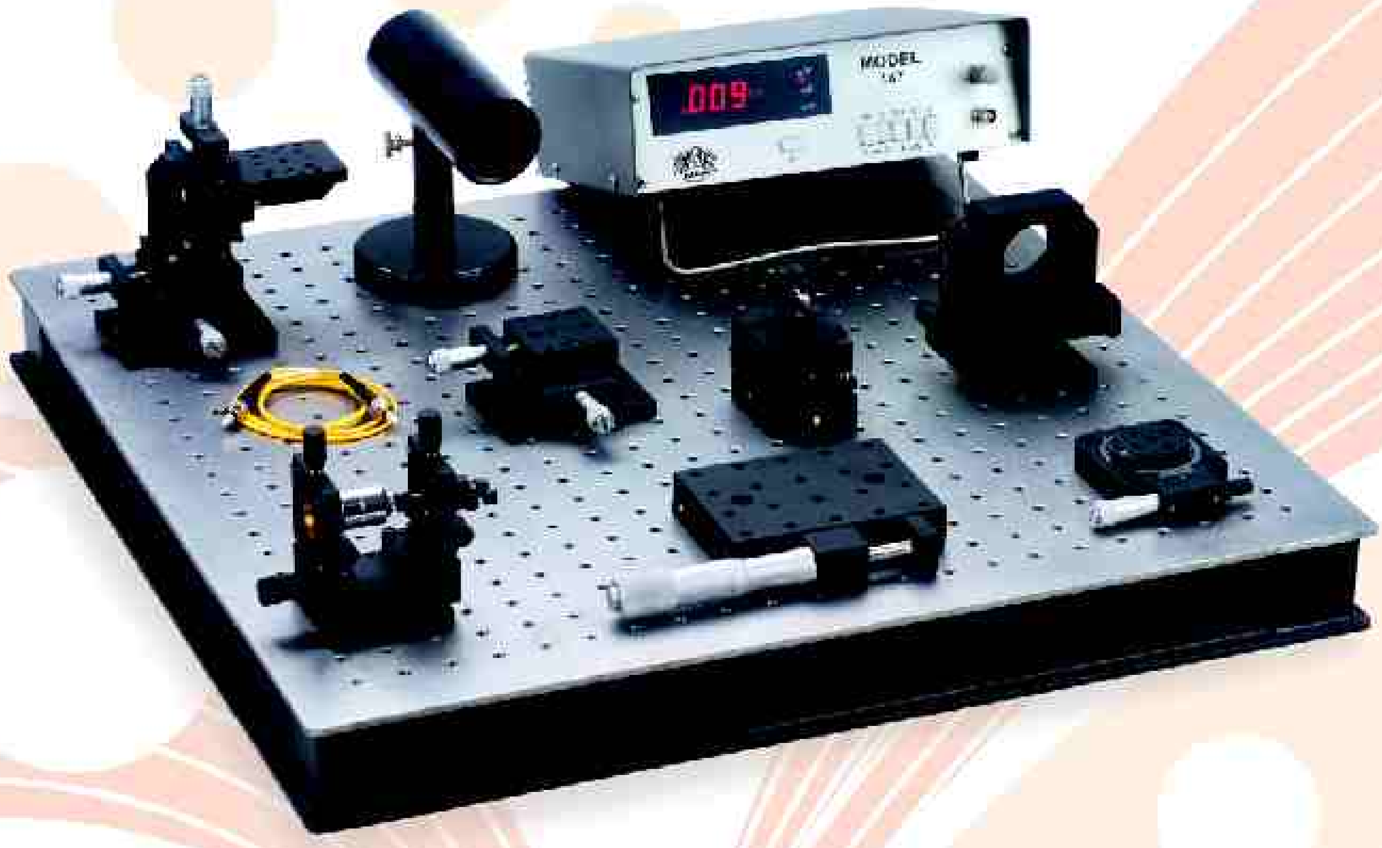
PHYSICS OF FIBER OPTICS LAB

This laboratory is designed to study the physics of fiber optics. It deals with the study of various important characteristics of optical fiber cable like numerical aperture, V number, attenuation, coupling loss and mode field diameter. Necessary components are provided to carry out the measurements and compare them with theoretical values. This laboratory covers following experiments

Measurement of coupling loss of an optical fiber:

