2.13 Losses in Optical fibres

When light propagates through an optical fibre, a small percentage of light is lost through different mechanisms. The loss of optical power is measured in terms of decibels per kilometre for attenuation losses.

Attenuation:

It is defined as the ratio of the optical power output (P_{out}) from a fibre of length 'L' to the power input (P_{in}).

$$Attenuation\ (\alpha) = \frac{-10}{L} \log \frac{Pout}{Pin} \frac{dB}{Km}$$

Since attenuation plays a major role in determining the transmission distance, the following attenuation mechanisms are to be considered in designing an optical fibre.

(1) Absorption

(2) Scattering and

(3) Radiative losses.

(4) Distortion and Dispersion

Absorption

Usually absorption of light occurs due to imperfections of the atomic structure such as missing molecules, (OH^-) hydroxyl ions, high density cluster of atoms etc., which absorbs light. Absorption also depends on the wavelength of the light used.

Scattering

Scattering is also a wavelength dependent loss, which occurs inside the fibres. Since the glass is used in fabrication of fibres, the disordered structure of glass will make some variations in the refractive index inside the fibre. As a result, if light is passed through the atoms in the fibre, a portion of the light is scattered (elastic scattering). This type of scattering is called Rayleigh scattering.

Rayleigh scattering Loss $\propto \frac{1}{\lambda^4}$

Radiative losses

Radiative loss occurs in fibres, due to bending of finite radius of curvature in optical fibres. The types of bends are

(a) Macroscopic bend and

(b) Microscopic bend

Macroscopic bends:

If the radius of core is large compared to fibre diameter as shown in figure, it may cause large- curvature at the position where the fibre cable

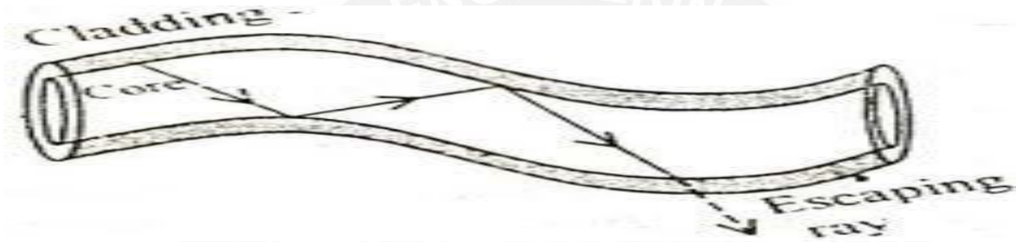

Fig 2.13.1 Macroscopic bends

turns at the corner. At these corners the light will not satisfy the condition for total internal reflection and hence it escapes out from the fibre. This is called as macroscopic/macro bending losses. Also note that this loss is negligible for small bends.

Microscopic bends:

Micro-bends losses are caused due to non-uniformities or micro-bends inside the fibre as shown in figure. This micro bends in fibre appears due to non-uniform pressures created during the cabling of the fibre or even during the manufacturing itself. It leads to loss of light by leakage through the fibre.

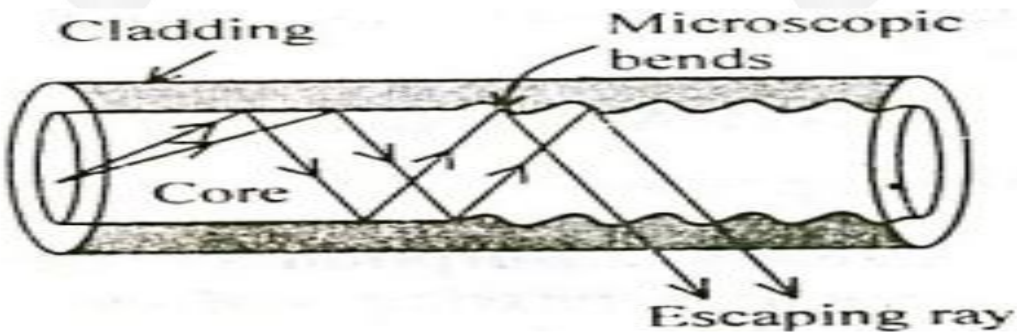

Fig 2.13.2 **Microscopic bends**

Remedy:

Micro-bend losses can be minimised by extruding (squeezing out) a compressible jacket over the fibre. In such cases, even when the external forces are applied, the jacket will be deformed but the fibre will tend to stay relatively straight and safe, without causing more loss.

Distortion and Dispersion

The optical signal becomes increasingly distorted as it travels along a fibre. This distortion is due to dispersion effect.

