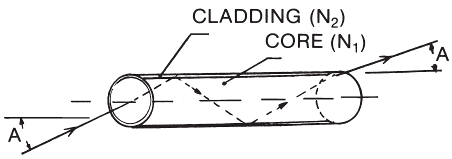
Fiber Characteristics



Fiber Composition

Most optical fibers consist of two different types of optically transmittive materials. The core, about 75-90% of the fiber depending on the fiber diameter, has a higher refractive index than the cladding. This creates a reflecting interface between core and cladding which keeps the light within the core due to total reflection.
Most optical fibers are made from glass, plastic or synthetic fused silica (often refered to as "quartz"). Each fiber has different properties producing various advantages and disadvantages. Due to their low attenuation silica fibers are commonly used in data communication. Glass is still the best choice for illumination and sensing applications, due to a reasonale cost-benefit ratio. Plastic fibers can be used for assemblies not requiring heat above 175°F. Single plastic fibers are usually larger in diameter than glass fibers, which results in restricted bending radii.

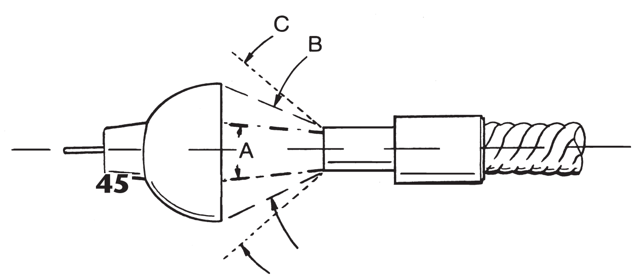
Numerical Aperture

The sketch above shows a typical fiber. The Core has a refractive index of N_1 and the Cladding an index of N_2. Light enters the fiber at angle A and is transmitted through the fiber. If angle A is too large, the light will go out the side of the fiber and will not be transmitted. We call the angle beyond which the light cannot be carried through the fiber the Critical Angle. This is calculated using the two refraction indices. The sine of the Critical Angle is the Numerical Aperture or N.A. The Acceptance Angle of the fiber is two times the Critical Angle.

$$N.A. = \sqrt{(N_1)^2 - (N_2)^2} \qquad f_\# = 1/2\ N.A.$$

EXAMPLE: If N_1 is 1.62 and N_2 is 1.52, the N.A. will be .56 which equals a Critical Angle of 34° and an Acceptance Angle of 68°. The f number/equivalent will be f/0.89.

Optical fibers tend to preserve the Angle of Incidence during the light transmission and therefore in the figure above, angle A is shown at both the entrance and exit ends of the fiber. The sketch below shows a typical projecting lamp illuminating a fiber bundle. Angle A is the Acceptance Angle of a .25 N.A. fiber (29°). Angle B is the Incident Angle from the lamp and angle C is the Acceptance Angle of a .66 N.A. fiber (83°).



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The calculated minimum N.A. required for the 45° Angle of Incidence is .38. Therefore, the fiber with an N.A. of .66 will accept all of the light from the lamp, but the output angle will only be 45° and not the 83° which might be expected. However, the .25 N.A. fiber which cannot accept all of the light, will have an output angle of 20°. Using a low N.A. fiber will not focus the light from a lamp because it can't receive any light beyond its Critical Angle and therefore has a narrow output cone. Multicomponent glass fibers typically reach numerical apertures up to 0.9, whereas quartz silica fibers typically do not exceed 0.4 numercal aperature.

Transmission Characteristics of Optical Fibers

High quality optical glass (crown and flint glass) is used for the light transmitting core of fibers and an optical glass with a different refractive index is used for the cladding. Wavelengths between 400 and 900 nanometers are transmitted uniformly, with only minor variations.

In this range SCHOTT's standard multicomponent glass fibers (A2, B3) have attenuation levels between 150 and 300 dB/km. Transmission in the UV range is very low and wavelengths below 350 nm are not transmitted. However, the near infrared range (0.8 micron to 1.3 micron) is transmitted very well by glass fibers. At 1.4 micron, all fibers except those specifically designed for IR transmission, show a significant drop in transmission due to OH-Absorption within the glass. In the range from 1.4 µm up to 2.0 µm specifically designed glass fibers for IR-transmission can be used.

