FIBRE OPTICS

Advantages

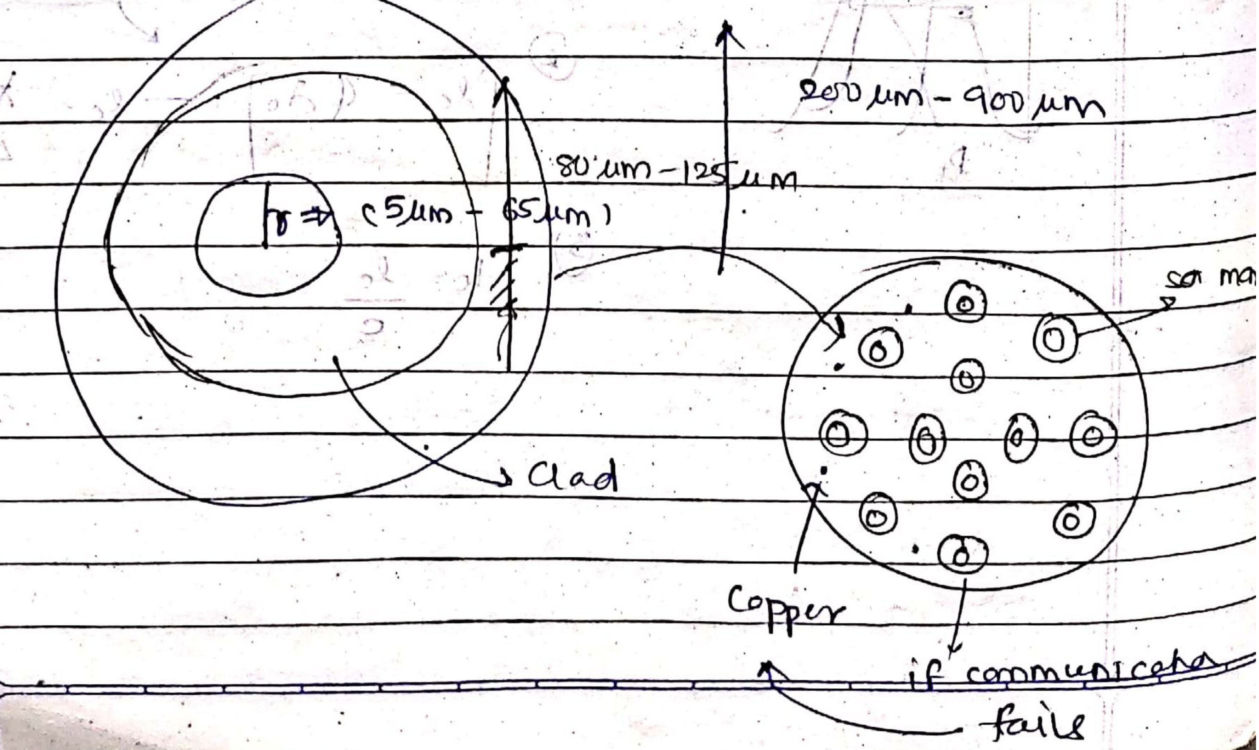
(1) Low cost one time investment 1 km → 1000 kg c...
c kg (fibr...
(2) Dimension is very small (hair)
(3) Transmission Rate
(4) Flexible & Low attenuation
(5) No EM interference & Radio interference
(6) Material "Silica" (insulating)
↓
less
Danger Non-hazardous (No - FIRE)
(7) Larger Bandwidth 100 MHz = Coaxial Bandwid...
(10^{14} Hz)

