OPTICAL FIBER COMMUNICATION

Subject

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* **Unit II.**
  * Introduction
  * Advantages of OFC
  * Disadvantages of OFC
  * Application of OFC
  * Block diagram.

Introduction → * To send information from Tx to Rx is called communication.
* When information signal is send in the form of light signal then it is called optical comm.
* Transmitting medium used → optical fiber.

Advantages (लाभ) of OFC

* Large Bandwidth - 10^4 GHz to 10^7 GHz
* Low transmission loss.
* Low crosstalk, Low noise
* Electrically Isolated (विद्युतरोधी)
* Signal Security
* Small size and weight
* Ruggedness and flexible (लचीले)
* No interfacing

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Disadvantages of OFC → OFc के दोष अथवा कमियां)

* Making cost of optical fiber for per meter is more in comparision of copper.
* Joints (जोड़) of optical fiber is a complex process.
* optical fiber are more fragile (आसानी से टूट जाते है) (splicing)

Application of OFC

* Medical field Ex endoscope, In operation
* To connect Computers Ex for Internet LAN, WAN
* In Communication System Ex. optical fiber system
* In Defence Area Ex. Defence Equipments

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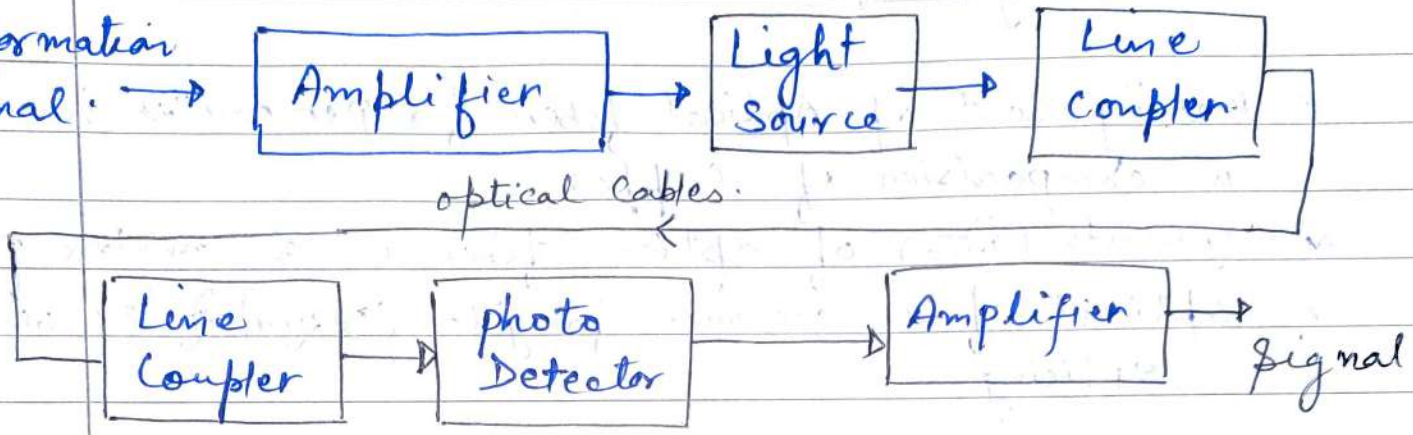
Basic Block diagm. of OFC



* Information Signal → Voice, Vedio, speech AM, FM any signal in any form i.e Analog or Digital. This signal may be weak so it is amplified
* Light Source → LED or LASER.
  It converts analog signal to optical signal
(analog sig को प्रकाश signal में परिवर्तन होता)

LINE coupler → It connects light source to fiber

optical cables → light signals को Tx से Rx तक ले जाती है।

photo Detector → PIN, APD, photo diode
optical signal converts → Electrical Signal.
यह optical signal को दूसरे signal में बदलता है।

