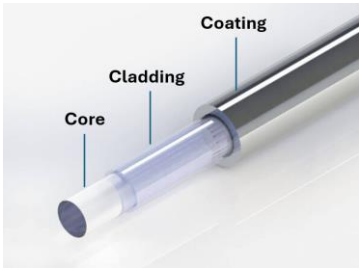
Optical fibers for Fiber-based Process Spectroscopy and other applications

This Technical Note gives an overview of common specialty optical fibers used in fiber optic products at art photonics.

Introduction

Optical fibers and waveguides are used to transmit light in the optical devices. Applications include spectroscopy, laser delivery, remote sensing and others. The fiber itself has three main components: the core, where the light actually travels; the cladding, which keeps the light confined inside the core, and the coating or jacket or buffer, which protects the fiber from physical damage and environmental factors, though it also limits the maximum operating temperature. Different types of optical fibers are employed based on the wavelength working range, transmission and environmental conditions required for specific application.



Classic optical fiber

Silica fibers (180 - 1200 nm & 400 - 2400 nm range)

Silica fibers are the most commonly used optical fibers, with a core primarily made from high-purity silicon dioxide (SiO_2) and cladding made from a fluorine-doped SiO_2. Low-OH silica fibers offer excellent transmission in the visible to near-infrared spectrum (400 nm to 2400 nm). High-OH silica fibers transmit the radiation from the ultraviolet to visible spectrum (180 nm to 1200 nm). Common protective coatings are acrylate with operating temperature ranges from -40°C to +85°C and polyimide working from -65 °C to +300 °C. For high temperature applications metal coating is used with temperature ranges from - 270 °C to +400 °C for aluminum and to +600 °C for copper in non-oxidizing atmospheres. In the case of fluorescence-sensitive applications metal coating is also a better option compared to polymer coating.

Fluoride fibers (0.3 - 4.5 µm & 0.3 - 5.5 µm range)

Fluoride fibers offer low losses in mid-IR: Zirconium fluoride ZrF_4 covers 0.3 to 4.5 µm, and Indium Fluoride InF_3 extends up to 5.5 µm. Fluoride fibers are recommended for applications beyond silica fiber range, but these fibers are more fragile and sensitive to moisture compared to silica fibers, necessitating careful handling. They are not recommended for high power laser applications. Operating temperature range is from - 180 °C to +150 °C.

Chalcogenide fibers (1.1 - 6.5 µm range)

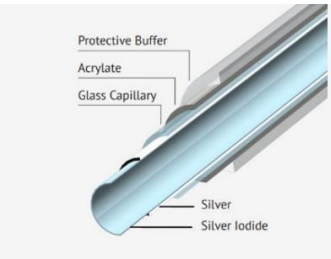
Chalcogenide infrared fibers (also known as CIR) are mode of As_2S_3 composition and transmit light in the 1.1 to 6.5 µm range, making them ideal for Mid-IR applications, especially between 2.5 to 4 µm, where they offer very low losses. CIR fibers are essential for mid-IR applications where silica cannot perform effectively. They are not recommended for high power laser applications. Operating temperature range is from - 273 °C to +90 °C for bare fiber. CIR fiber has higher numerical aperture compared to fluoride fibers and it is recommended for spectroscopy applications.

Polycrystalline fibers (3 - 17 µm range)

Polycrystalline silver halide infrared fibers (also known as PIR), made from silver halide (AgClBr) offer exceptional transmission in the mid-IR range (3-17 µm). These fibers are non-hydroscopic, non-toxic and non-brittle. Silver halide fibers are sensitive to prolonged UV radiation and reactive to many metals and SO_2 containing reactants, requiring careful handling for prolonged use. PIR fibers have no protective jacket and usually are used with a non-transparent protective tubing made of PEEK. These fibers should be handled with care, and connectorizing them requires professional experience. Operating temperature range (without cooling) is -273 °C to +140 °C. PIR fibers have a large numerical aperture and are extensively used in mid-infrared ATR fiber optic probes for FTIR spectroscopy applications and real-time in-situ reaction monitoring.

Hollow waveguides (3 - 17 µm range)

Hollow waveguides (also known as HWG) have a hollow core with a reflective inner coating to guide the light. Hollow Waveguides (HWG) design is a perfect option to transmit a low divergent IR-light of Mid IR-spectrum from 3 to 17 µm. High performance HWG are produced with double polymer jacket to secure a superior mechanical strength and high flexibility of HWGs. HWGs don't suffer from Fresnel reflection losses as solid core fibers but are more sensitive to beam coupling conditions and bending compared to PIR fibers. Operating temperature range is from –50°C to +90°C.



Hollow waveguide (HWG)

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