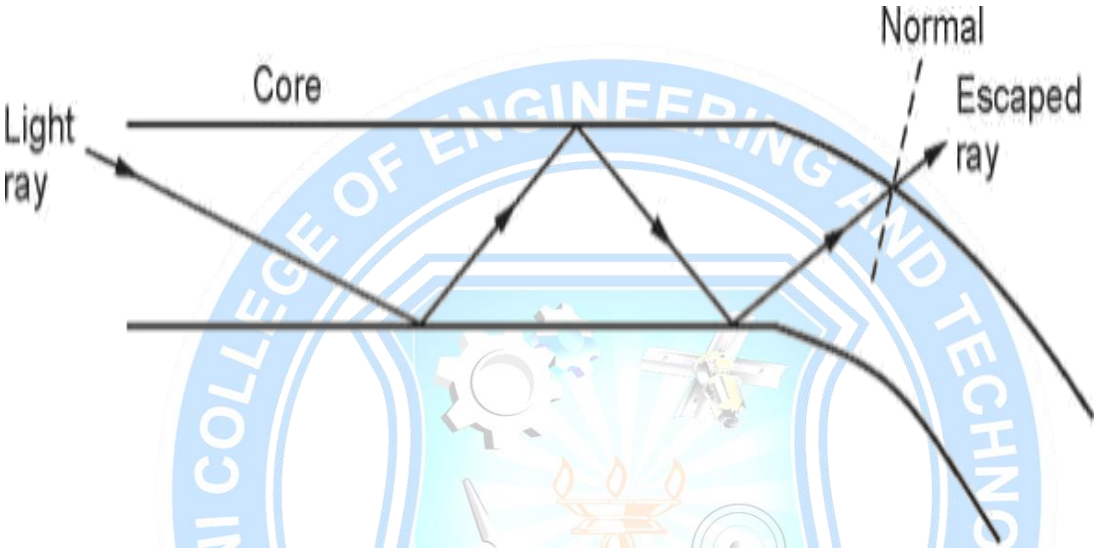
2.4 Bending Losses

- Losses due to curvature and losses caused by an abrupt change in radius of curvature are referred to as 'bending losses'.
- The sharp bend of a fiber causes significant radiative losses and there is also possibility of mechanical failure. This is shown in Fig.



- As the core bends the normal will follow it and the ray will now find itself on the wrong side of critical angle and will escape. The sharp bends are therefore avoided.
- The radiation loss from a bent fiber depends on

i) Field strength of certain critical distance x_c from fiber axis where power is lost through radiation.

ii) The radius of curvature R.

- The higher order modes are less tightly bound to the fiber core, the higher order modes radiate out of fiber firstly.
- For multimode fiber, the effective number of modes that can be guided by curved fiber is given expression :

$$N_{eff} = N_{\infty}\left\{1 - \frac{\alpha+2}{2\alpha\Delta}\left[\frac{2a}{R} + \left(\frac{3}{2n_2 k R}\right)^{2/3}\right]\right\}$$

where,

α is graded index profile.

A is core - cladding index difference.

n_2 is refractive index of cladding

k is wave propagation constant $\frac{2\pi}{\lambda}$

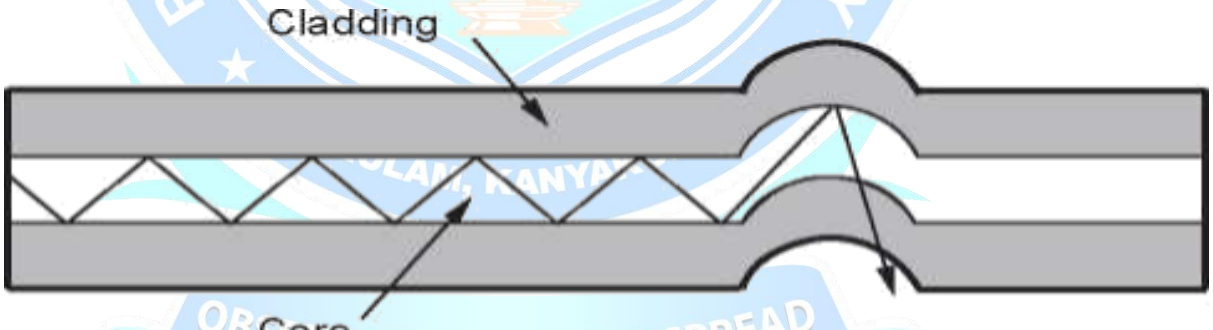
$N_\sim$ is total number of modes in a straight fiber

$$N_\infty = \frac{\alpha}{\alpha + 2}(n_1 k a)^2 \Delta$$

- The bending losses are categorised into two types.
    1. Microscopic bending losses
    2. Macroscopic bending losses