For improved transmission over the entire range from 250 nm up to 3.0 µm quartz (fused silica) fibers are the best choice, but have a lower numerical aperture.

Transmission Characteristics of Optical Fiber Bundles

Although specific information on the performance of a single fiber is valuable, it is important to understand how optical fibers perform when manufactured into bundles. Due to total reflection, a portion of the light will be reflected at the polished glass surface of the fiber at the entrance as well as the exit. In addition, the institial gaps between the fibers, usually filled with epoxy glue, will not transmit any light. The losses due to these two effects can be estimated at appoximately 25 % -30 %, depending on the polishing quality. The loss of the internstitial gaps can be reduced by hotfusing the entrance end instead of glueing the fibers together. Thus,transmission can be increased up to 15 %. In addition, transmission loss will be caused with increasing length of the lightguide. A 3-foot/1m fiber bundle will transmit approximately 60% of the light emitted by the lamp towards the fiber bundle within the acceptance angle. A 10-foot/3m bundle is expected to transmit about 55% of the light and a 30-foot/10 meter lightguide shows typical bundle transmissions of 40 %.

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Uniformity of Fiber Optic Products

SCHOTT North America, Inc. manufactures two product lines which require a uniformity specification across a given area: lightlines, also referred to as spot to line converters, or cross-section transformers and backlights.

The uniformity of lightlines and backlights can be evaluated utilizing a Machine Vision System:
· CCD area scan camera
· a framegrabber card
· image analysis software.

Backlights

The backlight is placed directly under the camera at a defined distance based on the size of the active area. The camera will be focussed onto the top surface of the backlight diffuser. Then the uniformity is measured by using an area of interest (AOI) histogram. The AOI will be slightly smaller than the active area to compensate for edge fall-off. The light source used for backlight calibration is a DCR® III with an EKE lamp.

Lightlines

Lightlines smaller than 16" (406 mm) in length are mounted on a 45 degree angle fixture. The fixture has a diffuser plate which is located .5" (13 mm) above the fiber line. The line is projected onto the diffuser plate, which is positioned directly below an area scan camera. The distance from the camera to the diffuser is determined by line length but is approximately 24" (610 mm). The camera's focus is adjusted to the top surface of the diffuser. The uniformity is then measured by taking a line profile of the image. The line profile will be approximately .5"-1" (13 mm-25 mm) shorter than the product to compensate for fall-off. The light source used for lightline calibration is a DCR® III with a DDL lamp. The above information is an overview of our calibration process.

Using these set-ups, backlights and lightlines will be calibrated to predefined uniformity values. Details are provided on the individual data sheets.

Product improvements may result in specification or feature changes without notice.

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Lamp Intensity versus Lamp Life

Halogen Bulbs

All SCHOTT Halogen cold light sources (including the ACE, DCRIII, KL 1500 LCD, KL 2500 LCD and KL 200) allow the user to adjust light intensity from zero to the full rated voltage of the lamp. However, voltage to the lamp effects lamp life. As a rule of thumb, a 10% reduction in voltage of most halogen lamps increases the anticipated life time to 400%. SCHOTT recommends using the minimum intensity setting needed to maximize the life of the lamp.

The Halogen Cycle is the operating principle of all Quartz Halogen lamps. At full voltage, the temperature of the glass envelope is hot enough to keep evaporated tungsten (thrown off from the filament) from collecting on the glass surface. The tungsten is cycled back to the filament and thus increases its lifetime. As voltage is reduced, the temperature of the glass envelope also decreases, which might effect the halogen cycle. For this reason the lamp life might not be increased as expected when the voltage is dimmed below 75%.

All types of quartz Halogen bulbs used in SCHOTT cold light sources (DDL, EKE, EJA, EFR and ELC) operate in the same manner.

Metal Halide Bulbs

The SCHOTT MHR-50 Light Source uses a Metal Halide lightbulb rated at 50 watts. Due to its electronical balast, the Metal halide lightbulb can only be dimmed between 40-60 watts. Reduction of intensity also increases lifetime, with a 40 watt setting up to 3500 hours.