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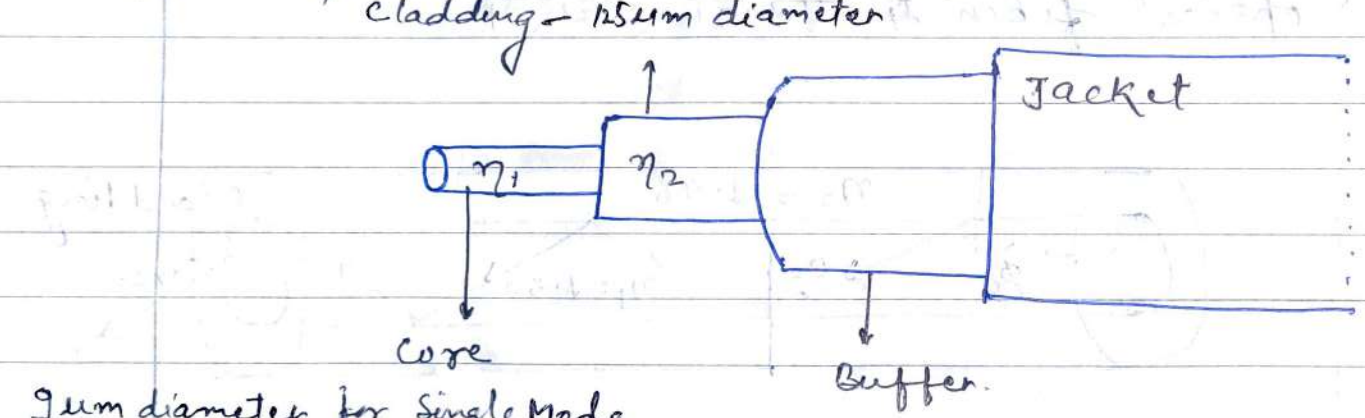
Unit II.

Construction of optical fiber (संरचना)
principle of OFC (TIR)
RI, critical, Acceptance angles. NA
Types of optical fiber, Mono Mode, Multimode
step Index, Graded Index.

optical fiber Construction (संरचना)



9 um diameter for Single Mode
50 um to 62.5 um diameter for Multimode

Core → 9 to 100 um diameter, plastic glass, plymer.
Reflective Index $\eta_1 = 1.5$

cladding → 100 um to 420 um diameter
plastic, polymer material is used
Reflective Index $\eta_2 = 1.4$

always: $\boxed{\eta_1 > \eta_2}$

Buffer → plastic coating
Jacket → PVC hard Plastic
] provide protection and strength to fiber bunch

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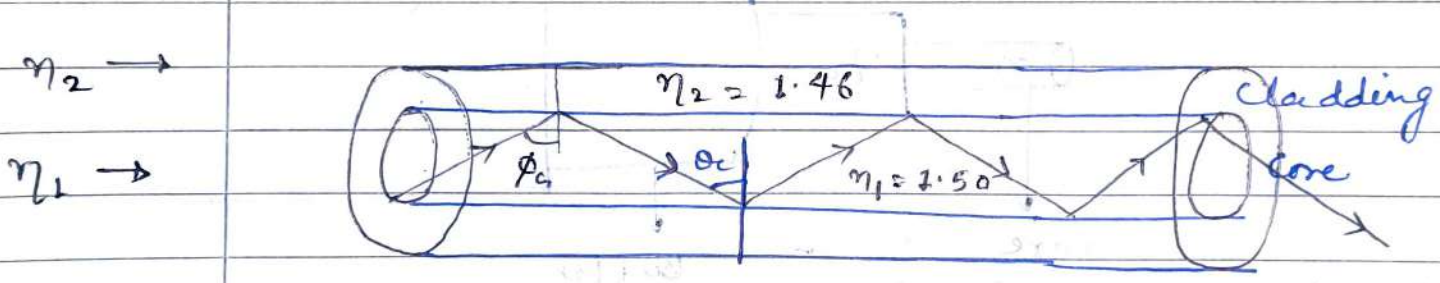
optical fiber में core-cladding के Diameter different size के हो सकते हैं. लेकिन core का Reflective Index हमेशा cladding से अधिक होता है। ($\eta_1 > \eta_2$)

core and cladding plastic, polymer, or silica based material के बने होते हैं।

Propagation of light through optical fiber
optical fiber में प्रकाश संचरण



जब कोई optical light core, cladding interface पर इस प्रकार पड़ती है कि Incidence angle θ_i is greater than θ_c (critical angle) तब optical light cladding से टकराकर वापस core में आ जाती है। यह process Total Internal Reflection (TIR) कहलाती है (पूर्ण आन्तरिक परावर्तन)