Vocal ⇒ 4 KHz
Video

Bandwidth requirement ↑ more channel ↑ accomodate

Bit rate = $\frac{1}{t}$

(8) No cross-talk in optical fibre



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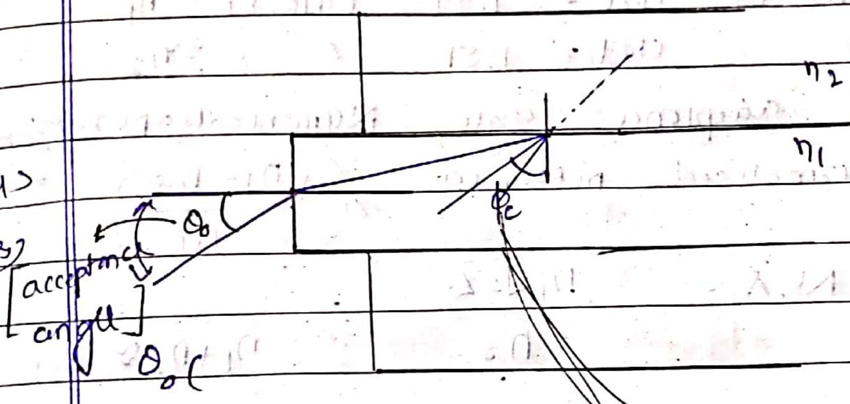
Principle : TIR = Total Internal Reflection

g (co-axial)
(fibre optics)



$(n_1 > n_2)$

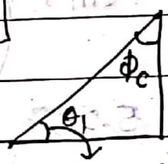
$n_1 \sin(\phi_1) = n_2 \sin(\phi_2)$

$n_1 \sin(\phi_c) = n_2 \sin(90°)$

$$\left[\sin(\phi_c) = \frac{n_2}{n_1} \right] \text{ — (1)}$$

$\theta > \phi_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$

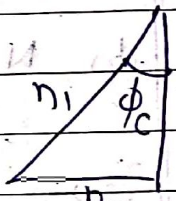
(launching angle)



$n_0 \sin(\theta_0) = n_1 \sin(\theta_1)$ $(90 - \phi_c)$

$n_0 \sin(\theta_{0\,max}) = n_1 \sin(90 - \phi_c)$

$n_0 \sin(\theta_{0\,max}) = n_1 \cos(\phi_c)$



$$n_0 \sin(\theta_{0\,max}) = n_1 \frac{\sqrt{n_1^2 - n_2^2}}{(n_1)}$$

$$\boxed{\text{N.A Numerical Aperature} = \sin(\theta_0 max) = \frac{\sqrt{n_1^2 - n_2^2}}{n_0}}$$

$$(\theta_{0\,max}) = \sin^{-1}\left(\frac{\sqrt{n_1^2 - n_2^2}}{n_0}\right)$$

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

not much difference

$NA = \frac{n_1 \sqrt{2\Delta}}{n_0}$ considering $n_1 + n_2 \approx 2n_1$

ial
dwidth

so many

eha

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(Q) Refractive index of core = 1.54 (Glass) = n_1
clad = 1.51 $= n_2$

find out acceptance angle, Numerical aperature
Normalised difference $\left(\Delta = \frac{n_1 - n_2}{n_1}\right)$ $\left(\frac{\sqrt{n_1^2 - n_2^2}}{n_0}\right)$

$$N.A = \frac{n_1\sqrt{2\Delta}}{n_0}$$ $n_1 + n_2 \approx 2n_1$

(Ans:)

$\theta_c = \sin^{-1}\Big($

$\sin^{-1}(0.3024)$

~~$\theta_c = 17.588$~~

(a) $\theta_{c_{max}} = \sin^{-1}\left(\frac{\sqrt{(1.54)^2 - (1.51)^2}}{1}\right)$ ~~17.6~~

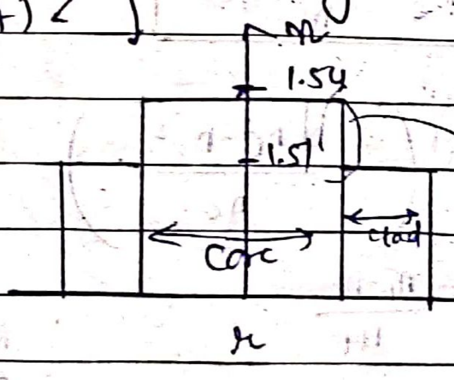
$= (17.6°)$ (65 μm)

(b) NA = (0.3024) 5 μm (n_2 = 1.535)
(n_1 = 1.54)
{Military single information}

(c) ND $= \frac{0.03}{1.54}$

ND = 0.01948

* Step Index finding
(A) ( )



At Edge, Refractive index drop
interface, value change abruptly, called step index.