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Light Source Safety and Electro Magnetic Compliance

Electronic devices manufactured within the USA

SCHOTT North America makes every effort to meet or exceed the guidelines set forth by CSA (Canadian Standard Association). To comply with fire/safety codes, products sold in the United States should be certified to comply with the requirements set by OSHA, the governing body responsible for product safety in the U.S.A. A well-known company providing this service in the United States is UL, a private, for-profit business that certifies to OSHA standards. CSA is a Canadian counterpart of UL, given permission by OSHA to test and certify to OSHA safety standards. SCHOTT North America uses CSA to certify that the manufactured products are in compliance with both OSHA and Canadian safety standards, and meet UL specification 1571. As a matter of operational policy, CSA randomly visits the Auburn facility 4 times a year. Each visit is made by a different inspector who follows the procedure according to the current CSA guidelines.

CE Safety
To pass the low voltage CE safety directive 73/23EEC, we chose British standard EN60950 (Canadian standard CSA950 equivalent) as a best match for our product. We declare the CE safety directive using a "Manufacturer's Declaration of Conformity".

CE Emissions
EN50082-1 Class A (Industrial). We use a third party facility to verify both conducted and radiated emissions and immunity compliance. Should you require verification of our compliance, a certificate is included with every light source. Duplicates are available upon request.

Electronic devices manufactured within the European Union

The SCHOTT KL-Series cold light sources for microscopy applications are certified as laboratory devices, the KL 1500 LCD and KL 2500 LCD are also certified as medical electrical devices. The 230 V versions are in conformity with the European Low Voltage Directive (73/23/EEC) and EMC Directive (89/336/EEC). Accordingly, they follow the European low voltage standard about laboratory devices EN 61010-1 and the corresponding EMC standard EN 61326-1. The KL1500 LCD and KL2500 LCD additionally comply with the European safety standard about medical electrical devices EN 60601-1. The 120 V versions of all KL light sources comply with the US safety standard UL 3101-1 and the Canadian standard CSA 1010.1. The KL1500 LCD and KL2500 LCD additionally comply with the standards about medical electrical devices UL 2601-1 resp. CSA 601.1 The compliance of all KL light sources with the listed standards have been tested and certified. The 230 V versions carry the European conformity sign and the certification marks and the 120 V versions carry the certification mark.

The VisiLED product line for Stereo Microscopy complies with the standards mentioned above (EN61010-1, EN60601-1, EN 61326-1, UL3101-1, UL 2601-1, CSA 1010.1 and CSA 601.1). Additionally, it is classified as a Class 1 product according to the European Laser standard EN60825-1. The VisiLED power supply carries the conformity sign, and has been approved by the TÜV Rheinland and carries the corresponding “GS” sign. Additionally, the certification mark proves the compliance with US and Canadian standards.

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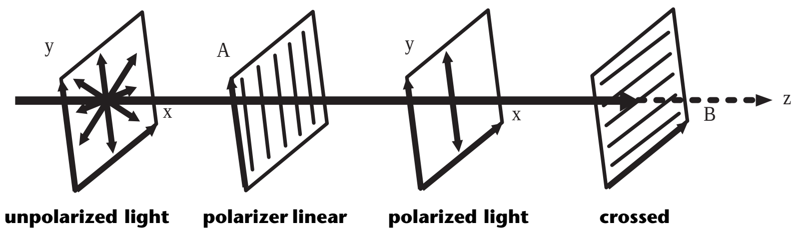
Working with Polarized Light

Some lighting applications show unwanted light reflections or glare. Using polarizing kits helps to eliminate these reflections.

