temperature resistance (up to 350 °C for long-term operation).
- High durability in combination with high power light sources.
- No light loss through interstitial gaps between the fibers, which make no contribution to light transmission.
- The fusing process is reshaping the fibers predominantly into hexagonal shape. Thus more fibers can be accommodated in the same optically effective cross-section resulting in a transmission increase of 15 % compared with epoxyed ends.



## End Termination: Grinding & Polishing

In order to efficiently launch or extract light from an optical fiber bundle, the ends of each fiber must be cut, ground and polished at right angles to their optical axis – usually perpendicular. Both, the quality and the method of termination will greatly influence the light guide properties.

Two apparently identical light guides may exhibit different transmission and angular output characteristics due to light guide assembly and in particular the way in which the end surfaces have been ground and polished.

In the final stage of production all fibers are optically ground and polished using special termination techniques to provide our customers with the highest quality.







# Expert solutions ...

## Lightline Technology

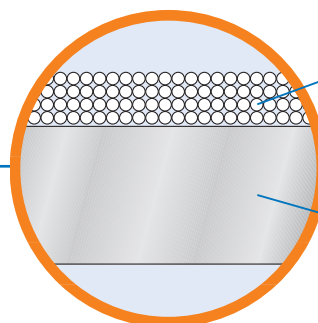
To evenly illuminate a strip of light is one of the most challenging applications in fiber optic lighting. In particular in surface inspection applications very even illuminations over lines up to 3 meter long are required, which demand the combination of sophisticated fiber optic manufacturing methods. SCHOTT developed two different manufacturing methods, each one with distinctive advantages.

## Winding Technology

Fibers from a single fiber drawing tower are wound onto a drum, layer by layer ("online"-winding), creating a "multi layer basic ribbon". Once the desired quantity of layers is positioned on the drum, the fibers will be fixed by clamping a metal bar to them and subsequently epoxying fibers and bar together.

Several basic ribbons can be combined to a modular system in a common housing. Specific segmentation of the line or randomization is possible.

Advantage of the winding technology is a very high packing fraction and the best possible parallelity of fibers, which makes it the technology of choice for highest demanding lighting and homogeneity requirements in lengths up to 500 mm.



Fibers

Metal bar

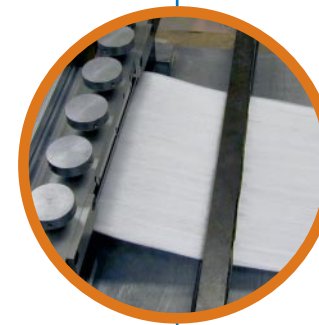
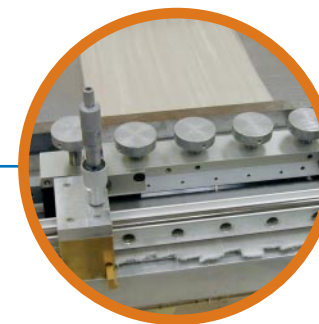
## Pulling Technology

For longer lengths of lightlines SCHOTT has developed a unique pulling technology, which in combination with the patented spatially randomizing process ensures even and homogeneous illumination in length up to 3000 mm.

Fiber bundles are positioned in a fixture and evenly spread out to form a multi-fiber layer, which is subsequently compacted into a uniform line. The opposite ends of the fibers are divided into a defined number of flexible arms, utilizing spatial randomization. This ensures distribution of fibers from each flexible bundle over the entire width of the line.

The fiber assembly is encased in nosepiece extrusions, which allow flexible design of light lines in various widths.

The pulling technology is an effective method to manufacture homogeneous lightlines in various slit dimensions and fiber lengths.



