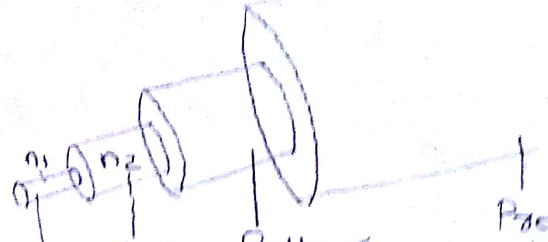
09/03/2021

OFC

Todd Keiser

→ Structure of OF



→ CLASSIFICATION :

1. Modes :

Single Mode

- single ray of light
- uses laser
- ↓ core dia
- intramodal loss
- 40% coupling ?

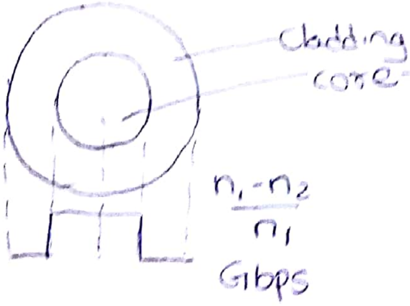
Multi Mode

- more than 1 ray of light
- uses LED
- ↑ att. loss
- intermodal loss
- 70% coupling ?
- ↑ NA
- easy splicing.

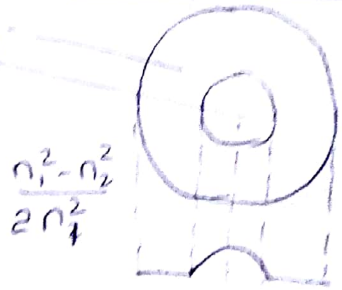
10/03/2021

2. RI Profile :

Step Index

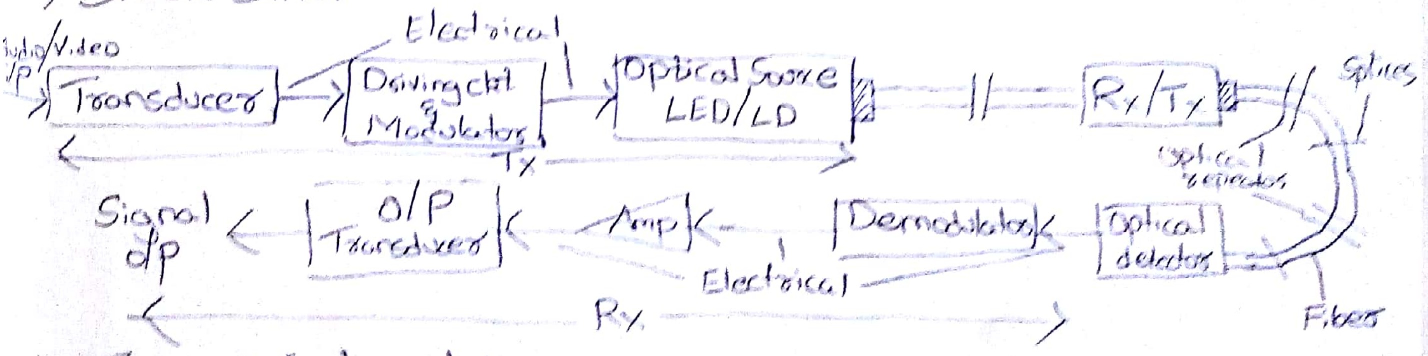


Graded Index



- Tbps
- min. speed at centre
- max speed at edges
- ↓ Pulse spreading
- ↑ att. loss.

