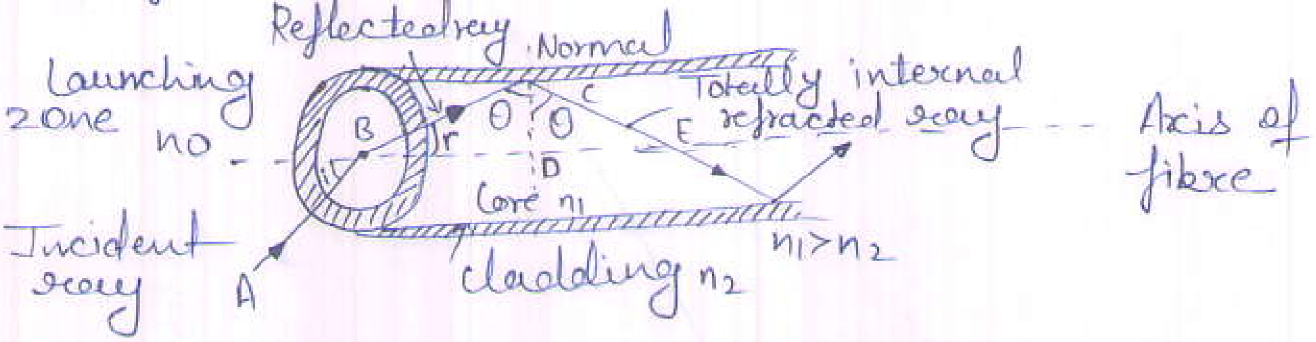
EL-304 II Test MW & OFC

Q(1) Explain Acceptance Angle.

Consider a cylindrical fibre wire which consist of an inner core of refractive index n_1 and an outer cladding of refractive index n_2 where $n_1 > n_2$. let n_0 be the refractive index of the medium from which the light rays enters the fibre. This end of the fibre is known as launching end. The ray refracts at an angle r and strikes the core-cladding.



Interface at an angle θ. let θ is greater than critical angle θ_c. As long as the angle θ is greater than θ_c, the light stay within the fibre.

Applying Snell's law of refraction at the point of entry of the ray AB into the core, we have

$$n_0 \sin i = n_1 \sin r \quad \text{-- (i)}$$

from triangle BCD, it is seen that

$$r = (90 - \theta) \text{ or } \sin r = \sin(90 - \theta)$$

$$\sin r = \cos\theta \quad \text{--- (2)}$$

Substituting the value of Sin r from eq.(2) in eq.(1) we get

$$n_0 \sin i = n_1 \cos\theta$$

or

$$\sin i = \left(\frac{n_1}{n_0}\right)\cos\theta \quad \text{-- (3)}$$

If i is increased beyond a limit, θ will drop below the critical value θ_c & the ray will escape from the side wall of the fibre. The largest value of i i.e. i_{max} occurs when $\theta = \theta_c$. Applying this condition in eq. (3), we get

$$\sin(i_{max}) = \left(\frac{n_1}{n_0}\right)\cos\theta_c \quad --- \quad (4)$$

we know that, $\sin\theta_c = \frac{n_2}{n_1}$

$$\therefore \quad \cos\theta_c = \sqrt{1-\sin^2\theta_c} = \sqrt{(n_1^2-n_2^2)}/n_1$$

from eq. (4), we have

$$\sin(i_{max}) = \frac{n_1}{n_0} \times \frac{\sqrt{(n_1^2-n_2^2)}}{n_1} = \frac{\sqrt{(n_1^2-n_2^2)}}{n_0} \quad --(5)$$

Quite often the incident ray is launched from air medium i.e, $n_0 = 1$.

Designating i_{max} as i_0, eq (5) can be written as

$$\boxed{\sin i_0 = \sqrt{(n_1^2-n_2^2)}}$$

Here i_0 is called the Acceptance angle of the fibre

$$\therefore \quad \boxed{i_0 = \sin^{-1}\sqrt{(n_1^2-n_2^2)}}$$

So, the acceptance angle is defined as the maximum angle that a light ray can have relative to the axis of the fibre so that it may propagate down the fibre. It may also be defined as the maximum angle from the fibre axis at which light may enter the fibre so that it will propagate in the core by total internal reflection.