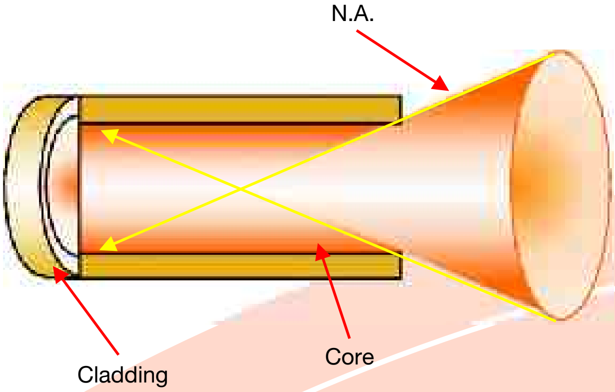
According to diffraction theory, the beam does not converge to a point but instead reduces to a central spot of light surrounded by rings of steadily diminishing intensity (Airy Discs). The central spot carries 95% of the intensity for laser beams with Gaussian profile.The Gaussian intensity distribution is given mathematically by the equation $I = I_0\, e^{-2(r/w)2}$ where e = 2.718 is the base of the natural logarithm. The Gaussian beam will appear circular where the edges of the circle are not sharp, but instead the light intensity gradually decreases from the center of the beam. An accepted definition of a radius of a Gaussian beam is the distance at which the beam intensity has dropped to $1/e^2 = 0.135$ times its peak value I_0. This radius is called spotsize. For the beam described by the above equation, the spot diameter is w. Most of the lasers have Gaussian beam profile. The spot diameter of a Gaussian beam focused by a diffraction limited lens is given by the equation Spot Diameter (d in micron) = Focal length of the Lens (f in mm) X Laser Beam full divergence angle (DA in mrad).

In order to achieve maximum coupling efficiency, the fiber core diameter has to be bigger than the spot diameter. Another factor which determines the coupling efficiency is the matching of fiber numerical aperture to numerical aperture of the focused rays. Numerical aperture of the focused rays (NA_{rays}) is given by the equation NA_{rays} = Laser Beam Diameter (BD) / (2 X Len Focal Length (f))



For smaller angles, Tanq $\theta \approx \sin\theta = NA_{rays} = BD/2f$; if $NA_{rays} \leq NA_{fiber}$ and spot diameter (w) $\leq$ fiber core diameter (d), then all of the laser light will be coupled into the fiber. The size of the singlemode fiber is very small, around 4-9 microns. In most cases, either fiber NA or core diameter will be too small. 90% coupling efficiency into the singlemode fiber from the HeNe lasers is achievable, provided that the coupler is aligned and the fiber, lens and laser beam characteristics are matched properly. For beginners, coupling efficiency of 50% is considered as a good result.

Measurement of Numerical Aperture & calculation of V number of an end prepared optical fiber



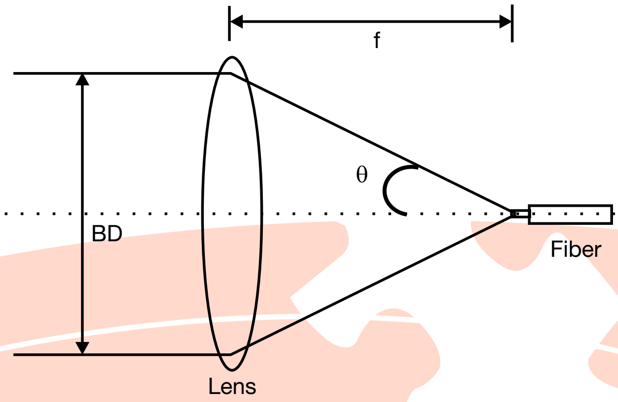
TYPICAL NUMERICAL APERTURE

In optics, the numerical aperture (NA) of an optical system is a dimensionless number that characterizes the range of angles over which the system can accept or emit light.

A detailed description of the propagation characteristics of an optical fiber can be obtained by solving Maxwell's equations for the cylindrical fiber waveguide. This leads to knowledge of the allowed modes which may propagate in the fiber. This is represented by the equation $V = K_f * a * NA$, where $K_f = 2P/lo$ is the free-space wave number (lo is the wavelength of the light in free space), a is the radius of the core and NA is the numerical aperture of the fiber. The V number is used to characterize which guided modes are allowed to propagate in a particular waveguide structure in the the cylindrical fiber waveguide.This leads to knowledge of the allowed modes which may propagate in the fiber.

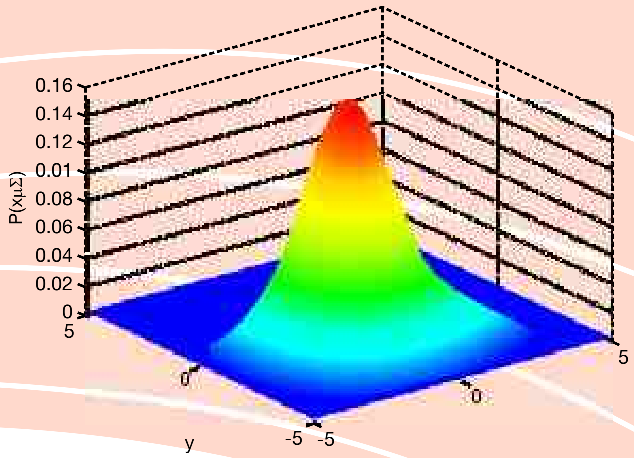
Measurement of attenuation of a optical fiber by cutback method:

Attenuation is the loss or reduction in signal strength over a certain distance. In the case of optical fiber, this is measured in decibels per kilometer (dB/km). When first developed, optical fiber handled attenuation of less than 20 dB per km. Now, typical attenuation for single mode fiber is 0.35 dB per km at a wavelength of 1310nm and even lower at 1550nm (0.25 dB per km). Several factors lead to increased attenuation, primarily scattering and dispersion. Molecular irregularities in the glass cause the light to scatter. Further attenuation is caused by light being absorbed by residual materials, such as metal and water ions.

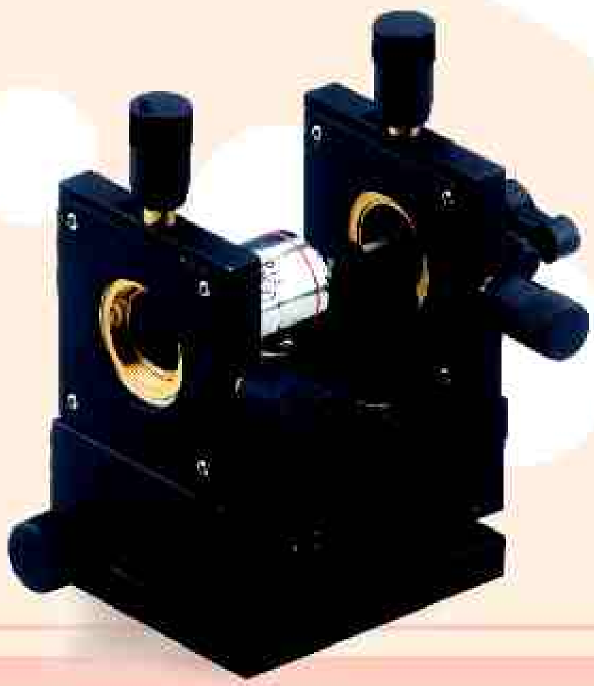


Calculation & measurement of far field pattern of an optical fiber as a function of angle:

In fiber optics, the mode field diameter (MFD) is an expression of distribution of the irradiance, i.e., the optical power per unit area, across the end face of a single-mode fiber.

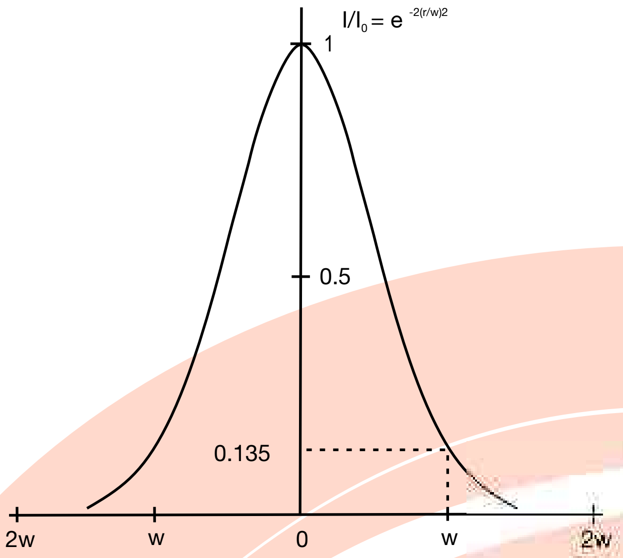


GAUSSIAN PROFILE

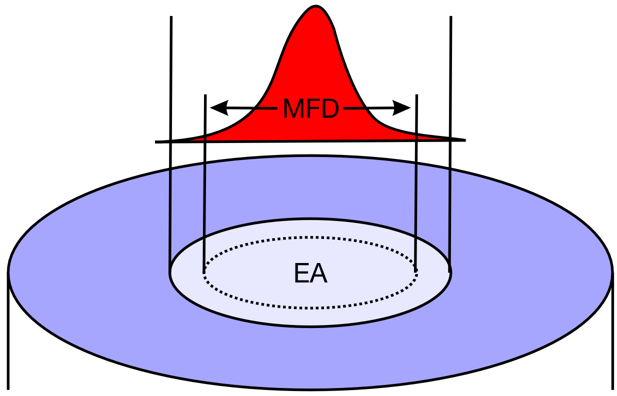


For a Gaussian power distribution in a single-mode optical fiber, the mode field diameter is that at which the electric and magnetic field strengths are reduced to 1/e of their maximum values, i.e., the diameter at which power is reduced to $1/e^2$ of the maximum power, because the power is proportional to the square of the field strength.