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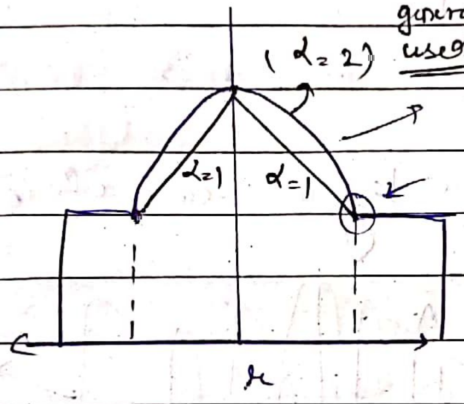
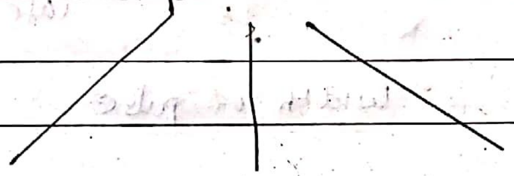
(B) Graded Index — Gradually decreases.



$\alpha \to \infty$ — $\alpha = 1$ — $\alpha = 2$ (paral) — $\alpha \to \infty$ (step index)

$$\left[n(r) = n_1 \sqrt{1 - 2\Delta\left(\frac{2r}{d}\right)^{\alpha}} \right]$$

(A) Step Index

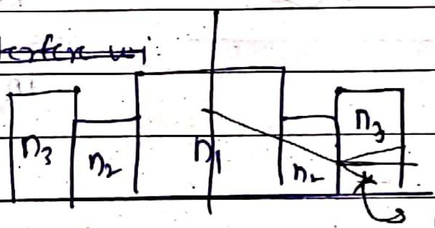


[Not good to have info in clad]

(I) Base fibre (only CORE) (during rainy season) water

(II) $n_1 > n_2$ step index

(III) W profile

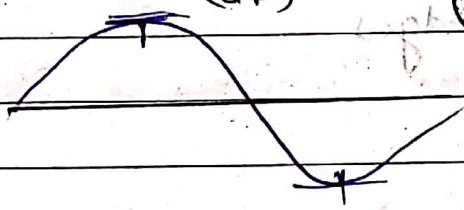


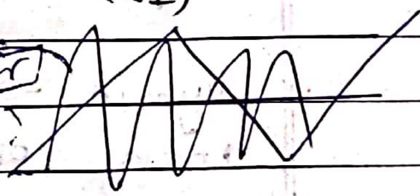
not come back → "It will interfere"

$(n_1 > n_3 > n_2)$

(B) Graded index Propagation (Better)

Advantage (end of core) (GI) ① (Slower) (SI)

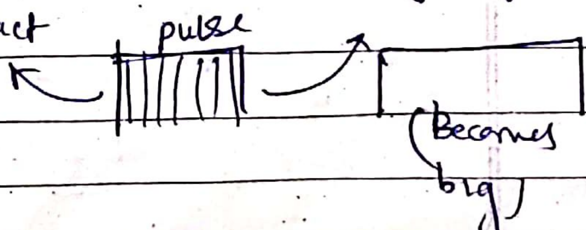




zig zag

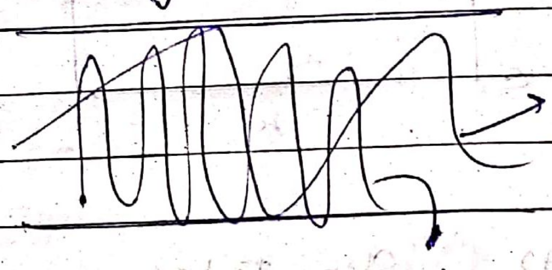
[It is Better]