→ BLOCK DIAG :

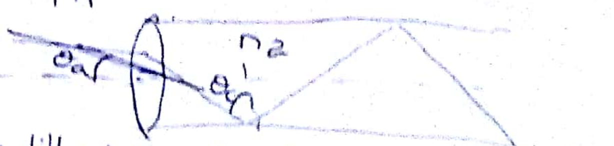


→ Fiber Material :

- Transparent
- Variants for core & cladding
- mech. st.
- ↓ wt.
- ↑ flexible
- ↑ Tensile
- easy fabricatⁿ
- temp. resis.
- ↓ att.
- Halides
- Polymers- PF, PMMA

15/03/2021 – Acceptance Angle

→ SI $\theta_a = \sin^{-1}\sqrt{n_2^2 - n_1^2}$



$V = \frac{2\pi a}{\lambda} NA$, $\Delta n = n_1 - n_2$, rel. index diff. $\Delta n_1 = \frac{n_1 - n_2}{n_1}$ $NA = n_1\sqrt{2\Delta}$

$V = \frac{\pi a}{\lambda} NA$ → GRI, Solid θ_a = $\mathcal{E} = \pi\theta_a^2 = \pi \sin^2\theta_a$ no. of mode $= \frac{V^2}{2}$ → MM $\frac{V^2}{4}$ → SM

1. Consider a multimode silica fiber of core RI n_1 1.40 & cladding RI n_2 1.48. Cal. θ_c, NA, θ_a

$\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$ $= \cancel{1.40}$ $= 80.57°$

$NA = \sqrt{n_1^2 - n_2^2}$ $= \cancel{0.242}$ $= 0.242$

$\theta_a = \sin^{-1}(NA)$ $= \cancel{0.245}$ $= 14.033$

2. A step index fiber has a normalised freq. V = 26.6 at 1300 nm wavelength. If core rad. is 25 µm. Cal. NA, core RI for cladding RI of 1.47.

$V = \frac{2\pi a}{\lambda} NA \Rightarrow NA = \frac{26.6 \times 1300 \times 10^{-9}}{2\pi \times 25 \times 10^{-6}} = 0.22$

$NA^2 = n_1^2 - n_2^2$

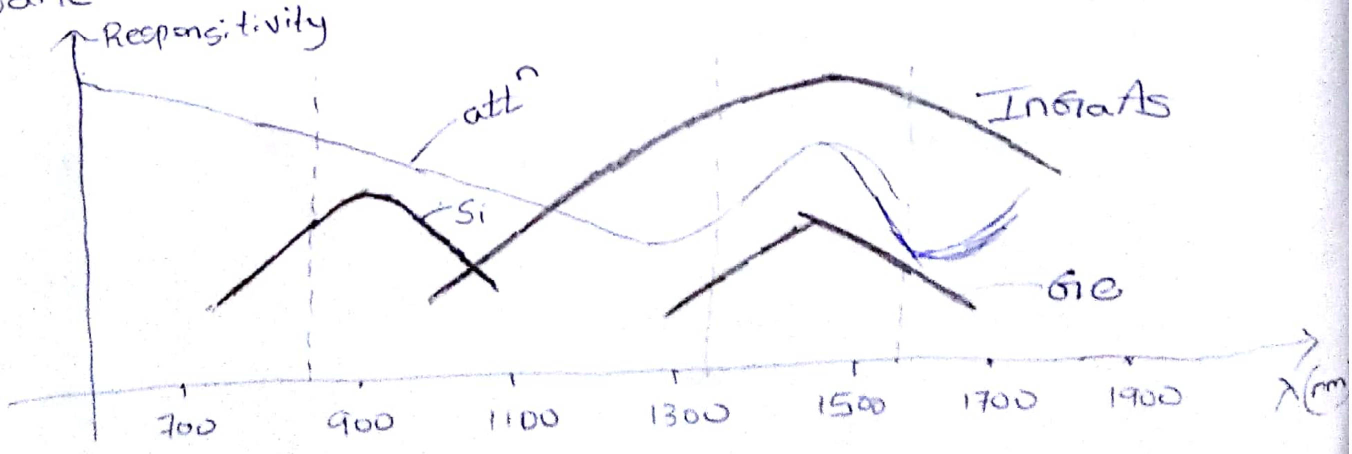
$\Rightarrow NA^2 + n_2^2 = n_1^2 \Rightarrow 1.486 = n_1$

