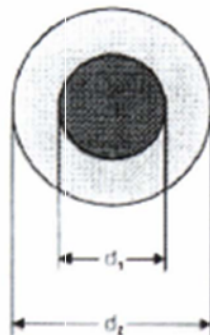


Versuch 2.7 Lichtwellenleiter / Optical Fiber

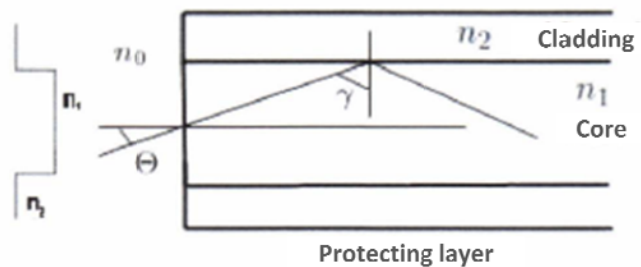
The aim of this experiment is to investigate the propagation of light in optical fibers. In modern communication systems there is an increasing application of optical fiber as transport medium for information instead of the classical copper cable. Therefore, in this experiment, the telecommunications aspects of information transport in optical fiber are in addition to the principles of the light propagation in optical fiber is investigated. The quality of the fiber, which can be characterized in particular by the intensity losses and dispersion, can be characterized by simple measuring methods.

Theoretical basics

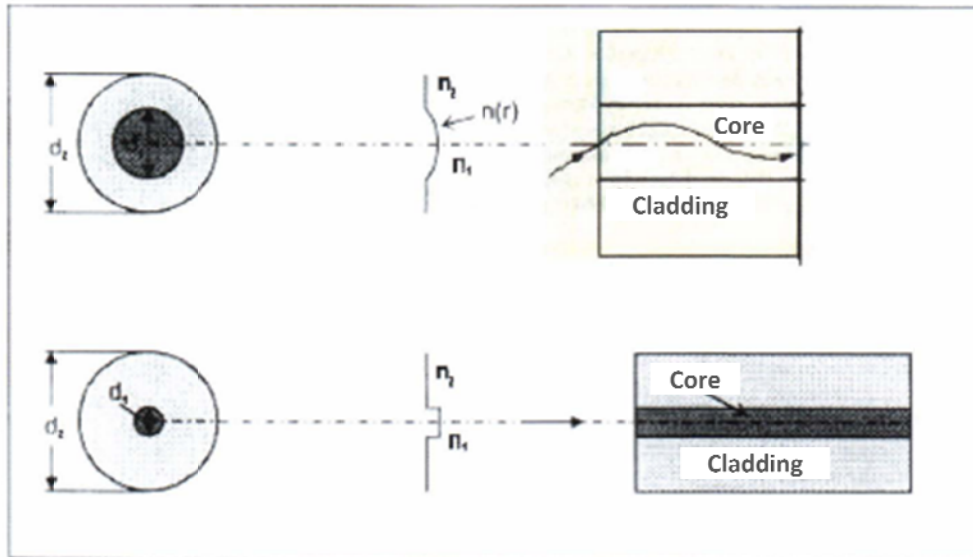
The propagation of light in fiber is based on the total reflection at the interface between the fiber core with refractive index n_1 , and the fiber cladding with refractive index n_2 . Basically, $n_1 > n_2$.



$$n_1 > n_2$$



Depending on the refractive index profile in the fiber, a distinction is made between step index and gradient index fibers. The core diameter d_1 determines the number of propagation modes in the optical fiber. For a core diameter in the order of the wavelength the light is guided only in a single mode. An important characteristic of an optical fiber is the numerical aperture NA, which describes the opening angle of the cone of light at the fiber entrance, determined by the total reflection condition in the fiber. Absorption and scattering causes losses in the fiber, which lead to an attenuation of the light. These losses show characteristic wavelength dependence. Together with the dispersion of the fiber results in an optimal working wavelength for the fiber in the near infrared range between 1300 and 1550 nm.



Literature:

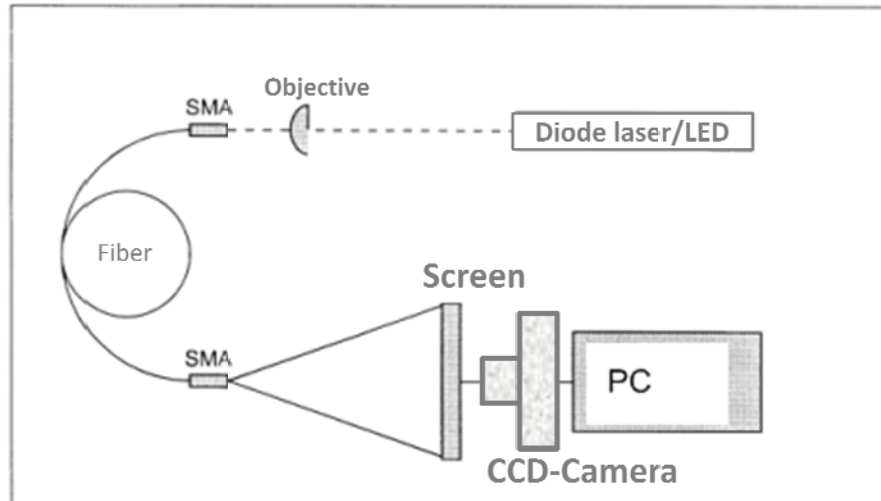
Kneubühl, Sigrist	laser
Demtröder	Laser spectroscopy
Young	Optics and Lasers
Grimm, Nowak	Fiber optic technology

Experimental setup

The optical mechanical components can be plugged into a microbank-system, which is fixed on an aluminum breadboard. For measurement of the far field and near field distribution of the light from the fiber the semiconductor laser (670nm) and LEDs (red 625nm blue 455nm and white) are used, for the calibration an IR LED (940 nm), millimeter and micrometer scale (200 scales in 5 mm). The measurements are carried out on different types of fibers assembled in SMA connector. For coupling the light into the optical fiber a microscope objective with XY-adjustment is used. The intensity profiles are recorded in all experimental parts with digital CCD cameras. To measure the wavelength-dependent attenuation, a spectrometer with a transmission grating is built.