GI →

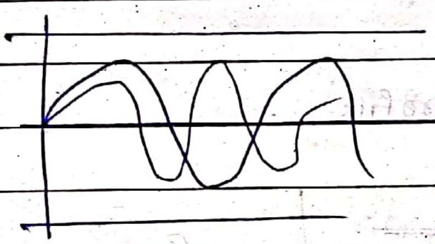


Pulse with many channels

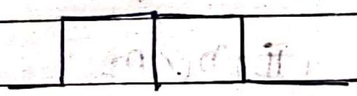
 → time lag in case of SI



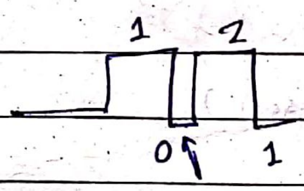
② width of pulse {SI Not preferred}



Not ← in GI



intersymbol interference takes



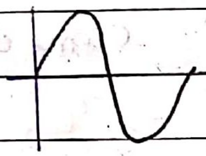
③ (Higher modes)

Hybrid → modes in edges
{ Inside CORE only }

(D) Communication And types of Modes.

(1)

Vocal → electrical → Light → fibr → photodetecter
(signal) (signal) signal ↓
Electrical
signal
↓
(2) Eg : Vocal Back

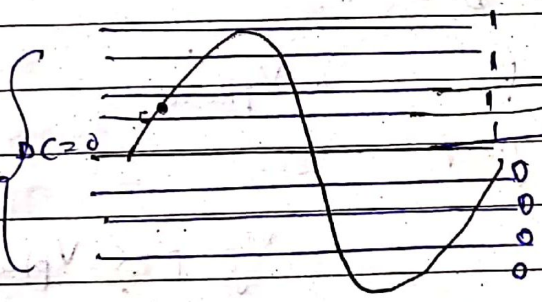


⟹ Semiconducter
Laser
(for point source
∵ Acceptance
Angle < very
less 17.6°)

Vocal to
sinosodial

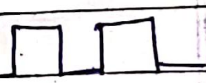
3 bit system ⟹ 2^3 (we use 16 bit system)

first Bit represent



111
110
~~101~~ ~~Voltage = 101~~
100
000
001
010
011

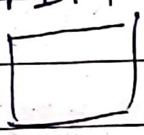
Vocal → Electrical / Analog ⟶ Digital
↓
Line waveform
101



1 0 1

P type Intrinsic N type
& sencitivity
&
instantly

PIN ⟵ Fibre ⟵ Semiconducter ⟵
Laser
on off on



Ph

object

(solar works like (but NOT)
cell)

(photodiode is not solar cell)

(Digital)
↳ (Analog)

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(E) TYPES OF MODES

Each channel is given one mode]

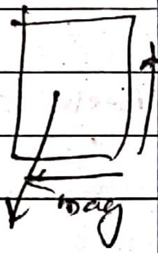
Light

Transverse EM mode

(TEM) ↳ Electro magnetic

Frontal plane

moving in dire^n of prop



$V_g = V_{ph}$ (same direction)

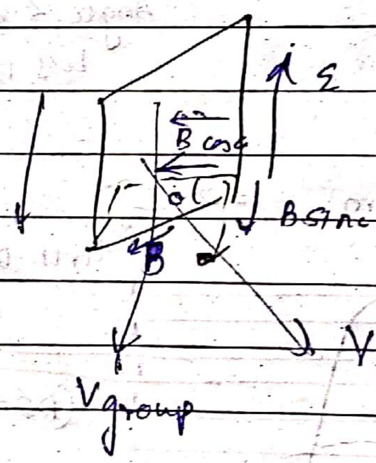
(A) TEM mode

$V_{group} = V_{ph}$

01, 02, ---- 'n'

(B) TE mode

Electric

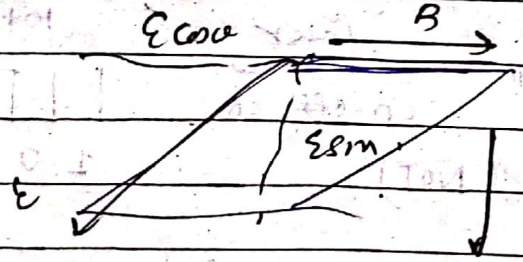


$V_{group} < V_{phase}$

Magnetn

(C) TM mode

01, 02, --- 'n'