# ... guarantee high quality ...

## Physical principles of LEDs

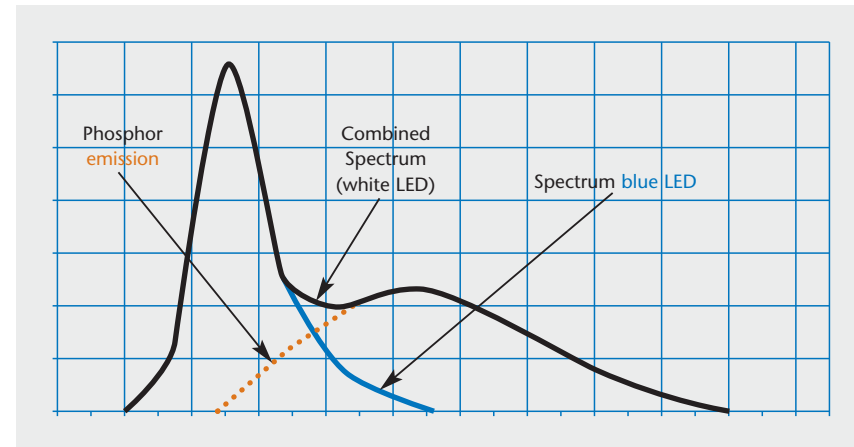
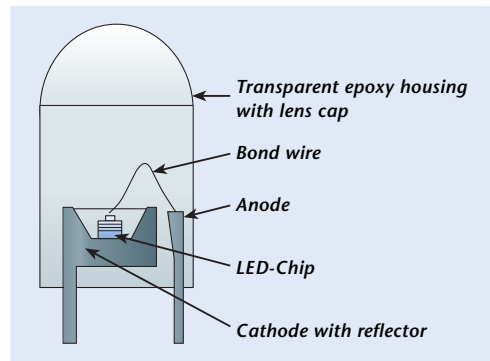
Alternatively to fiber optics with separate light sources inorganic Light Emitting Diodes are of increasing importance for industrial lighting applications.

The LED semiconductor chip emits radiation proportional to the current through the LED. The wavelength of the emitted radiation is always discrete. Today wavelengths from UV via the visible spectrum to the deep IR are available on the market. Of increasing importance for lighting applications are white LEDs. White light though LEDs commonly is generated using a blue chip with a fluorescent layer. The combination of the blue wavelength and the yellow fluorescent radiation overlays to white light with color temperatures of approximately 6000 K.

### Benefits of LEDs:

- Significant longer lifetime than conventional illuminants
- Excellent electronic controllability, useable for segment control as well as complete PC control
- Excellent strobeability and remote control options
- Low power consumption
- Noiseless, free of vibration
- Small geometrical dimensions
- Large range of discrete wavelength available

### Principle design of a LED:



## Design of LED Lighting Components

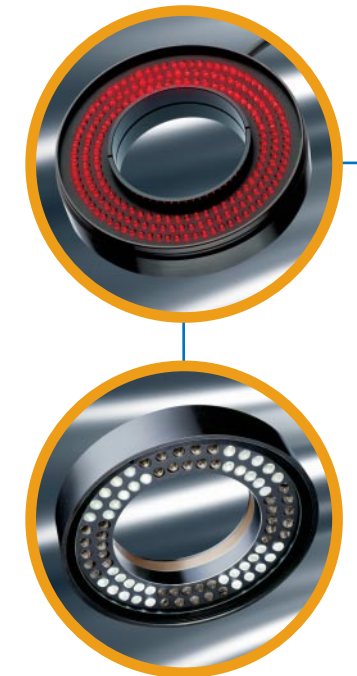
Single LEDs will be assembled into lighthead assemblies in shapes of brightfield and darkfield ringlights, backlights, lightlines and spotlights. Adding special hardware like dome or coaxial attachments, polarizers, diffusers illuminators specialty illumination effects can be achieved. Custom designs are available.

