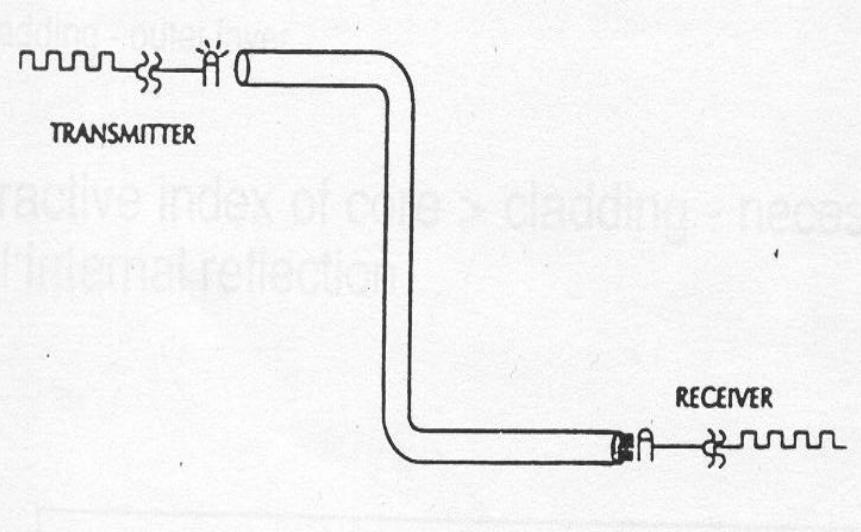
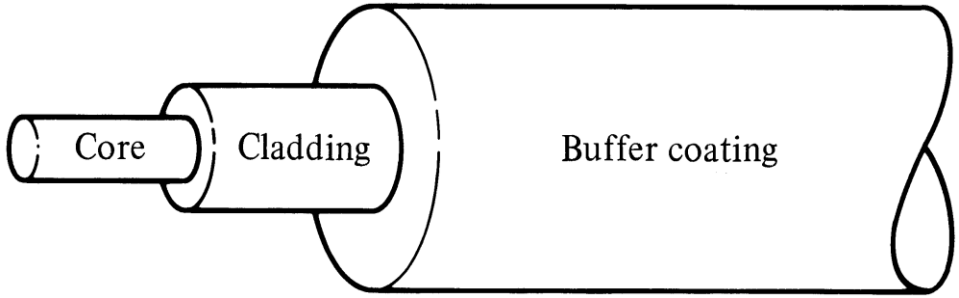
Transmission Characteristics of Optical Fiber I



OPTICAL FIBER

- An optical fiber is a long cylindrical dielectric waveguide, usually of circular cross-section, transparent to light over the operating wavelength.