ನಲಿವಾದ ನೆನಪುಗಳು
ಕೊನೆಯಾಗದ [illegible]
[illegible] (~~[illegible]~~ ನಿನ್ನ ನೆನಪು) ಅಗಲುತಿರಲು
ಅಗಲದೆ ಇರಲಾರ (ಇರೆನಾ)

16/03/2021

→ EM Spectrum :

Short wavelength : 850 nm
O band : 1318 nm
C band : 1550 nm



3. A typical rel. RI diff. for OF designed for long dis Tx is 1%. Estimate NA & solid θ_a in air for fiber with core RI 1.46. Also cal. θ_c at core cladding interface.

$$\Delta n_1 = \frac{n_1 - n_2}{n_1} \Rightarrow 0.01 = \frac{1.46 - n_2}{1.46} \Rightarrow n_2 = 1.445$$

$$NA = \sqrt{n_1^2 - n_2^2} = 0.209 \quad \boxed{OR} \quad NA = n_1\sqrt{2\Delta}$$

$$\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right) = 81.78^\circ$$

$$\theta_a = \sin^{-1}(NA) = \cancel{11.88} \ \cancel{12.09} \ 12.09^\circ$$

$$\varepsilon = \pi \cancel{\theta_a^2} \sin^2\theta_a \ \cancel{443.39} \ 0.137$$

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4. A multimode step index fiber has core dia. of 80 µm & relative RI^d of 1.5%, operating at wavelength of 0.85µm. If core RI is 1.48, a. estimate the normalised freq. of fiber & no. of guided modes ~~Find no. of modes supported~~ b. Cal. core dia. if the fiber is replaced with a single mode fiber 1.48.

a. $$\Delta_{n_1} = \frac{n_1 - n_2}{n_1} \Rightarrow n_2 = (0.015 \times 1.48) = 1.4578$$

$$NA = n_1\sqrt{2\Delta} = 1.48\sqrt{2 \times 0.015} = 0.256 \rightarrow \text{small}$$

$$V = \frac{2\pi a}{\lambda} NA = \frac{2\pi \times 80/2 \times 10^{-6}}{0.85 \times 10^{-6}} \times 0.256 = 75.694$$

nor. freq.

$$\text{no. of modes} = \frac{V^2}{2} = 2864.784 \approx 2865$$

* $\boxed{\text{Single mode : } V \leq 2.405}$ $\boxed{\uparrow NA \text{ easier coupling}}$

~~5. A mm SIF has core ... prev.~~

b. WKT

$$V = \frac{2\pi a}{\lambda} NA \Rightarrow \cancel{2.405 = 2\pi} \ \cancel{\frac{V^2}{4} = 1}$$

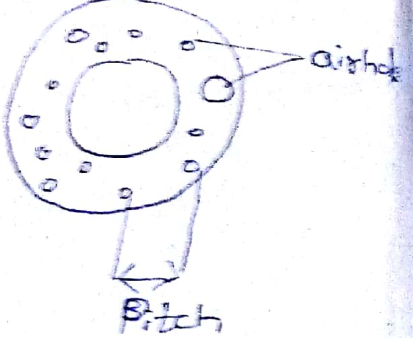
$$\Rightarrow \cancel{\frac{4\pi^2 a^2 NA^2}{\lambda^2} = 1} \Rightarrow a^2 = 0.528$$

$$\Rightarrow 2.405 = \frac{2\pi a}{\lambda}(\cancel{NA}) \ 0.256 \Rightarrow a = 1.27 \ \mu m$$