To maintain the long lifetime of individual LEDs also in a lighthead assembly SCHOTT has developed intelligent LED lighting solutions:

### for Machine Vision ...

- **Temperature Management** through heat absorbing hardware and integrated temperature sensor to maintain the maximum allowed LED temperatures during operation
- **Matrix circuit design** vs. parallel chains reduces the influence of LED failures to the individual LEDs
- **Lightfeedback** sensor to compensate for degradation of light output over time due to altering and change in environmental conditions
- **Online control** via RS-232-Interface

... SCHOTT iQLED lighthead and controller



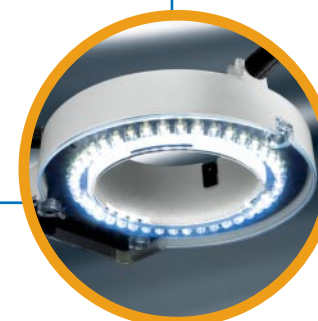
### and Stereo-Microscopy ...

- **New contrasting options** through segment control of ringlights and transmitted light stage
- **Rotation** of illumination segments
- Freely settable **memory positions** for easy to use storage of parameters for fast change in between illumination modes
- Simple options for **mixed light** conditions

... SCHOTT VisiLED lighthead and controller

... or the compact SCHOTT EasyLED Ringlight  
LCR 100 Ringlight for easy to use bright white light for Stereo-Microscopy.

**For further information** please ask for SCHOTT's "Industrial LED Components" brochure or the individual datasheets.





# ...for our customers

## Physical principles and manufacturing/Design of image guides

### Leached Technology

SCHOTT's flexible leached image guides are used in a variety of industrial endoscopes requiring high resolution image transfer.

Our wide range of sizes enables our image guides to be designed into larger diameter viewing scopes as well as into smaller instruments with multiple working channels.

SCHOTT's high resolution image guides satisfy the stringent standards of leading OEMs. Our imaging solutions offer a value-based balance of performance, quality and cost.

### Faceplates and Tapers

SCHOTT's fiber optic faceplates and tapers are used for high resolution image transfer in CCD coupling, image intensification, x-ray imaging and to meet other industrial market needs.

Tapers provide virtually distortion-free image transfer with magnification or minification of the image. Fiber sizes of tapers range from 4 to 25  $\mu\text{m}$  at the large end to 2 to 6  $\mu\text{m}$  at the small end. Tapers can be machined into shapes from round to round, rectangular to rectangular, and round to rectangular in sizes up to 150 mm with magnification ratios up to 4:1.

Fiber sizes of faceplates range from 4 to 25  $\mu\text{m}$  and larger. Shapes range from round to rectangular. Faceplates are available in sizes up to 150 mm square.

### Wound Technology

In addition to leached image guides, SCHOTT also provides customized, flexible wound image guides with larger rectangular image formats. Wound image guides are used in machine vision, remote viewing, and to satisfy a variety of imaging needs of industrial markets.

- The standard numerical aperture of faceplates and tapers (small end) is 1.0. Numerical apertures of 0.35 and 0.58 are available.
- SCHOTT's faceplates and tapers are designed to meet customer specific requirements.
- SCHOTT's glass types are designed for use in the visible and near IR spectrum. Radiation attenuating and radiation hardened materials are available.

## Finished Products

### SCHOTT's Standard Program

In addition to customer-specific components SCHOTT offers a range of standard components for specific applications. Particularly for Machine Vision and Stereomicroscopy applications SCHOTT's product scope includes light sources, flexible light guides, lightlines, ringlights, backlights and various accessories. For further details see "Fiber Optic Light Sources" brochure.

### Customized light guides / Made-to-measure design

Our specialists work together with you on the fiber optic solution for your particular application. Starting from the basic technical conditions laid down by you we can jointly draw up a plan of action addressing each stage leading to series production. During this process, we will provide you with complete assistance through the sample and prototype phases to ensure that everything is ready for a seamless transition into series production.

