Optical fibre – Industrial parameters

The industry has defined new quantities to qualify an optical fibre. These are

(1) – numerical aperture

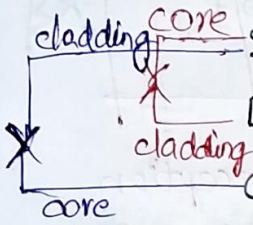
(2) Fractional refractive index

Fractional refractive inden

The difference in the refractive indices of materials used for core and cladding is very small compared

to the typical media like air-water interface, water-glass interface

Medium	n
Air	1
Water	1.33
SiO_2 (silica)	1.458
B_2O_3 doped SiO_2	< 1.458
GeO_2 doped SiO_2	> 1.458



Usually silica based fibres are used. Doping of silica with other oxides alters the refractive index slightly.

This slight change is reported in the industry as a fractional refractive index Δ given by

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

In order to guide light rays effectively through a fibre $\Delta \ll 1$

Typically, Δ is of the order of 0.01.

Numerical aperture

Numerical aperture of an optical fibre is defined as the sine of the acceptance angle

$$\begin{aligned} N.A. &= \sin\theta_0 \\ &= \sin\left(\sin^{-1}\sqrt{n_1^2 - n_2^2}\right) \\ &= \sqrt{n_1^2 - n_2^2} \end{aligned}$$

$$= \sqrt{(n_1+n_2)(n_1-n_2)}$$

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

$$\simeq \sqrt{n_1 \Delta 2n_1}$$

(Approximate $\frac{n_1+n_2}{2} \simeq \frac{n_1+n_1}{2} = n_1$

$$\boxed{N.A. = n_1\sqrt{2\Delta}}$$

Problem

Calculate the refractive indices of the core and cladding material of fibre from the following data

Parameter	Value
N.A.	0.22
Δ	0.012

Optical fibre communication system

- Optical fibre is the backbone of modern communication system.
- Any form of communication can be generalized as the process of sending a signal from one location to other location
- Since light travels faster than any signal and the optical losses are minimal compared to electrical losses, optical signal is preferred ~~for~~ over electrical signal for long distance communication.

- However, at the end points, signals are usually of the electrical type. Therefore, before transmission of ~~sig~~ optical signal, we need to generate optical signal from electrical signal. Similarly, on the other end, the received optical signal needs to be convert from optical signal to electrical signal Therefore, there are three steps involved in the communication of an optical signal.

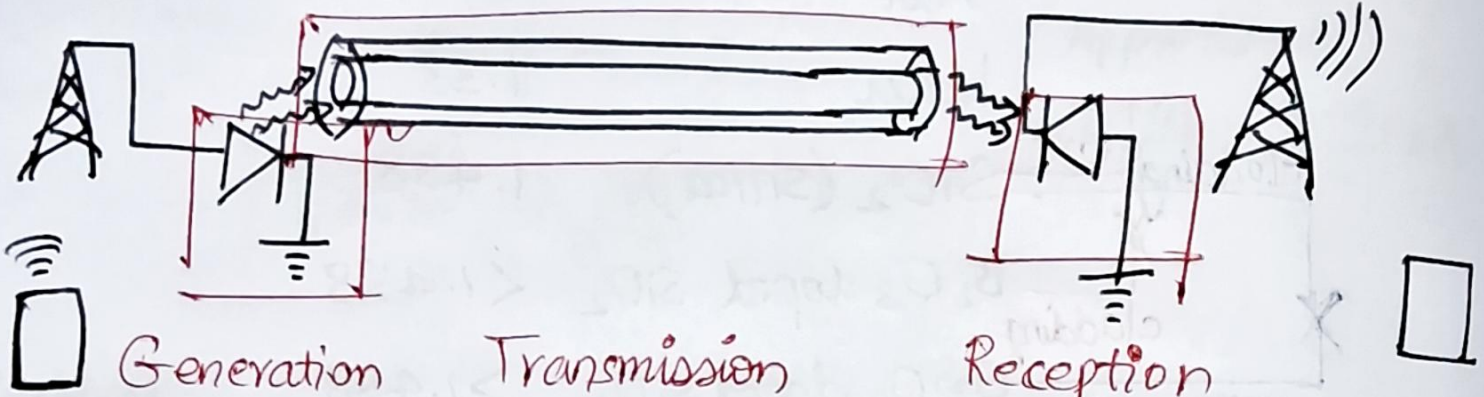
Step	Nature of signal	Device
Generation	Electrical → Optical	LED, diode laser
Transmission	Optical	Optical fibre
Reception	Optical → Electrical	Photo diode

- An optical fibre is not a standalone opto-electronic device. However, in the broader content of fibre optic based communication system, it is an opto-electronic device since other opto-electronics devices like

Transducer	Role
LED / laser diode	E → O
photo diode	O → E

are involved in the conversion of nature of signal.

- A device that converts signal from one form of energy to other form is called a transducer.



Fibre optic based communication system

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