Experimental Procedure

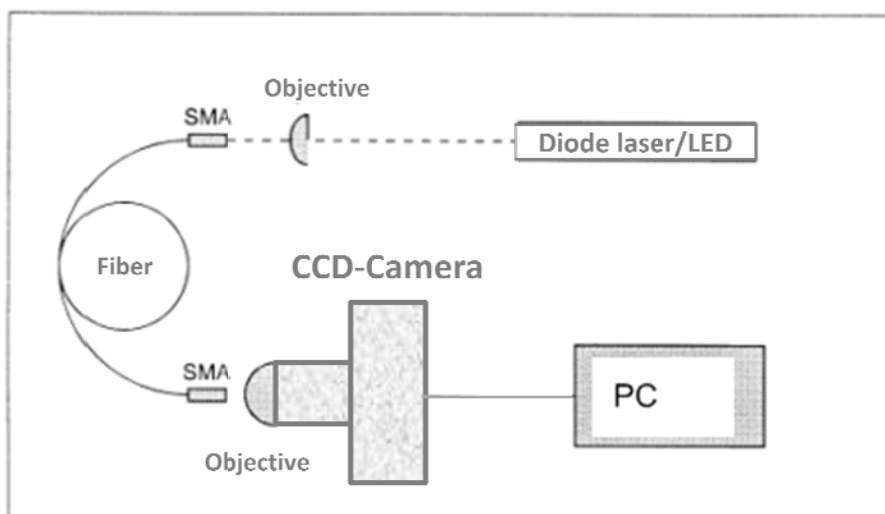
**Extreme care should be taken when operating the semiconductor laser.
Laser beam can cause retinal damage in the eye.
Never look directly into the laser beam.**



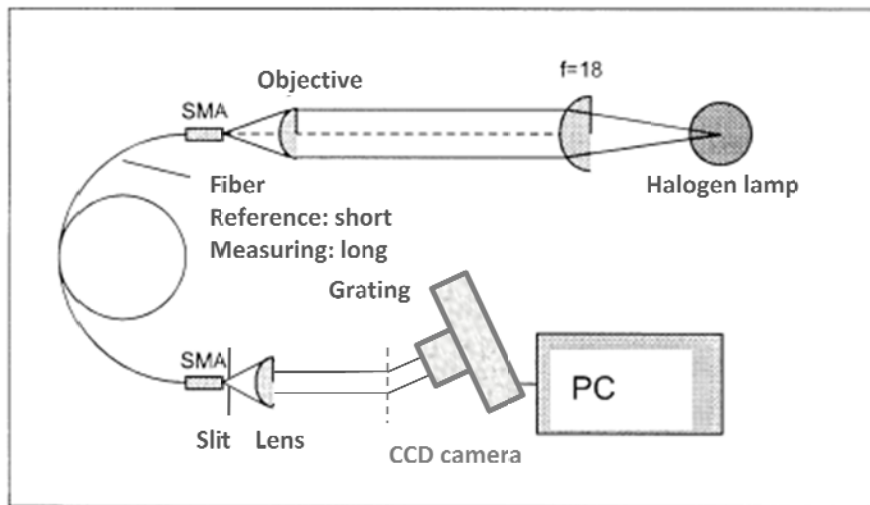
a) Measurement of the numerical aperture:

The numerical aperture of a fiber is determined from the Intensity profile in the far field. The light from the end of an illuminated optical fiber with a core diameter d is projected on a screen in the far field (ie, distance $r \gg d^2/\lambda$). The screen is imaged to the CCD camera for measuring the intensity profile. From the geometry of the arrangement and the measured intensity distribution, the numerical aperture of the optical fiber can be determined. These measurements must be made with the laser and the LED's at the different fibers (specification of fibers: <http://www.thorlabs.de>).

b) Measurement of the index profile



The refractive index profile of an optical fiber is determined by the measurement of the near field Intensity profile from the end of illuminated fiber. For this purpose, the end of the fiber is imaged by a microscope objective to the CCD-Camera. These measurements are also carried out with all fibers and the laser as well as the LED's as light sources.

c) Measurement of the wavelength dependent transmission:

For the determination of the wavelength dependent transmission $T(\lambda) = I(\lambda) / I_0(\lambda)$ of a optic fiber, a Halogen-lamp is used as broad band light source. The spectral characteristic of the Light source $I_0(\lambda)$ becomes by using a short fiber. The spectral attenuation in units of dB/m is calculated from the measured spectrum of the transmitted light through the long (10 meters) fiber. The wavelength is limited to a range between 400 to 1100 nm. Compare the measured transmission with the specification by the manufacture (<http://www.thorlabs.de>).

Questions for self-control

- 1) Explain the mechanism of light propagation in fiber.
- 2) Which influences make the step index and gradient index profiles?
- 3) Explain the difference between multi-mode and single-mode fiber.
- 4) Explain the operation of a light emitting diode and a semiconductor laser.
- 5) What is meaning of numerical aperture and mode dispersion?
- 6) Which processes influence the optical transmission and the dispersion behavior of the optical fiber?