- Single and multibranch light guides
- Ringlight assemblies
- Lightline assemblies
- Backlights

## Quality Control

The entire ordering process from order acknowledgement through purchasing components and shipping the finished goods to the customer is well defined and documented in SCHOTT's integrated management system fulfilling the ISO 9001 and 14001 standards. Through defined control steps along the process of manufacturing the quality of raw materials, glass fibers and mechanical components as well as finished products correspond to defined specifications to meet the customers expectation.

Routine measurements comprise transmission and aperture of fibers and light guides as well as geometric dimensions to maintain specified quality standards. Fiber optic components can also be tested according to customers specifications in measurement units which reflect the individual application.





# SCHOTT's products @ work

## Transmitting light

(for industrial lighting applications)

- Illumination of a specimen in the target area. Special lighting techniques are used to enhance the contrast to make special features visible.
- Two different options are possible:
  1. Illumination from a separate light source (Halogen, Metal Halide or Xenon) via fiber optic light guide
  2. Illumination by means of an LED assembly
- Main applications are Stereo-Microscopy and Machine Vision.
- Larger range of standard products is described in the brochure „Fiber Optic Light Sources“

## Transmitting signals

(for sensors and control applications)

- Sending or receiving of light or optical signals through optical fibers.
- Light guides used for sensor applications are mostly customized design and OEM solutions.
- Application examples are described in the applications section of this brochure.

## Transmitting images

(for image transfer applications)

- Using image bundles with fibers, which consists of millions of individual fibers that are bonded together in a highly ordered array.
- Image guides are mostly custom or OEM solutions.

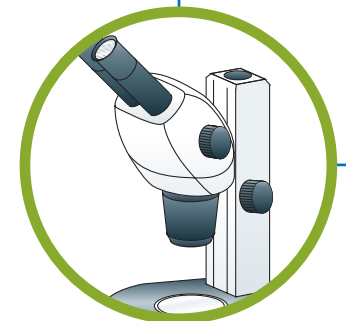
## Machine Vision and Stereo-Microscopy

Illumination is an important in Machine Vision or Stereo-Microscopy. With optimized illumination the desired features of the object will be made visible for the camera respective microscope operator by well-aimed amplification of the contrast.

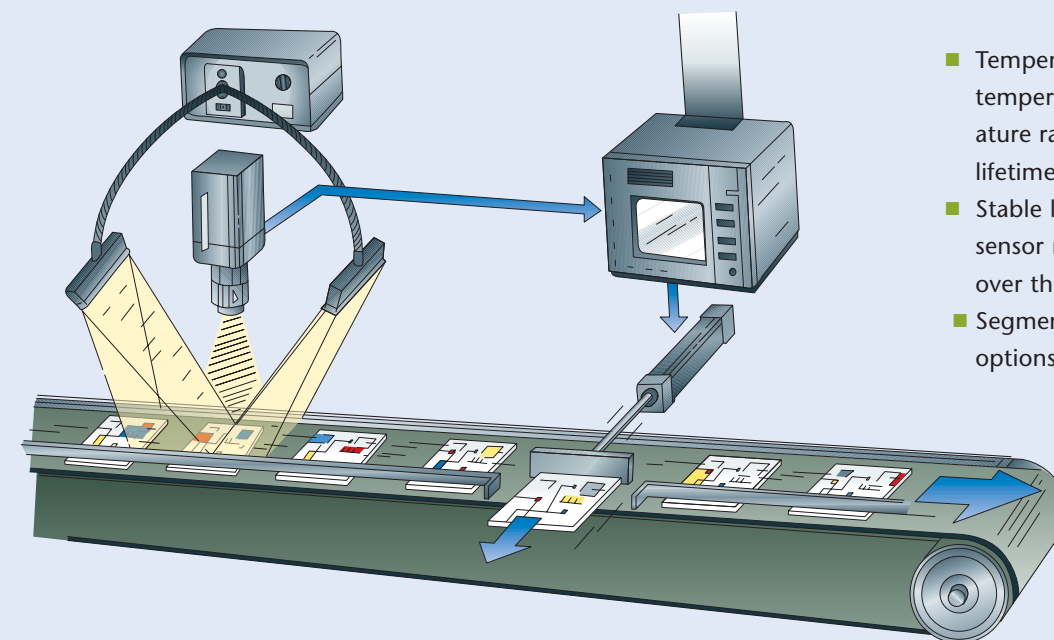
Versatility in designs of lightheads enables the application of different lighting techniques like brightfield, darkfield, transmissive light, diffuse lighting, polarized light or other specialty illuminations. Wherever a large amount of light must be distributed homogeneously onto small areas SCHOTT will find a solution.