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(D) HE or EH mode

11, 12, 13, - -

'H' 'E' mode

transverse component of 'B' Y 'E' [Jiska Transverse component Jyada hai]

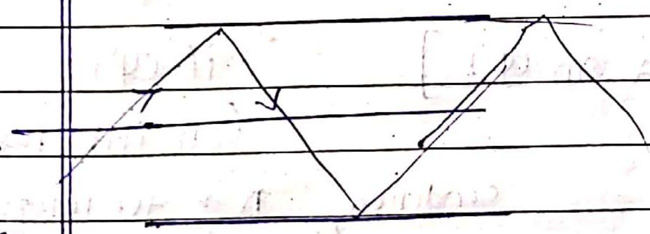
'E' Y 'B'

TEM
TE } simple Modes
TM

HE } Hybrid Modes
EH

{Each mode has own Angle of Propogation}

Propopogation of [simple] (SI)



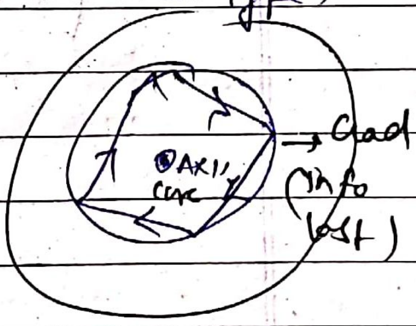
axis ko cross

pro = "meridional" mod

{(GI) "Core" More preferred}

write this [Hybrid] [Skew mode] only

Not cross axis (screw type)



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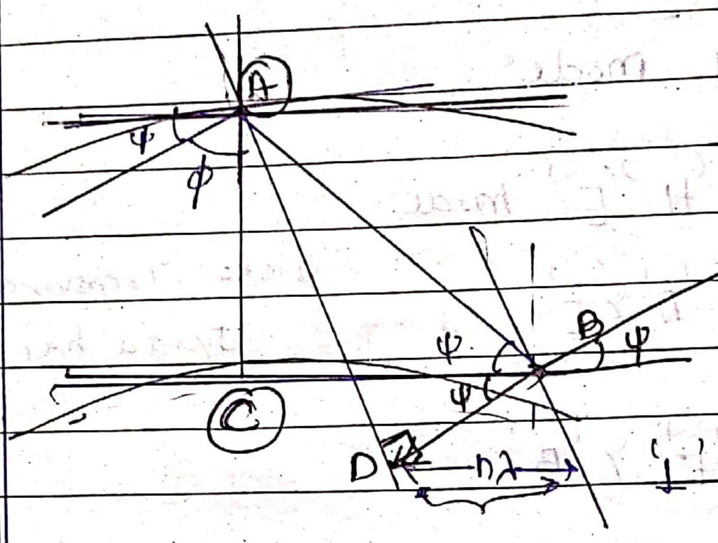
Step index meridonorial



(frequency parameter)
(V Number)/(cut-off parameter)

$$V = \frac{\pi d}{\lambda} (N.A)$$

Ray will be propogating

$\Delta x_{path} = n\lambda$
(will be in phase)

$$\sin(\psi) = \frac{d}{AB}$$

$$\cos(2\psi) = \frac{DB}{AB} = \frac{n\lambda}{d} \sin(\psi)$$

1 Condition :

$$[d \cos(2\psi) = n\lambda \sin(\psi)]$$

if (ψ) full fill this condition, n → +ve integer, will ONLY PROPOGATE.

d → [5 μm - 50/80 μm = Diameter]

2 λ {
- 0.8 - 0.9 micrometre
- 1.2 - 1.3 micro metre
- (1.4 - 1.5) μm
}

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(2) How many? Decided by the dimension of core

$$V_{core} = \frac{\pi d}{\lambda} (N.A) = \frac{\pi d}{\lambda} \left(\frac{\sqrt{n_1^2 - n_2^2}}{n_0} \right)$$