Relation between Refractive Index and θ_c

Critical Angle $\boxed{\theta_c = \sin^{-1}\left(\frac{\eta_2}{\eta_1}\right)}$

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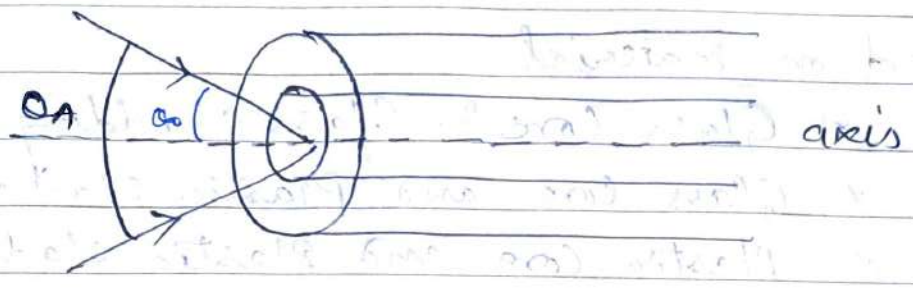
Acceptance Angle (ग्राही कोण) θ_A



वह Maximum angle जो light ray fiber axis से बनाती है और इस angle से अधिक angle बनाने वाली light ray optical fiber से escape/skip हो जाती है या optical fiber ग्रहण नहीं कर पाती है, acceptance angle कहलाता है।

$$\theta_A = 2 \sin^{-1}\left(\frac{\sqrt{\eta_1^2 - \eta_2^2}}{\eta_1}\right)$$

$\theta_A = 2\theta_0$

Numerical Aperture → It shows light carrying capacity of optical fiber

यह optical fiber की प्रकाश ग्रहण करने की क्षमता को बताता है। इसका मान जितना अधिक होता है optical fiber की light carrying capacity उतनी ही अधिक होती है

NA range 0.13 to 0.50

$$\boxed{NA = \eta_1\sqrt{2\Delta}} \qquad NA = \sin\theta_0$$

$$\Delta = \frac{\eta_1 - \eta_2}{\eta_1}$$

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Types of optical fiber and Their Classification

Based on Material

* Glass Core & Glass Cladding
* Glass Core and Plastic Cladding
* Plastic Core and Plastic Cladding

Based on Refractive Index (अपवर्तनांक)

Step Index optical fiber
Graded Index Optical fiber

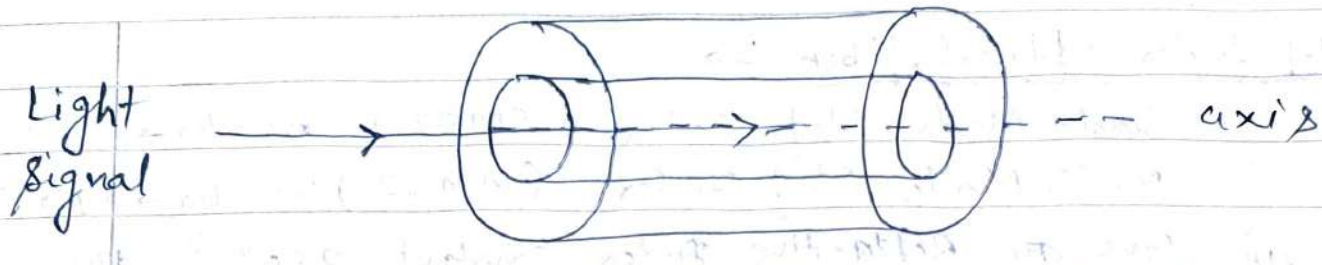
Based on Mode (फाइबर के अन्दर के प्रकाश पथ, जिन पर तरंगे समान कला में चलती है, Modes कहलाते हैं)

* Single Mode fiber
* Multimode fiber

Single Mode optical fiber :→

* Core का diameter बहुत कम होता है ~ 8 um to 10 um
* एक समय पर केवल एक ही light signal travel करता है
* इसलिए attenuation कम पाया जाता है।
* Long distance travel के लिए इसका प्रयोग होता है। (40 to 60 km)
* Support Gigabit Ethernet i.e Higher speed than Multimode
* No Modal Dispersion
* Optical Source used in this LASER