Fiber optic illumination is of great importance for Machine Vision and Stereo-Microscopy applications due to high light intensity of the halogen or metal halide light sources and the large variability of fiber optic components. Fiber optic components from SCHOTT distinguish themselves by the following characteristics:

- Very high transmission
- Excellent color temperature
- Good fiber randomization for very even illumination
- High flexibility
- Mechanical stability
- Chemical resistance
- Temperature resistance up to 350 °C



LED lighting components increasingly gain importance for illumination applications due to their long lifetime and excellent electronic controllability.



SCHOTT's LED Illumination systems offer the customer:

- Temperature control to keep LED temperatures within allowed temperature ranges and thus maintain long lifetimes.
- Stable light output via light feedback sensor resulting in constant light over the operating period.
- Segment control for new contrasting options.

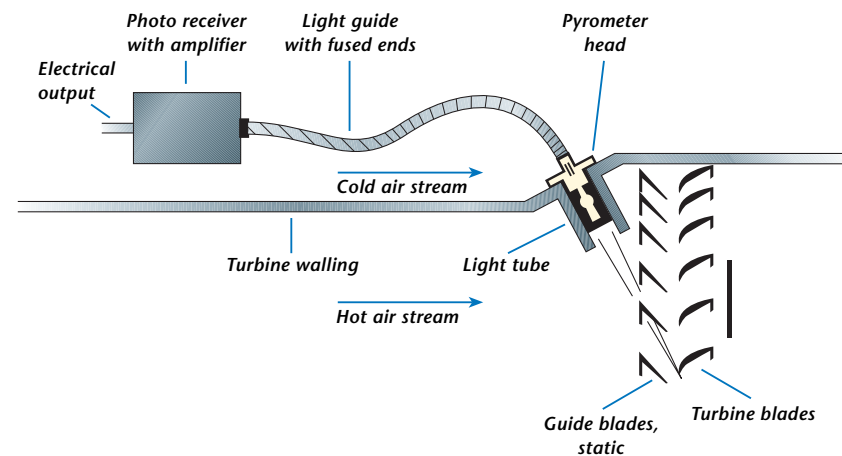


# Unique solutions...

## Pyrometry

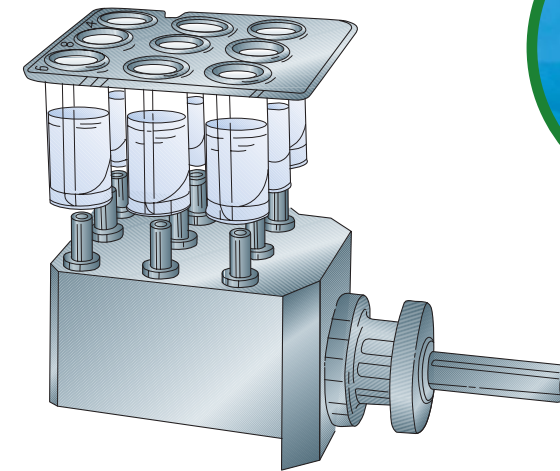
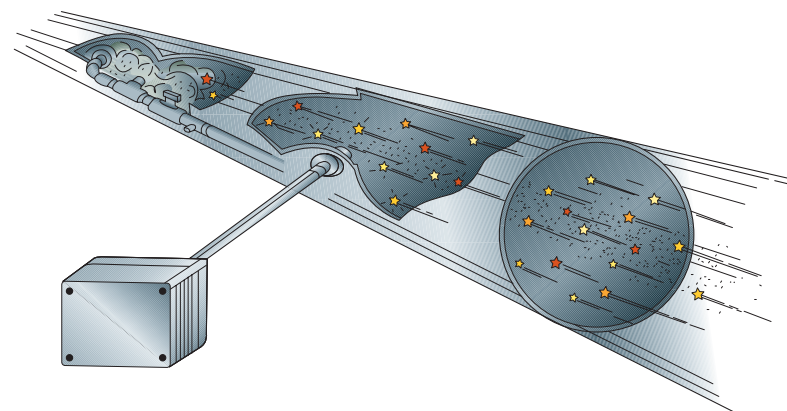
Pyrometers are used for the contact-free measurement of surfaces and liquids. They are used to measure the temperature of turbine blades, for example in aircraft engines, to avoid damage to the material through over-heating. In this sensor application, light guides transfer the temperature radiation from the turbine blades to the pyrometer.