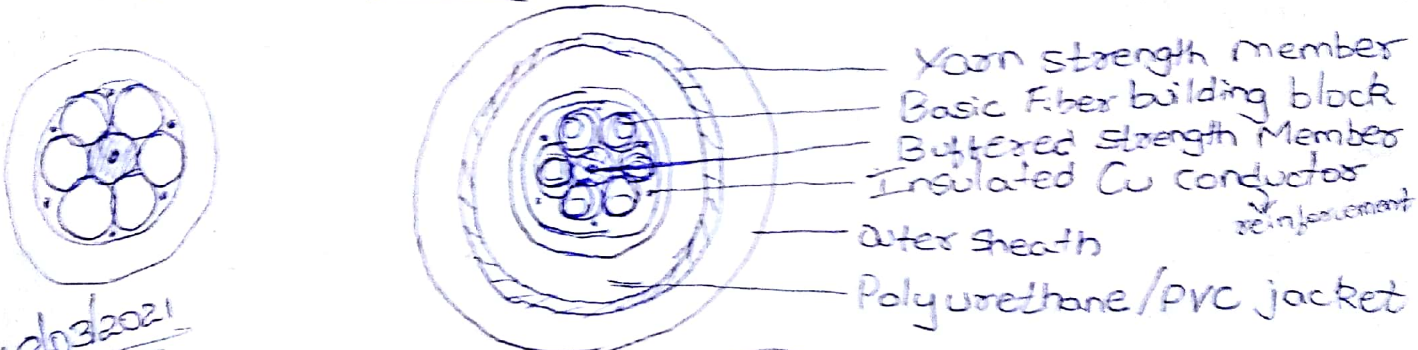
Core dia = 2.542 µm

→ Photonic Fiber / Faber Holey Fiber

- core & cladding → same material
  ↳ air holes ⇒ ↓ RI
- ↓ RI of cladding depends on
  - air hole dia
  - Pitch
- ↑ resis. to darkening effects → nuclear ~~effect~~ radiat^n
  ↑ Power
  long range (dis.)



→ Fiber Optic Cabel



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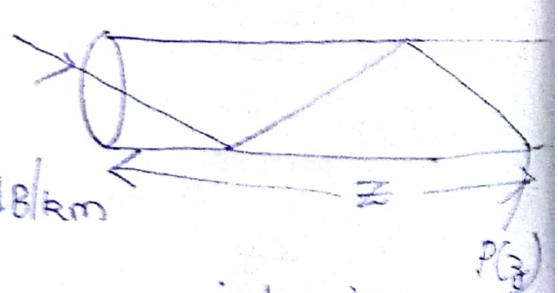
2. Signal Degradation In Fibers

- Attenuation:

$$P(z) = P(0)e^{-\alpha_p z}$$

$$\alpha_p = \frac{1}{z}\ln\left[\frac{P(in)}{P(z)}\right] Np = \frac{10}{z}\log\left(\frac{P(in)}{P(z)}\right) dB/km$$



- Absorption: loss due to abs. of light — intrensic / extrensic / atomic deffects
  ↳ 5-10%
- ~~Scattering~~ - 60-70%
- Bending.

22/03/2021
23/03/2021

Intrensic factor:

$$\alpha_{UV} = \frac{154.2}{46.6x+60} 10^{-2} \exp\left(\frac{4.63}{\lambda}\right) \; ; \; x \rightarrow \text{mole fract}^n$$

— Scattering loss: (60-70%)

$$\alpha_{scat} = \frac{8\pi^3}{3\lambda^4}(n^2-1)^2 k_B T_f \beta_T \quad \text{Napers}$$

$\beta_T \rightarrow$ isothermal compressability of glass

1. Mean optical power launched into a 8 km length of OF is 12 μW with o/p Power of 3 μW. Find overall signal att.^n in dB & Np. For 10 km of same OF, compare att^n. loss if splices are located at 1 km intervals each having att^n loss of 1 dB.

Sol. a. $\alpha_p = \frac{1}{z}\ln\left(\frac{P(in)}{P(z)}\right) = \frac{1}{8\times10^3}\ln\left(\frac{12}{3}\right) = 1.\cancel{73}\times10^{-4}$ Np

$= \cancel{30}\ 22$ dB.