(3) Each mode has its own V-number and its universal.

modes	V_{mode}
✓ HE_{11}	0
✓ TE_{01}, TM_{01}	2.405
✓ TE_{02}	2.83
✓ TM_{02}	2.95
HE_{21}	3.4

$n_1 = 1.54$ $n_2 = 1.51$ $d = 50\ \mu m$ $\lambda = 1.4\ \mu m$

3.05

$$V_{core} = \frac{\pi d}{\lambda} \frac{\sqrt{n_1^2 - n_2^2}}{(n_0)}$$

0.3024 x

$= 33.9392C$

[Modes less than V_{core}, are allowed to Propogate]

HE_{52} 33.5 ✗ Not propogate

EH_{51} 34.2 ✓ Propogate

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$$V = \frac{\pi \times 4}{1.4} \sqrt{3.075 \times 0.005}$$

$= (1.1129)$

Single mode will $(HE_{11} = 0)$

$HE_{11} : 0$ → Any frequency will support it.

(2)

V_{number} in skew Rough (Approx) $N \approx \phi \left(\frac{V^2}{2}\right)$ No. of modes that can propogate

(3) GI fiber → will also reduce
Graded Index

$$(N_\alpha) = N_\infty \frac{(\alpha)}{(\alpha+2)}$$

$(\alpha \approx 2)$

(E) LOSSES IN FIBRE

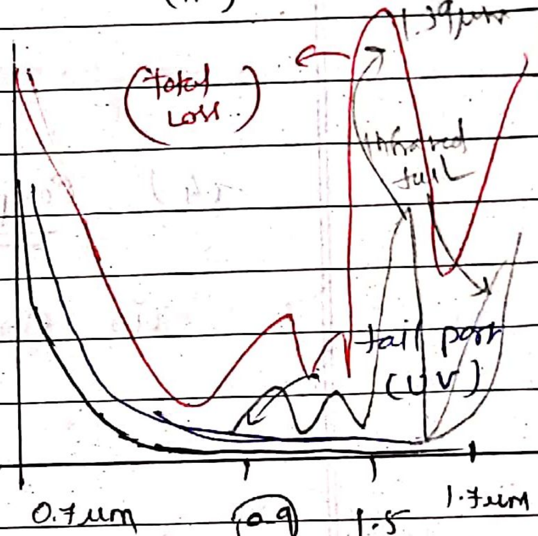
(1) Rayleigh Scattering Loss $\propto \frac{1}{(\lambda)^4}$

During fabrica

If impurities are fabricated between fibres,
↳ scattering centres ⟶ $\propto \frac{1}{(\lambda^4)}$

Visible

0.9 light → scattering ↑
1.2 - 1.3 Blue
1.



0.8 - 0.9
1.2 - 1.3
1.4 - 1.5

to minimize Loss

(2) Absorption Loss

(i) Ultraviolet Region — Silica. Band gap > 3eV
↳ $\boxed{\text{Ionisation}}$ takes — silica absorb 'UV', info Loss.
0.14 μm = 8.9 eV

(ii) Infrared Region — Silica will absorb HEAT
$\boxed{\text{phonon}}$ → ~~Absorp~~ scattering !
$\boxed{\text{Vibration}}$ by $\boxed{\text{absorbing}}$ Infra

(iii) ~~Loss~~ Ion resonance Absorption

~~wat~~

water molecules inside fibre
(during fabrication)
↓ at this 'λ'
0.95 μm, 1.25 μm, 1.39 μm = Largest absorption of energy
Band absorb energy & vibrate

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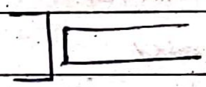
(3) Leaky Modes :

Hybrid modes / Higher modes = skew way

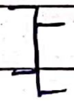
Leaky modes : { radial component in clad reagion → Lost