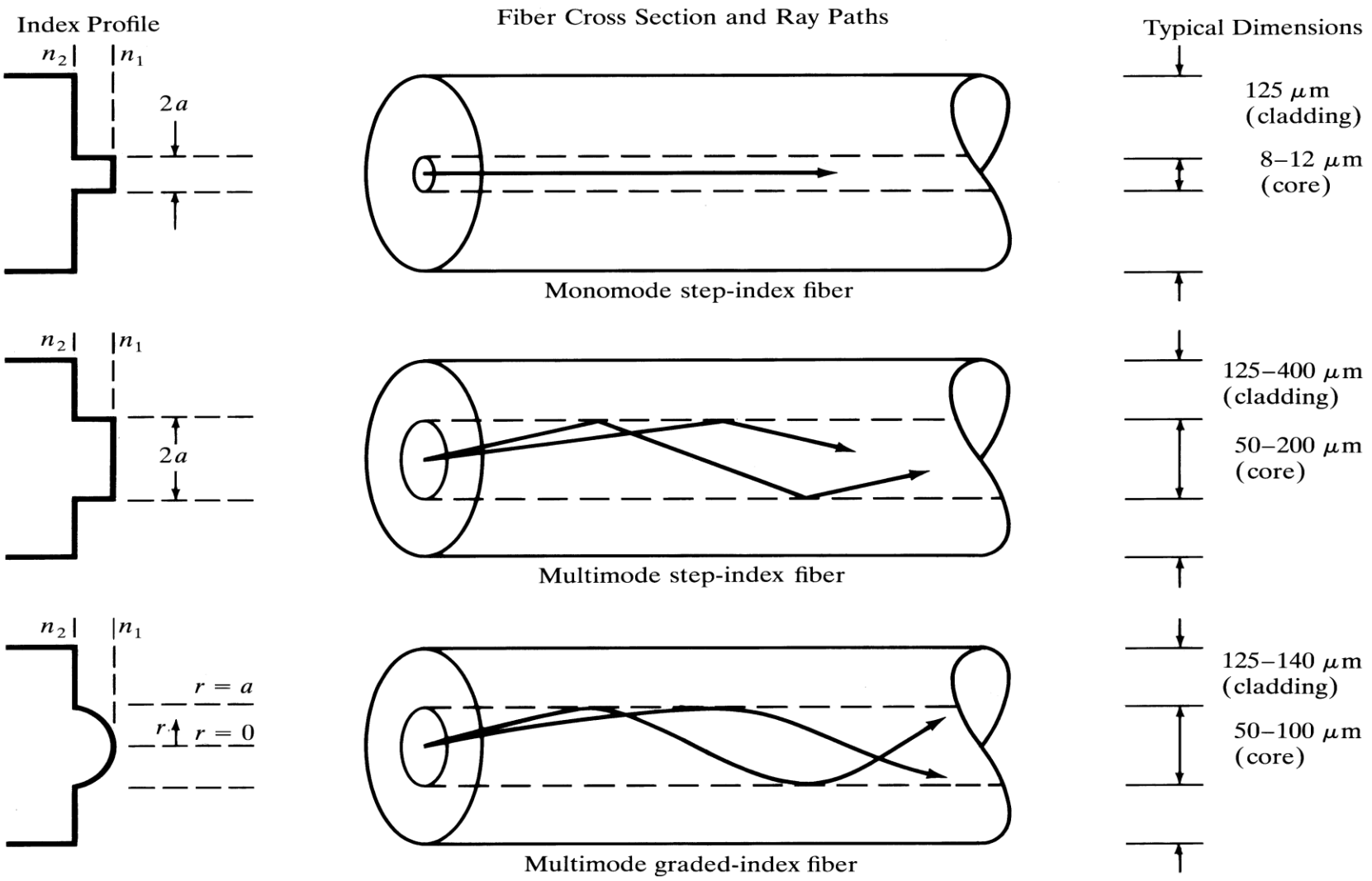
Fiber Structure



- A single solid dielectric of two concentric layers. The inner layer known as **Core** is of radius 'a' and refractive index 'n_1'. The outer layer called **Cladding** has refractive index 'n_2'.

$$n_2 < n_1 \rightarrow \textbf{condition necessary for TIR}$$

Step Index / Graded Index



DESIGNER'S PARAMETERS

Numerical Aperture (NA) :

$$NA = \sin\theta_a = [(n_1)^2-(n_2)^2]^{1/2}$$

0.10-0.25 for SMF, 0.20-0.50 for MMF

Relative Refractive Index Difference (Δ):

$\Delta = (n_1 - n_2)/n$; n- the average refractive index

<0.4% for SMF, >1% for MMF

Normalized Frequency or **V-Number:**

$V = [(2\pi a)/\lambda]\ NA$

$V \leq 2.405$ for SMF; ≥ 10 for MMF

Transmission Characteristics

Characteristics of Primary Importance

- **Attenuation (or Transmission loss):** determines the maximum ***repeater less separation*** between a transmitter and receiver.