Microbending Losses

- Microbending is a loss due to small bending or distortions. This small microbending is not visible. The losses due to this are temperature related, tensile related or crush related.
- The effects of microbending on multimode fiber can result in increasing attenuation (depending on wavelength) to a series of periodic peaks and troughs on the spectral attenuation curve. These effects can be minimized during installation and testing

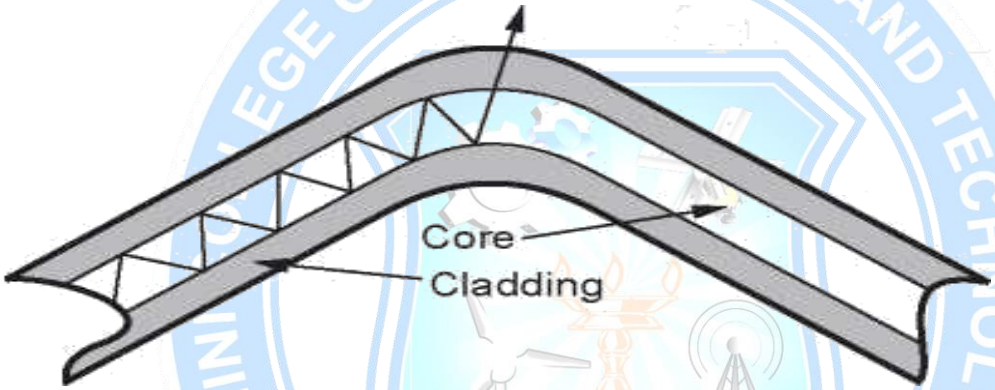


- For a multimode graded index fiber with core radius a and outer fiber radius as b, the microbending loss is given by

$$F_{(\alpha m)} = \left[1 + \pi \Delta^2 \left(\frac{b}{a}\right)^4 \frac{E_f}{E_j}\right]^{-2}$$

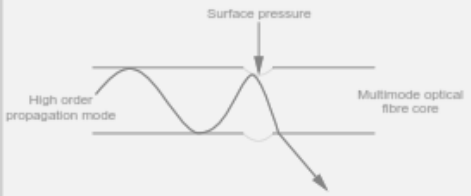
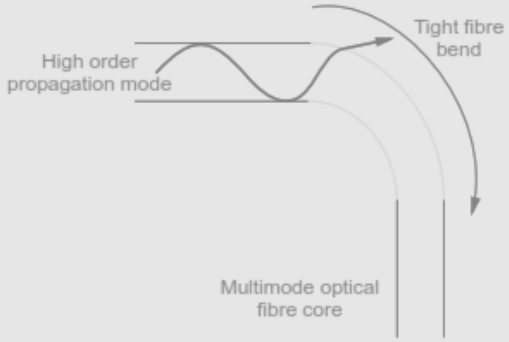
Macrobending Losses/Large Radius Losses

- The change in spectral attenuation caused by macrobending is different to microbending. Usually there are no peaks and troughs because in a macrobend no light is coupled back into the core from the cladding as can happen in the case of microbends.
- The macrobending losses are caused by large scale bending of fiber. The losses are eliminated when the bends are straightened. The losses can be minimized by not exceeding the long term bend radii
- The bending losses are large in multimode fibers at critical radius of curvature. The critical radius (R_c) is given by:



$$R_c = \frac{3 n_1^2 \cdot \lambda}{4\pi (n_1^2 - n_2^2)^{3/2}}$$

Comparison of Macrobending Loss & Microbending Loss

	Macrobending Loss	Microbending Loss
1.	Macrobending loses occur when fibres are physically bent beyond the point at which the critical angle is exceeded	Microbending occur when pressure is applied to the surface of an optical fibre. The pressure applied to the surface results in deformation of the fibre core at the core-cladding interface.
2.	 Microbending	 Macrobending