The hot-fused light guide ends in the turbine are temperature-resistant to 350 °C, thus ensuring reliable transfer of the light in spite of extreme temperature, high pressure, vibration, acceleration and chemical influences.



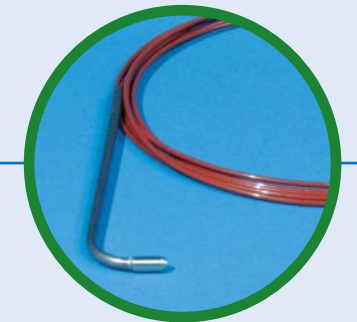
## Spark recognition

In filtering equipment, silos and dryers, dust fires and explosions can often occur, endangering human life and causing immense material damage. SCHOTT light guides play an integral part in spark recognition systems. In case of a spark occurring the light guide transmits the light to a detection unit, which in turn activates extinguishing equipment meaning the spark can be automatically put out before it ignites. Due to our hot-fusing process the spark recognition systems can operate in high-temperature environments.



## Spectroscopy

Spectroscopy is the study of molecular structure and dynamics through the absorption, emission and scattering of light. A spectrometer is an instrument used to break light transmitted through a sample or emitted light into its various wavelengths and subsequently analyze. The light guides facilitate the spatial separation of signal source, sample and signal analyzer. By using multi-branch light guides several individual samples can be analyzed using only one sender and receiver.

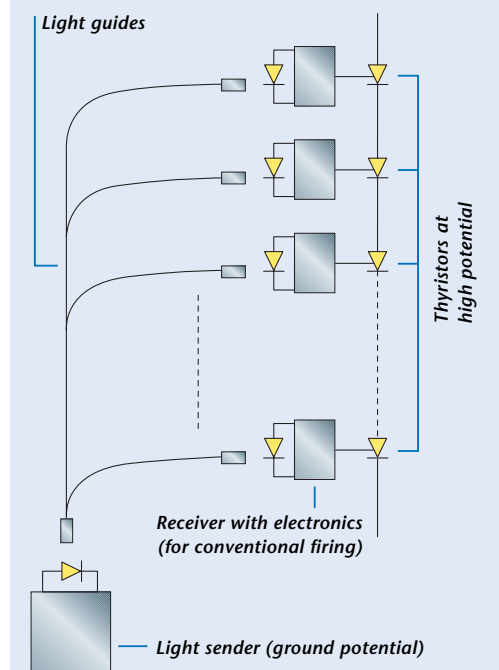


## Thyristor control for HVDC

Electrical power requirements are increasing all over the world. An optimal balance of electrical generation and consumption often means pooling of resources between networks. With an interconnection made by high voltage direct current (HVDC) stations, the power exchange between the networks can be precisely controlled.