Dispersion

When an optical signal or pulse is sent into the fibre the pulse spreads/broaden as it propagates through the fibre. This phenomenon is called dispersion as shown in figure.

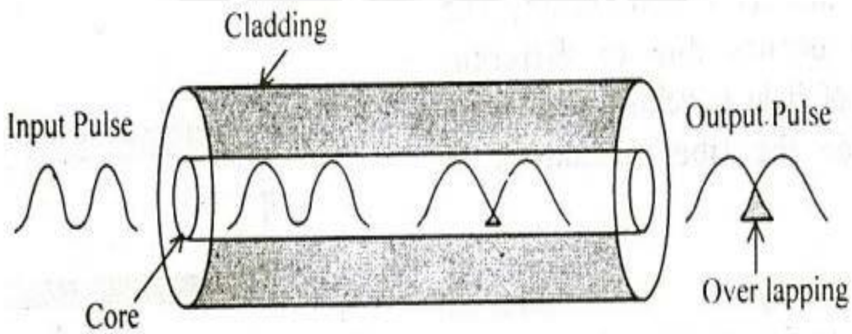

Fig 2.13.3 Dispersion

From figure we can see that the pulse received at the output is wider than the input pulse. Hence the output pulse is said to be distorted, due to dispersion effect.

The pulse broadening or dispersion will occur in three ways, viz,

(1) Inter-modal dispersion
(2) Material dispersion or chromatic dispersion
(3) Waveguide dispersion.

Inter-modal dispersion

When more than one mode is propagating through a fibre, then inter modal dispersion will occur. Since, many modes are propagating, they will

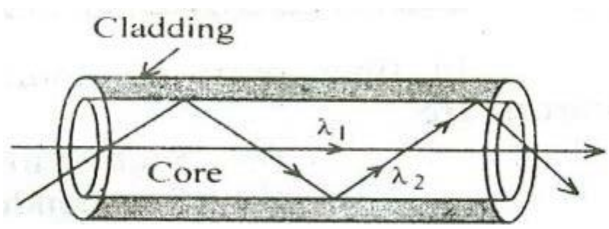

Fig 2.13.4 Inter-modal dispersion

have different wavelength and will take different time to propagate through the fibre, which leads to inter-modal dispersion.

Explanation:

When a ray of light is launched into the fibre, the pulse is dispersed in all possible paths through the core, so called different modes. Each mode will be of different wavelength and has different velocity as shown in figure. Hence, they reach the end of the fibre at different time. This results in the

elongation or stretching of data in the pulse. Thus causes the distorted pulse. This is known as inter- modal dispersion.

Material dispersion/ Chromatic dispersion

In material dispersion, the dispersion occurs due to different wavelength

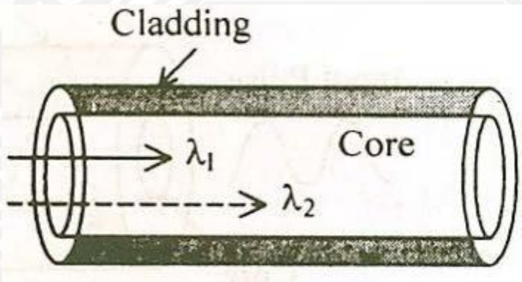

Fig 2.13.5 Material dispersion

of light travelling at different speed inside the fibre as shown in figure.

Remedy:

The material dispersion can be minimised at certain wavelengths say 870 nm, 1300 nm and 1550 nm, these wavelengths are termed as Zero Dispersion Wavelength (ZDW). When the light wavelength is lesser than the zero dispersion wavelengths (ZDW), it travels slower and when it is higher than ZDW it travels faster. Thus the speed is altered and adjusted in such a way that all the waves passing through the fibre will move with constant speed and hence the material dispersion is minimised.

Wave guide dispersion

The wave guide dispersion arises due to the guiding property of the fibre and due to their different angles at which they incident at the core-cladding interface of the fibre as shown in figure.

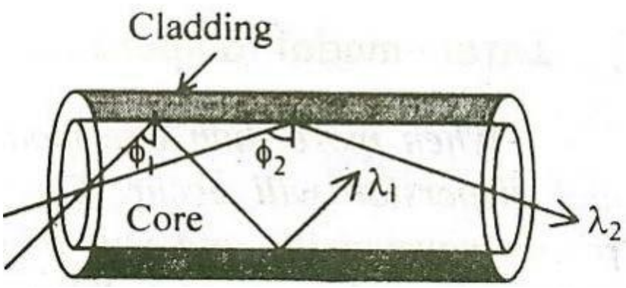

Fig 2.13.6 Wave guide dispersion

In general

Inter-modal dispersion > Material dispersion > Waveguide dispersion