(4) Coupling Loss

(i) Core mismatch



(ii) Lateral mismatch

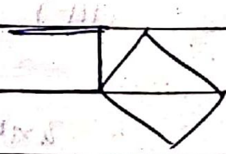


(iii) Longitudinal optical mismatch

n_1 | n_0 | n_1

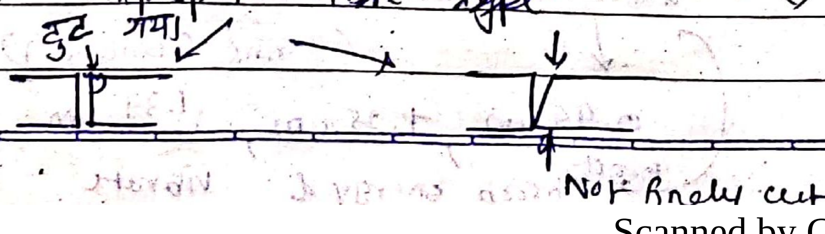
↑ air gap & dust particle

(iv) Angular misalignment



(v) Improper fiber ~~fibre~~ end type

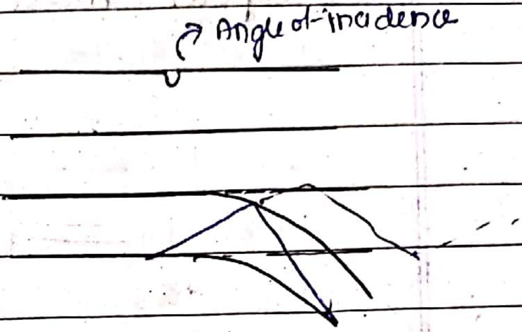
(vi) →