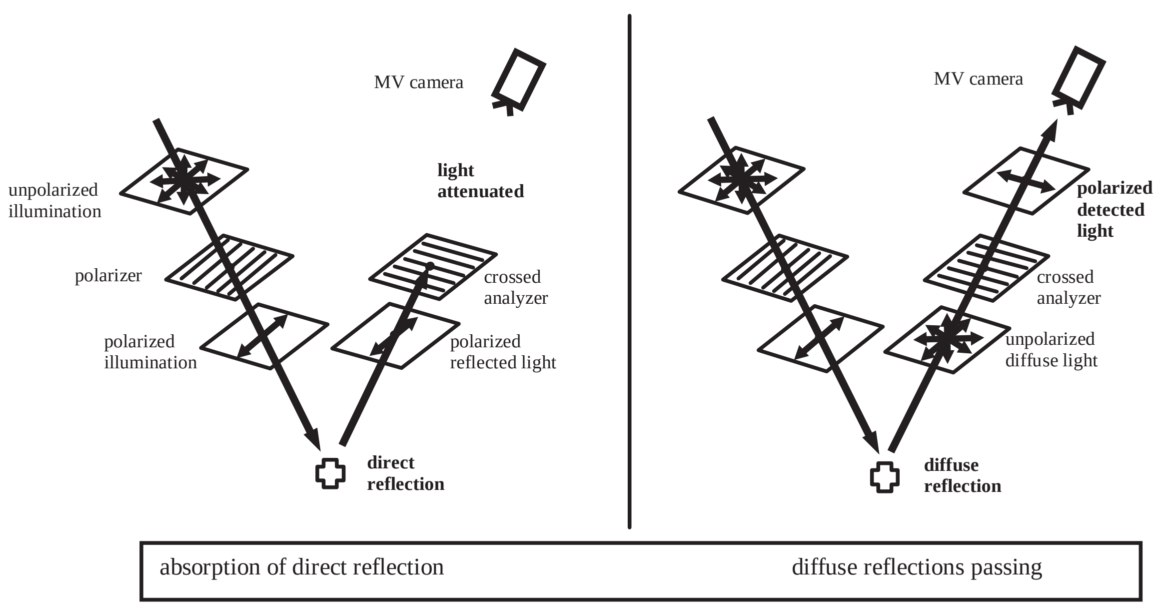
Theory

The electrical field strength of ordinary light vibrates in all possible directions (x, y) perpendicular to the direction of the light propagation (z). It is called unpolarized light.
When unpolarized light enters a linear polarizer, only the light vibrating parallel to the filter's transmission axis (A) passes, while all other parts of the light are absorbed. The transmitted light vibrates in direction (A) only, it is called (linear) polarized light with polarization direction (A).
A second polarizing filter in the optical path, so-called analyzer, absorbs mostly all of the polarized light entering, if it's transmission axis (B) is set perpendicular to the polarizer's axis (A). By turning the analyzer in the (x,y) plane the portion of the light passing through the analyzer can be changed from nearly 0% to nearly 100%.



Using Polarizing kits in Machine Vision and Microscopy

A machine vision system or stereo microscope equipped with incident light illumination detects light reflected from the specimen under investigation. The light entering the specimen can be reflected directly (like mirrors do) or diffuse.
In many cases direct reflections and glare make it impossible to observe the specimen because of their high light intensity.
The fact that direct reflections preserve polarized light while diffuse reflections convert it into an unpolarized state, can help to attenuate unwanted glare on the observed specimen:
The specimen have to be illuminated with linear polarized light. The light reflected directly will be still linear polarized, it might just have changed it's direction of polarization.
By turning the following analyzer into a crossed position, most of the direct reflections / glare will be attenuated. The intensity of the direct reflections can be varied by turning the analyzer slightly out of crossed position.
Light reflected diffuse leaves the specimen unpolarized. The portion that vibrates parallel to the analyzer's transmission axis will pass through and can be detected by the camera or microscope.



TECHNICAL SPECIFICATIONS

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Notes:

If totally unpolarized light enters a linear polarizer, 50% of the light passes the filter polarized and 50% of the light is attenuated.

If linear polarized light enters a second linear polarizer (analyzer), the portion of the transmitted light can be varied from 0% to 100% by turning the analyzer's transmission axis.

The polarizer must be the last component in the illumination path before the light enters the object while the analyzer must be the first component in the detection path after the light is reflected from the specimen.

Using polarizing kits will attenuate the direct reflections from a mirrored surface to a large extent, but in practice not totally eliminate them. So the reflected image of an illuminating light guide (e.g. a ring light) might still be detectable by a camera. If this is not acceptable, other lighting techniques have to be chosen.

When looking at objects through water, plastic, glassine envelopes or similar materials, polarization will attenuate the reflections from the covering layer and make the specimen observable.

If a material is non-reflective (e.g. blotter paper, textured fabric, woven materials, dull metal or matte finished products) polarizing will probably not enhance the image.

Fibers will not maintain polarization, except fiber types developed specially for that purpose.

SCHOTT offers polarizing kits for ringlights, lightlines, flexible light guides and goosenecks.

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