Q(2) Explain the term. Numerical - Aperture.

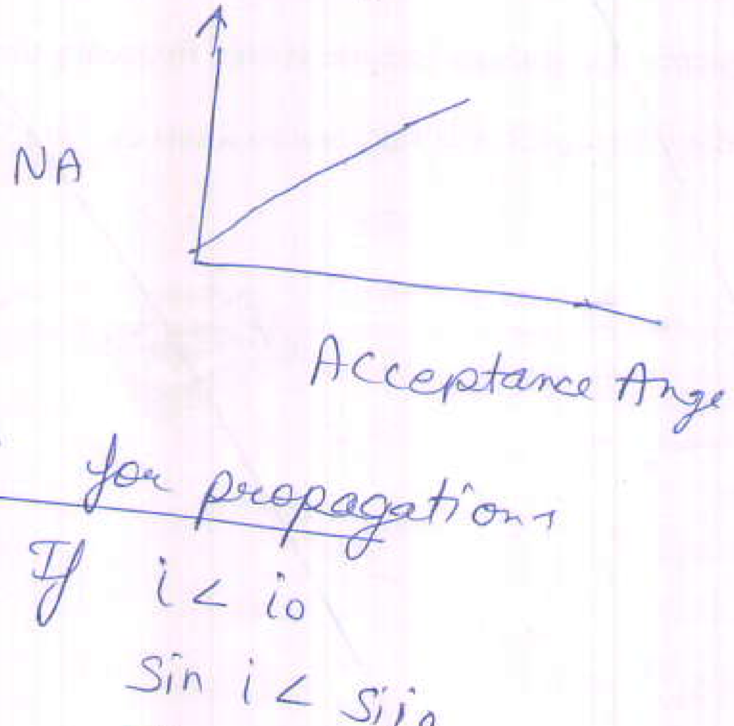
Ans) N.A → N.A is also called Figure of Merit of optical Fibre.

This is defined as Sin of Acceptance Angle.

$$NA = \sin i_0$$

$$= \sqrt{n_1^2 - n_2^2}$$

NA determines the light gathering ability of Fibre. So, it is called Measure of Amount of Light.



Condⁿ for propagation →

If $i < i_0$

$$\sin i < \sin i_0$$

$$\sin i < \sqrt{n_1^2 - n_2^2}$$

$$\boxed{\sin i < NA}$$

This is the condⁿ of propagation of light ē in the fibre.

$$\Delta = \frac{n_1 - n_2}{n_1}$$

$$NA = \sqrt{n_1^2 - n_2^2}$$

$$n_1^2 - n_2^2 = (n_1 + n_2)(n_1 - n_2)$$

$$n_1^2 - n_2^2 = \left(\frac{n_1 + n_2}{2}\right)\left(\frac{n_1 - n_2}{n_1}\right) 2n_1$$

$$\frac{n_1 - n_2}{n_1} = \Delta$$

$$n_1^2 - n_2^2 = \frac{n_1 + n_2}{2} (2n_1 \Delta)$$

$$\because \frac{n_1 + n_2}{2} \cong n_1 \quad (\text{If } n_1 \simeq n_2)$$

$$n_1^2 - n_2^2 \cong n_1 (2n_1 \Delta$$

$$n_1^2 - n_2^2 = 2n_1^2 \Delta$$

$$\boxed{\sqrt{n_1^2 - n_2^2} = \sqrt{2\Delta}\, n_1}$$

$$\boxed{NA = n_1 \sqrt{2\Delta}}$$

Q(3) Write Short Note on →

(i) Attenuation in OFC

(ii) Dispersion in OFC

Ans → Attenuation in Fibres means loss of optical fibre suffered by the optical Signal in fibre itself.

Attenuation is defined as the Ratio of optical fibre o/p Power from a fibre of length L to the I/P optical Power (P_{in}).