(5) Bending Loss

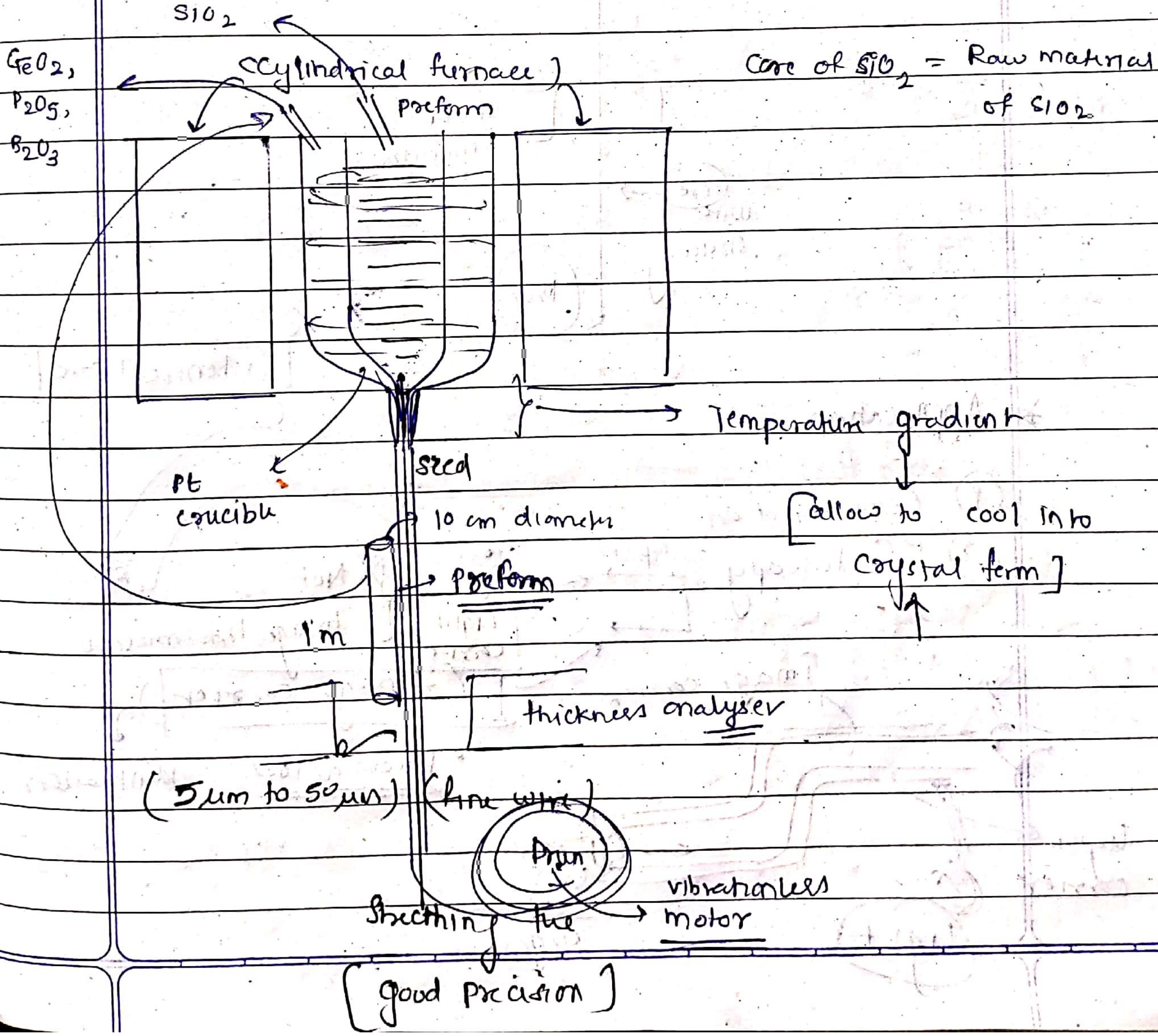
(i) microbending

(ii) macro bending

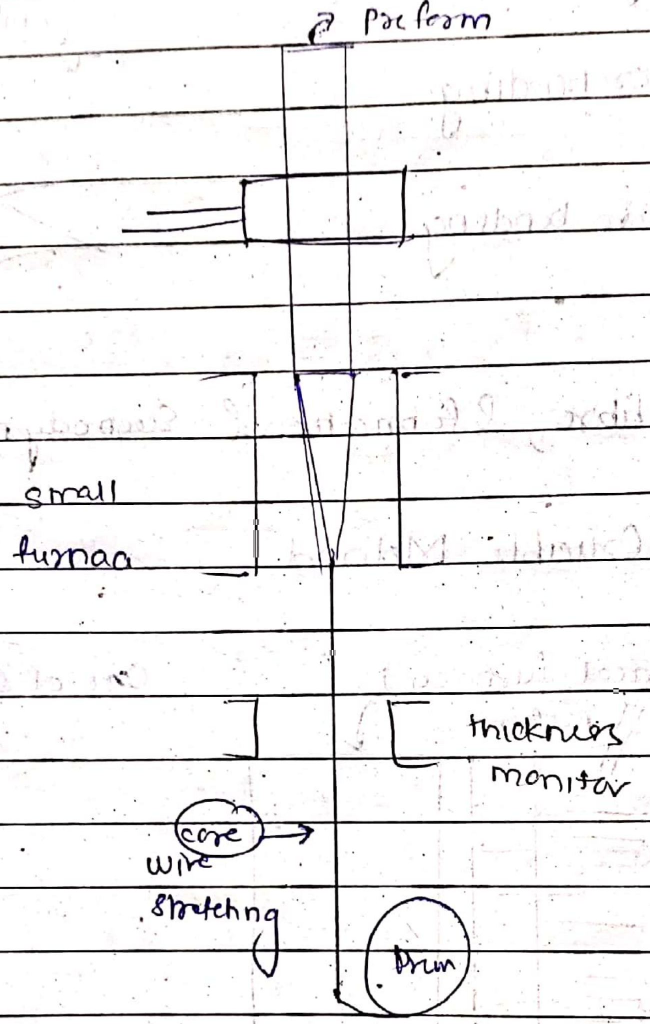


⇒ Application of Fibre, & fabrication & Electrodynamics

① Double Crucible Method



(B) Vapour phase oxidation method [efficient method] [for Bare Core] {No clad}



* Application

(1) Communication

(2) Endoscopy