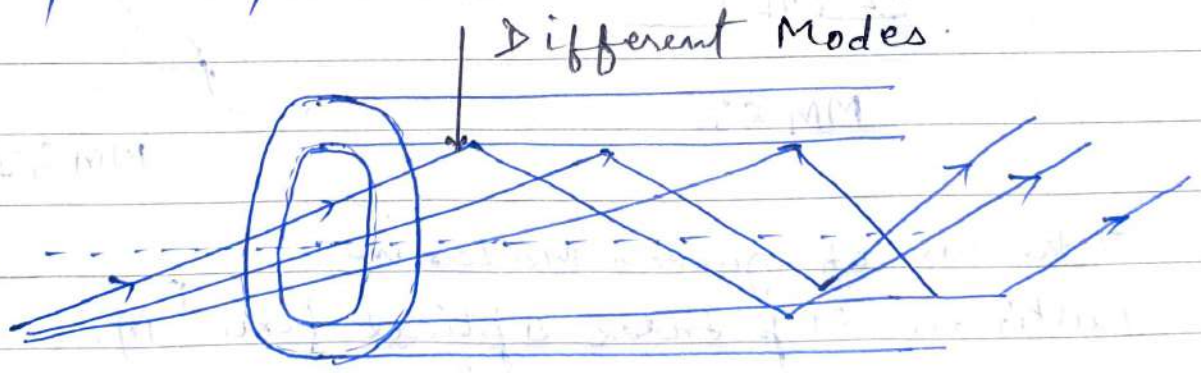
Disadvantages:
* Coupling is complex in such fiber
* It has expensive components and connectors.



core is so small that light incident at 0° to axis

Multimode optical fiber

* एक से अधिक Modes पाये जाते है।
* Many light signal can travel at a time
* Core diameter 50 to 62.5 μm का होता है।
* Used for short distance जैसे LAN
* Easier to couple
* Transmission speed is low.
* optical source used is LED



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Step Index optical fiber :→

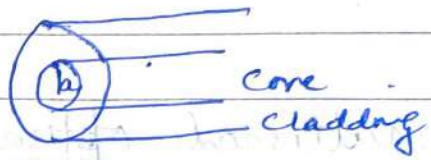
Single Mode Step Index (SMSI) Core dia → 2 to 10 μm

Multi Mode Step Index (MMSI) Core dia → upto 50 μm

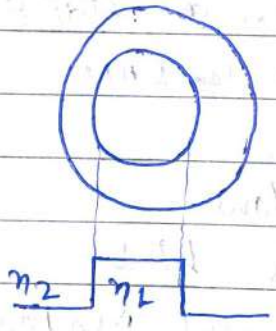
इसमें core का Refractive Index constant रहता है तथा इसका मान cladding के R.I से अधिक होता है

$$\eta(r) = \begin{cases} \eta_1 & r < a \\ \eta_2 & r \geq a \end{cases}$$

$$\eta_1 > \eta_2$$



Refractive Index profile



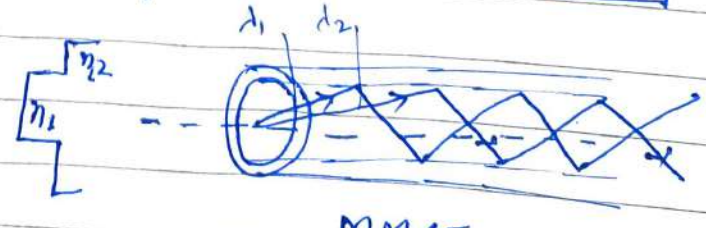
MMSI

MMGI

Total No of guided Modes in Multimode step Index optical fiber $M_s = V^2/2$

V = normalized freq.

SMSI



MMSI

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* MMSI में अलग अलग wavelength of light ray different path पर चलती है जिस कारण o/p पर ये Rays different path पर प्राप्त होती है और signal o/p पर distortion हो जाता है.
इसे Intermodal dispersion कहते हैं.

No of Modes

$$SMSI = \frac{2\pi^2 r^2}{\lambda^2}(n_1^2 - n_2^2)$$

r = radius of core

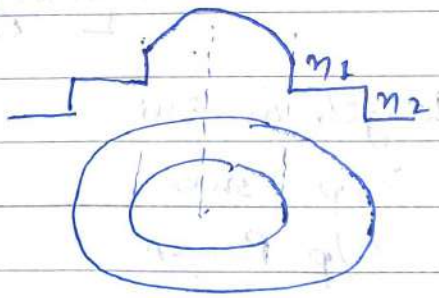
No of Modes in MMSI

$$M_s = \frac{V^2}{2}$$

V = normalized freq.