- **Dispersion**: limit the information – carrying capacity of a fiber i.e. ***Bandwidth***

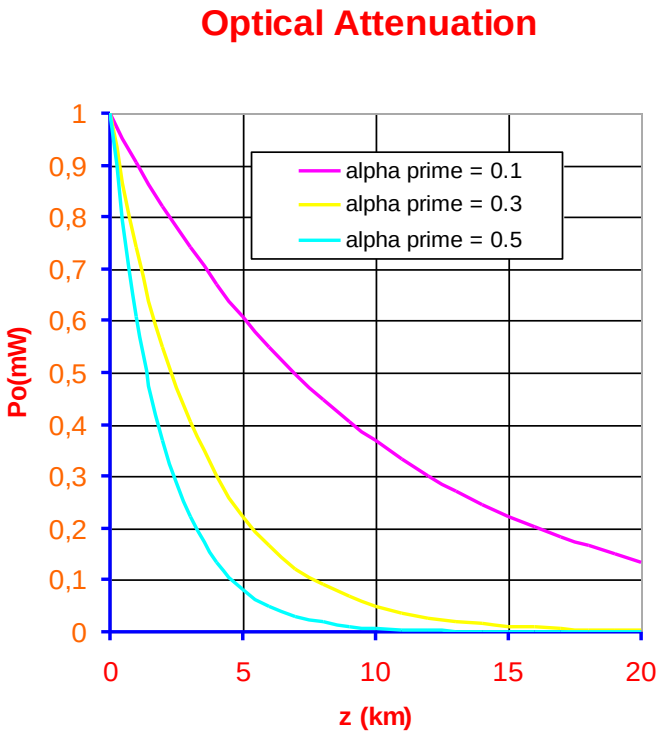
Fibre Performance

Optical Fiber Attenuation

> **Logarithmic relationship between the optical output power and the optical input power**

> **Measure of the decay of signal strength or light power**

$$P(z) = P_{in} e^{-\alpha(z)}$$



where,

P(z) **:** Optical power at distance ‘z’ from input

P_o **:** Input optical power

α **:** Fiber attenuation coefficient, [dB/km]

Optical Fiber Attenuation

> **Usually, attenuation is expressed in terms of decibels or mostly dB/km**

$$\alpha = \frac{1}{z} 10 \log\left(\frac{P_{out}}{P_{in}}\right)$$

- **Attenuation is because of different mechanisms**

$$\alpha_{Total} = \alpha_{absorption} + \alpha_{scattering} + \alpha_{bending}$$

Basic Attenuation Mechanisms

1. **Material Absorption (Intrinsic and Extrinsic)**

2. **Scattering (Linear and Non-linear)**

3. **Bending loss (Macrobends and Microbends)**

Material Absorption

A loss mechanism related to the bulk materials and the fabrication process for the fiber

- Results in the loss of some of the transmitted optical power in the waveguide

Absorption of light (optical energy)

a. Intrinsic : caused by the interaction with one of the major components of the glass

- Absorption in the IR-wavelength region (Molecular absorption)
- Absorption in UV wavelength region (Electronic absorption)

b. **Extrinsic** : caused by impurities within the glass

- Mainly absorption by **transition metal** impurities (Cr, Cu, Fe, Mn, Ni, V etc.)

  > Reduced to acceptable levels (i.e. one part in 10^{15}) by traditional glass refining techniques.

- Another major extrinsic loss mechanism is caused by absorption due to water (Hydroxyl- OH ion) dissolved in the glass

  > Hydroxyl groups are bonded to glass structure and have fundamental stretching vibrations depending on group position.