This describes the size of the light-carrying part of fiber, including the core and a small part of the cladding glass for single-mode fibers. Mode-field diameter (MFD) is important to note because it is a performance parameter that can determine the effect of bend-induced loss as well as splice loss. Rather than being only the core diameter, MFD is a function of wavelength, the core diameter, and the refractive-index.



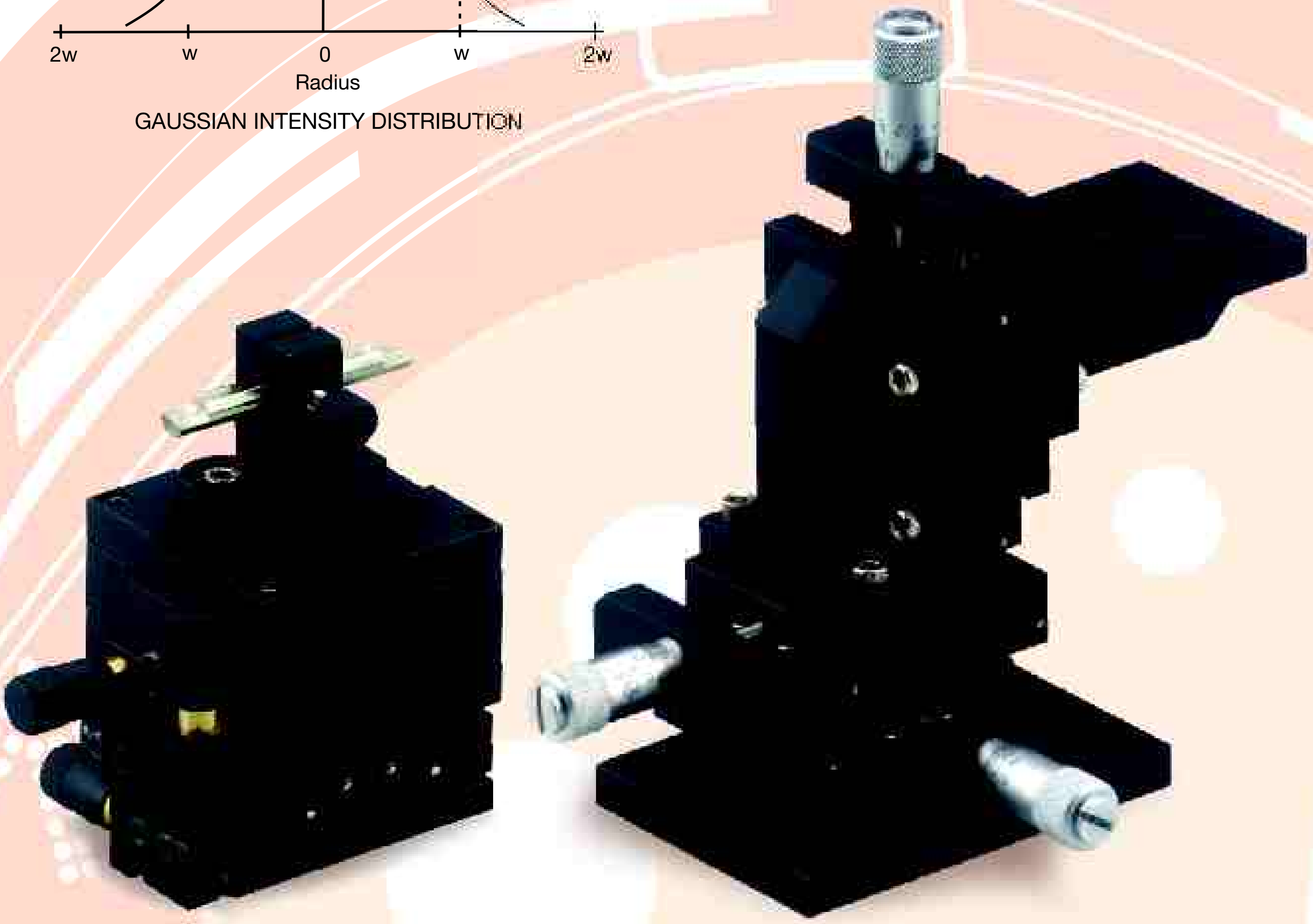
GAUSSIAN INTENSITY DISTRIBUTION



LIGHT DISTRIBUTION

This laboratory consists of the following components:

- Laser source - HeNe Laser (1mW)
- Laser power meter with detector
- Laser to Fiber Coupler for bare fiber
- Laser to Fiber Coupler for Patch Chords
- Fiber Single mode,multimode large core patch chords and cables
- X-Y-Z positioners
- Rotary stage
- Fiber Holder Assembly
- Optical platform
- Mounting stands and plates
- Necessary accessories
- Experimental manual



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