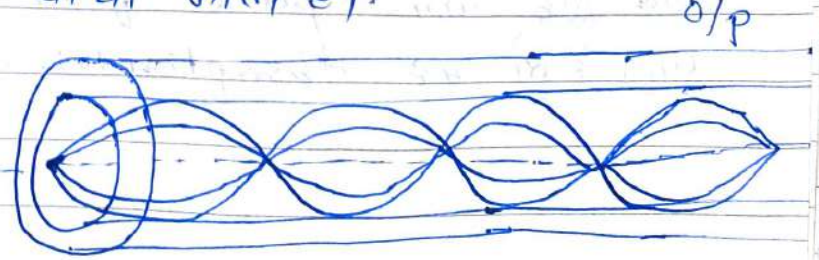
Graded Index Fiber →

* इसमें core का Refractive Index (RI) central axis से किनारो तक धीरे-धीरे घटता है। तथा cladding का RI constant रहता है।



* इसमे TIR ना होकर Refraction होता है।
* Modal Dispersion नहीं पाया जाता है.

* Outer side light wave travels faster and follows long path
* Inside ray is slower and follows small path
* So at o/p all rays reached at the same time So No Modal Dispersion in this case.



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(हानियां) Losses In optical Fiber Cables

* Attenuation
* Absorption loss (अवशोषण) → Intrinsic, Extrinsic
* Scattering → linear → Mie, Rayleigh
  Non linear Scattering
* Bending loss → Macro Bending, Micro Bending
* Dispersion loss → Modal, Material, Chromatic

Attenuation → It is the loss of optical power when light travels in optical fiber

$$\text{Attenuation} = \frac{10}{L} \log_{10}\left(\frac{P_i}{P_o}\right) \quad dB/km$$

L = Length in km

P_i = I/p power

P_o = O/p Power

Absorption loss (अवशोषण हानि): optical power का जब कुछ भाग optical fiber द्वारा अवशोषित कर Heat में बदल जाता है तो यह Absorption loss कहलाता है।

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Intrinsic Absorption

This absorption is caused by basic fiber material properties

* Impurities are not used
* pure silica glass (SiO_2) में Si-O Bond vibration और EM energy में interaction के कारण Absorption होता है।
* i.e. this absorption is caused by Si-O bonds vibration and Imperfection of Material structure used.

Extrinsic Absorption

* It is caused by impurities introduced into the fiber Material
* Impurities may be Cu, Ni chromium and OH^- ion.
* $Si-O_2$ → Si-OH Bond.
* This Absorption can be minimized by using dry fiber

Scattering loss. जब किसी optical fiber में Roughness या irregular surface या किसी प्रकार का impurity Atom हो तो optical light को रोक कर light ray को diffuse or spread कर देता है तो यह scattering loss कहलाता है।

Cause of Scattering loss

* Roughness, irregular optical surface
* Impurity Atom.
* Irregular Molecular density
* Refractive Index variation

Linear Scattering → Rayleigh, Mie

In this optical power transferred from one mode to another mode linearly without changing freq.

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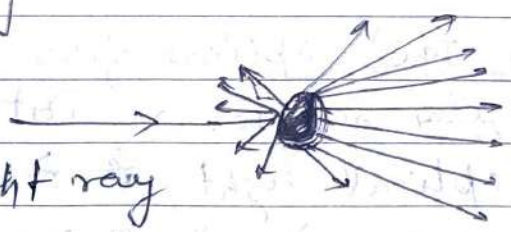
Rayleigh Scattering :- When their is a obstacle(अवरोध) in the path of light ray whose size is very small to ray wavelength (λ) then Rayleigh Scattering is arises. obstacle may be air bubble, droplet Density fluctuation etc.

Mie Scattering. If size of obstacle is larger than optical light wavelength the it is called Mie Scattering



lobe direction is more in forward direction.

Non. Linear Scattering → If obstacle translates optical light mode one form to another and in this case freq is also changed. then it is called Non. Linear Scattering.