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

If $P_{in} = P_{out}$ then

$$\alpha = 0$$

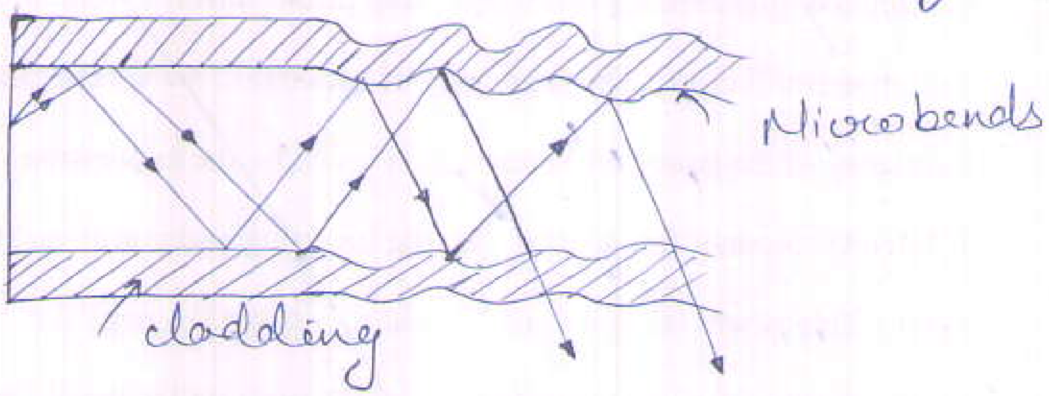
that means No Loss, No Attenuation

There are three types of Attenuation losses in OFC →

(a) Absorbtion losses → It depends on the Wavelength of light & on any impurities in fibre itself. Impurities like transition Metals such as Cu, Ni, Cr, Mg, OH(ions) are major sources of these losses. During light Signal. Propagation the photons of light interact c e⁻ of impurities later on e⁻ give up absorbed energy either in form of Heat etc. So losses occurs.

(b) Scattering Loss : We know glass is disordered structure in which there are microscopic inhomogeneities & material density fluctuations in composition. These cause local variations in Ref. Index. When light propagates through such a structure it suffers scattering losses. This type of scattering is same as Rayleigh Scattering.

(c) Fibre Bend Losses : These are caused by non-uniformities in the manufacturing of the fibre or by non-uniform lateral pressures created during cabling of fibre. Microbends change the angle at which light strikes the core to cladding interface.

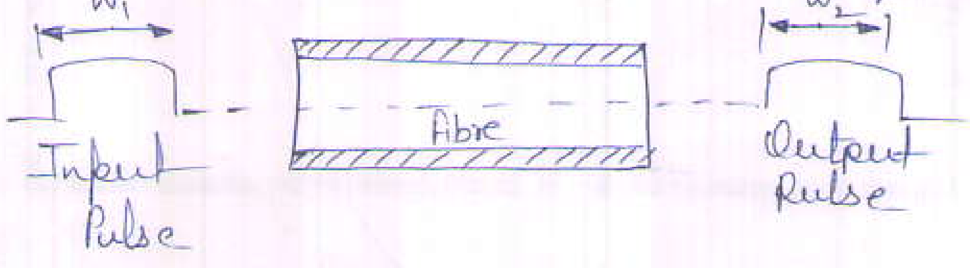


Dispersion:- When data is sent along the Commn fibre, information is generally contained in the form of pulses of Intensity of light. Fig. shows the I/P & O/P Pulses across fibre. It is seen that O/P pulse is wider the I/P pulse, the Amplitude of o/p is also decreased. It shows the pulse becomes distored. as it propogates through fibre. The reason of this distortion is dispersion. So Dispersion means 'Pulse Broadening'.

$$D_{(Dispersion)} = \sqrt{W_2^2 - W_1^2}$$

$W_2 \rightarrow$ O/P Pulse width
$W_1 \rightarrow$ I/P Pulse width.

There are three Mechanism which causes the distortion due to dispersion are,



Dispersion Mechanism

Dispersion Losses Mechanism →

(i) Material Dispersion
(ii) Waveguide Dispersion
(iii) Intermodal Dispersion

Material Dispersion arises due to the Variation of Refractive Index with wavelength or freq. of light i.e. it is a wavelength Based effect.

Waveguide dispersion arises from the guiding properties of fibre. The effective refractive Index for any mode Varies c̄ wavelength.

Intermodal Dispersion: In Multimode fibres, in each mode ray travels c̄ diffⁿ velocity, So there is a difference in propagation times for diffⁿ Modes. This results in pulse spreading. It is not present in Single Mode fibres.