The MK light conducting cable developed by Schott as a high voltage resistant cable is particularly well suited for the transmission of data and control signals required for such applications.

In conventional thyristor firing applications a conversion of the optical signal into an electrical pulse is required to operate the thyristors. Light-triggering thyristors are triggered directly by means of a powerful light pulse. The trigger command from a high power diode at ground potential is transmitted via a high-voltage resistant light guide to a thyristor at high potential. Light guides can also be used to monitor the triggering process.





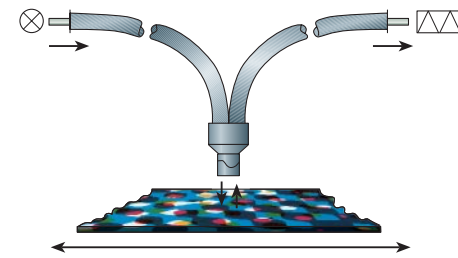
# ...for a variety of applications

## Positioning

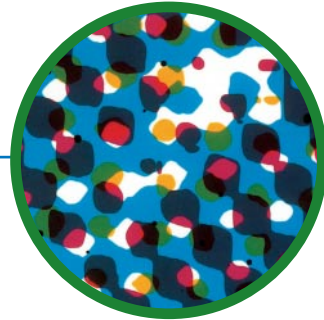
A good example for positioning is the printing industry. Paper is printed in various colors and steps. It is thus essential for the paper to be well positioned during the entire process. This is guaranteed by small “structures and patterns” on the side of the paper. These are repeatedly illuminated and the reflected light is then analyzed. Any “mismatch” is corrected immediately.

The measuring system is exposed to high mechanical pressures. In addition, there is risk of explosion due to evaporating solvent.

The advantages of fiber optics are most welcome: no live parts in the danger zone and a greater separation distance to the printed sheets meaning better recognition of marks.



*One end of a dual light guide is used to illuminate a specific spot and the other end to transport the reflected light into an electronic unit.*



In semiconductor manufacturing, microlithography is used to transfer the pattern of circuitry from a photomask – a quartz plate containing the master copy of a microscopic IC – to a wafer, a thin slice of silicon or other semiconductor material on which the ICs are made. To be able to manufacture such ICs microlithography strongly depends on the ability to precisely position the wafer.

Light guides are used to position the wafers. These light guides are very complex, in particular as the individual fibers have to be positioned with a precision of 10 µm.

Several light guides are used to illuminate specific spots, other light guides to transport the diffracted light to an electronic unit where the signals are analysed to position the wafer correctly.



Out of the vast field of applications for rigid or flexible image guides two are explained in more detail, X-ray imaging and semiconductor inspection.

## X-ray imaging

In conventional radiography images are created using a phosphor/film combination. The resulting images are analog, the signals being highly susceptible to noise and degradation much as an LP record can skip when contaminated with dust or dirt.

In digital X-ray imaging, where faceplates and tapers are a key component, the X-rays are converted into digital images which are not susceptible to noise. Digital X-ray imaging eliminates the film processing delays, reducing exposure to radiation by as much as 80 %.

The faceplates and tapers

- provide a surface for a coating such as a phosphor screen,
- protect the CCD surface from physical damage,
- provide an X-ray absorption layer to protect the CCD from x-ray damage and
- allow a direct 1:1 coupling with other optical devices



## Semiconductor inspection

IC manufacturers continually have to reduce the size of ICs while at the same time make them perform faster. The required semiconductor manufacturing machines are thus becoming more and more complex and compact.

While most IC production functions are performed and controlled automatically with the help of complex light guides certain initial production steps require a visual inspection. As the IC production area is not directly accessible and is also operated under special environmental conditions, a flexible image guide is used to transport the required image to the operator allowing him to visually control the initial operation.



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