Ex. Stimulated Brillouin Scattering
Stimulated Raman Scattering

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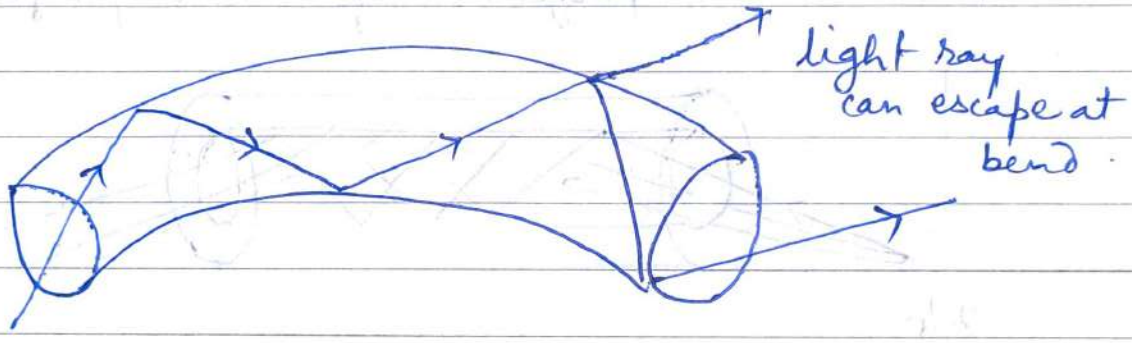
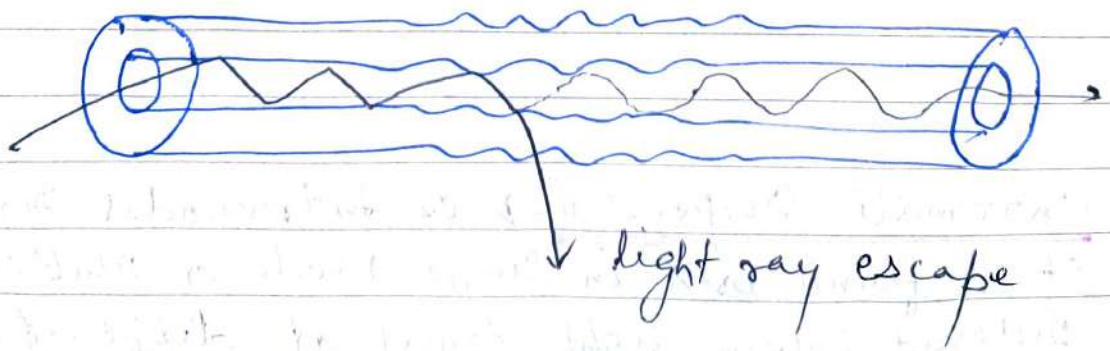
Bending loss → when optical fiber Bends or their is curve in the path then Bending loss arises.

Macro bending → when curvature of the bend is much larger than fiber diameter then lightwave suffers serve loss due to radiation of the evanescent field in the cladding region.



Micro bending → bend size is smaller than diameter of optical fiber. It is due to core cladding interface is not perfect or their axis is not linear.



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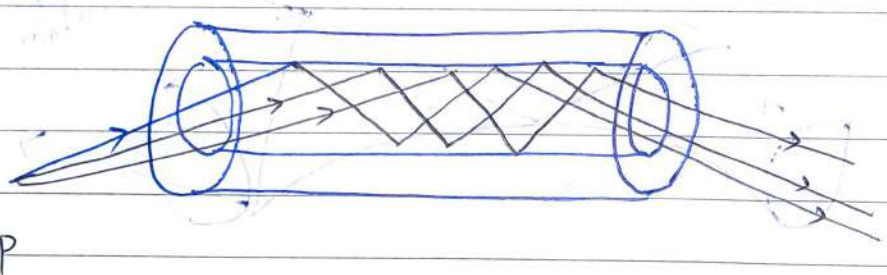
Dispersion loss - When optical light spread out due to some ~~region~~ reason and its Bandwidth changes then it is called Dispersion loss.

Due to this loss optical light becomes weak after travelling a specific distance.

* **Modal Dispersion** - It is found in Multimode step Index optical fiber

It is due to imperfection of index profile of fiber



* **Material Dispersion** :- It is due to change of refractive Index in optical fiber therefore light ray travels with different speeds.

* **Chromatic Dispersion** → or Intramodal Dispersion

It is found both in Single Mode or Multimode fibers Different colour light travel at different speed in optical fiber therefore light ray pulse broadening as light travel in forward direction.