Material Absorption & Scattering Losses

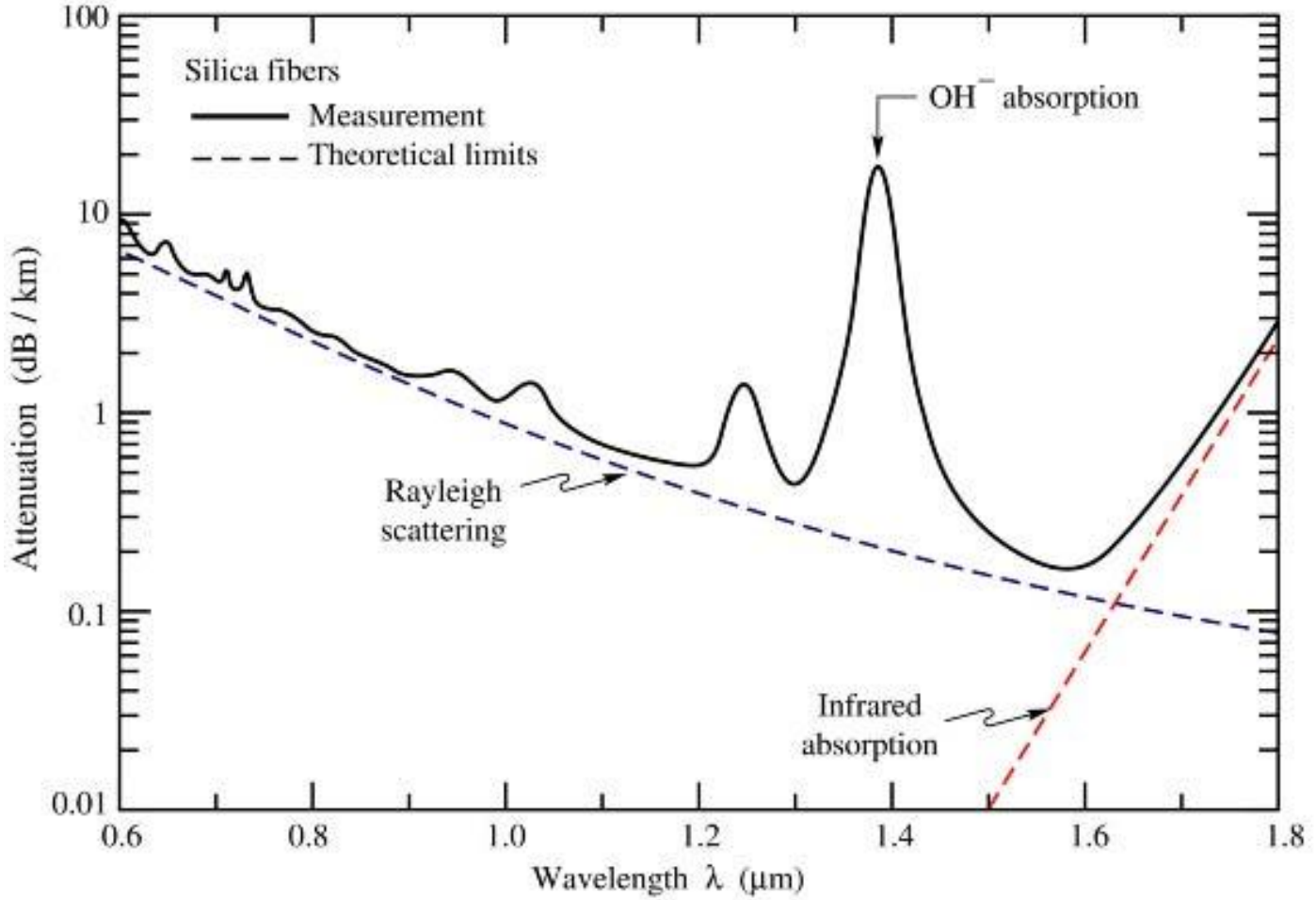
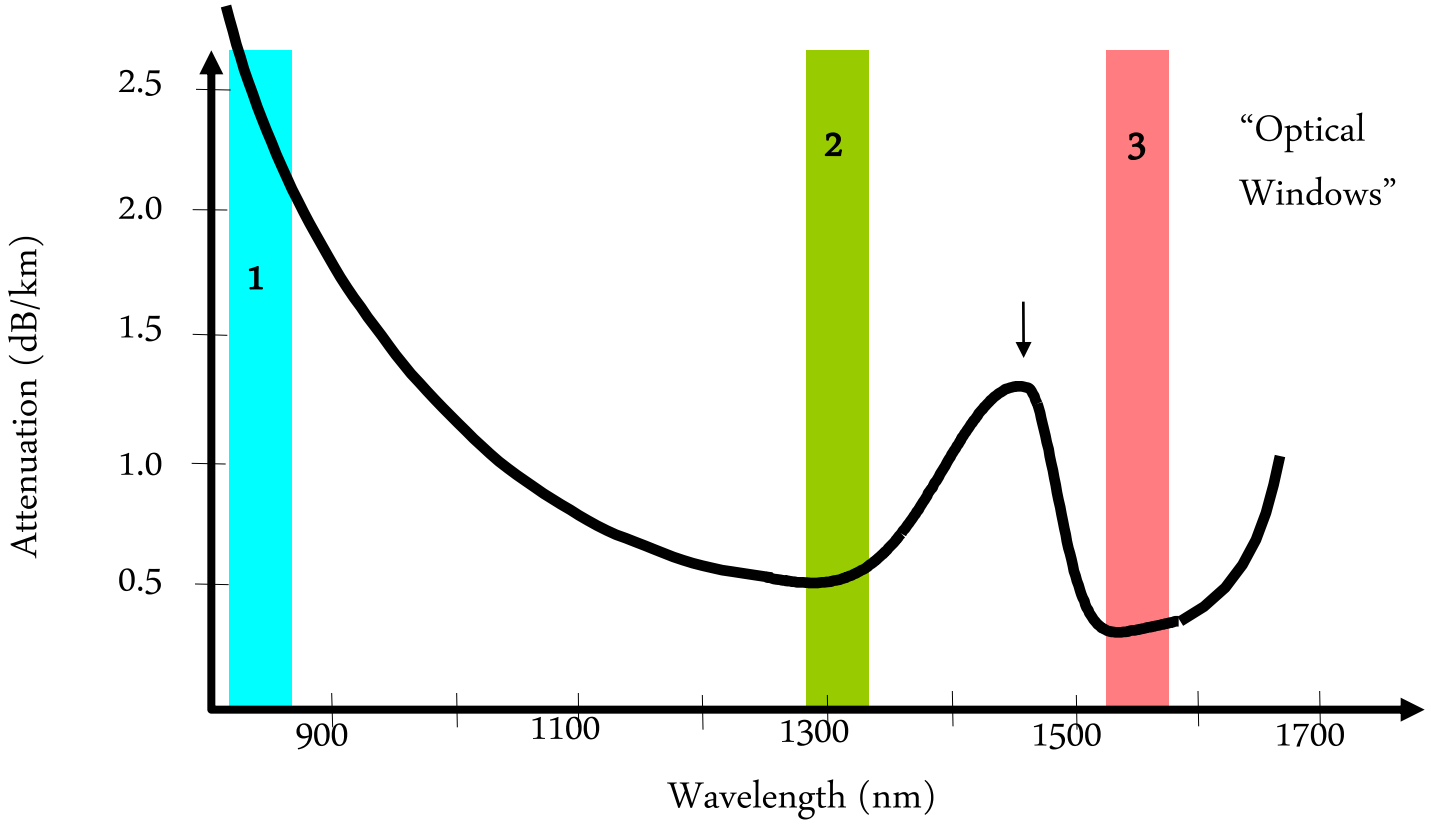


Fig. 12.2. Measured attenuation in silica fibers (solid line) and theoretical limits (dashed lines) given by Rayleigh scattering in the short-wavelength region, and by molecular vibrations (infrared absorption) in the infrared spectral region.

Attenuation in Silica Fibers



850 nm **1310 nm** **1550 nm**

THANK YOU