$\frac{10}{z}\log\left(\frac{P(in)}{P(z)}\right) = 0.75$ dB/km

b. ~~$\alpha_p = \frac{10}{z}\log$~~

loss per km = 0.75 dB/km

$\Rightarrow$ loss for 10 km = 7.5 dB/~~km~~

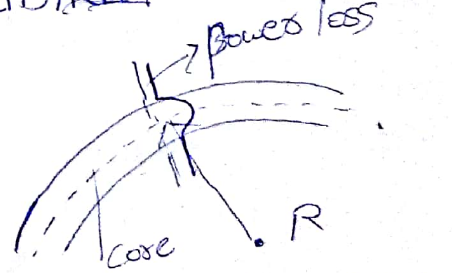
& splicing loss = ~~10~~ 9 dB

25/03/2021 ∴ overall loss = ~~10~~ 9 + 7.5 = 1~~7~~6.5 dB/~~km~~

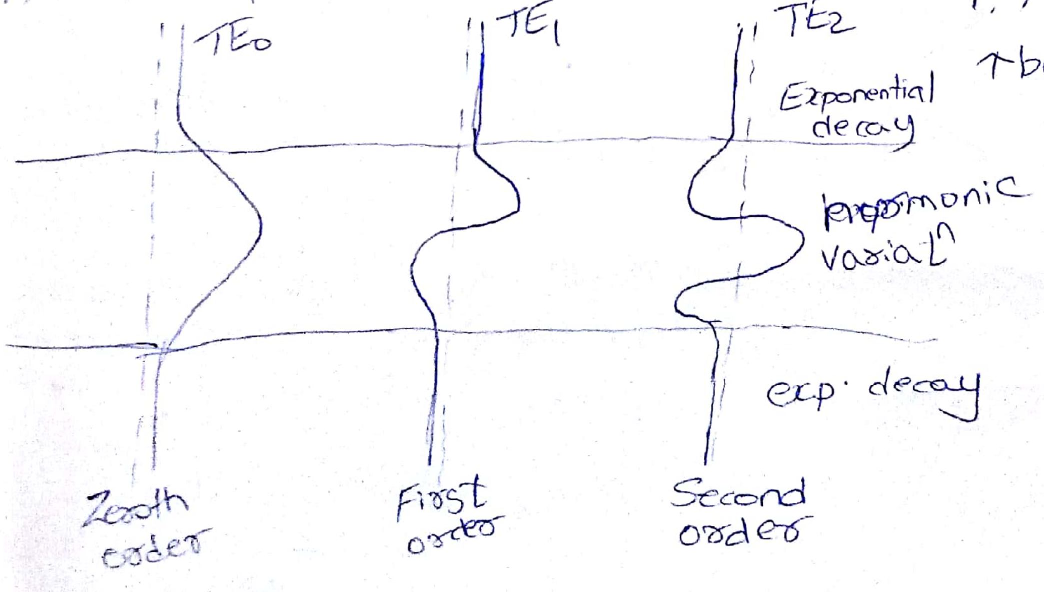
— Bending Loss → due to bends of OF

i. Macroscopic B L

ii. ~~Microscopic BL~~



↑bending → ↓R → ↑BL
↓
expo.



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

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

• Avoided by making R↑

ii. Microscopic BL (Packaging loss)

• Avoided by using thicker outer jacket

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

E_f → Young's modulus of fiber

E_j → — " — — " — of jacket

— Core & Cladding Losses

abs. coeff. of core

$$\alpha_{rm} = \frac{\alpha_1 P_{core}}{P} + \frac{\alpha_2 P_{clad}}{P}$$

$$\alpha_{rm} = \alpha_1 + (\alpha_2 - \alpha_1) \frac{P_{clad}}{P}$$

} Step index

$$\alpha(r) = \alpha_1 + (\alpha_2 - \alpha_1) \frac{n^2(0) - n^2(r)}{n^2(0) - n_2^2}$$ → Graded index

att^n coeff.

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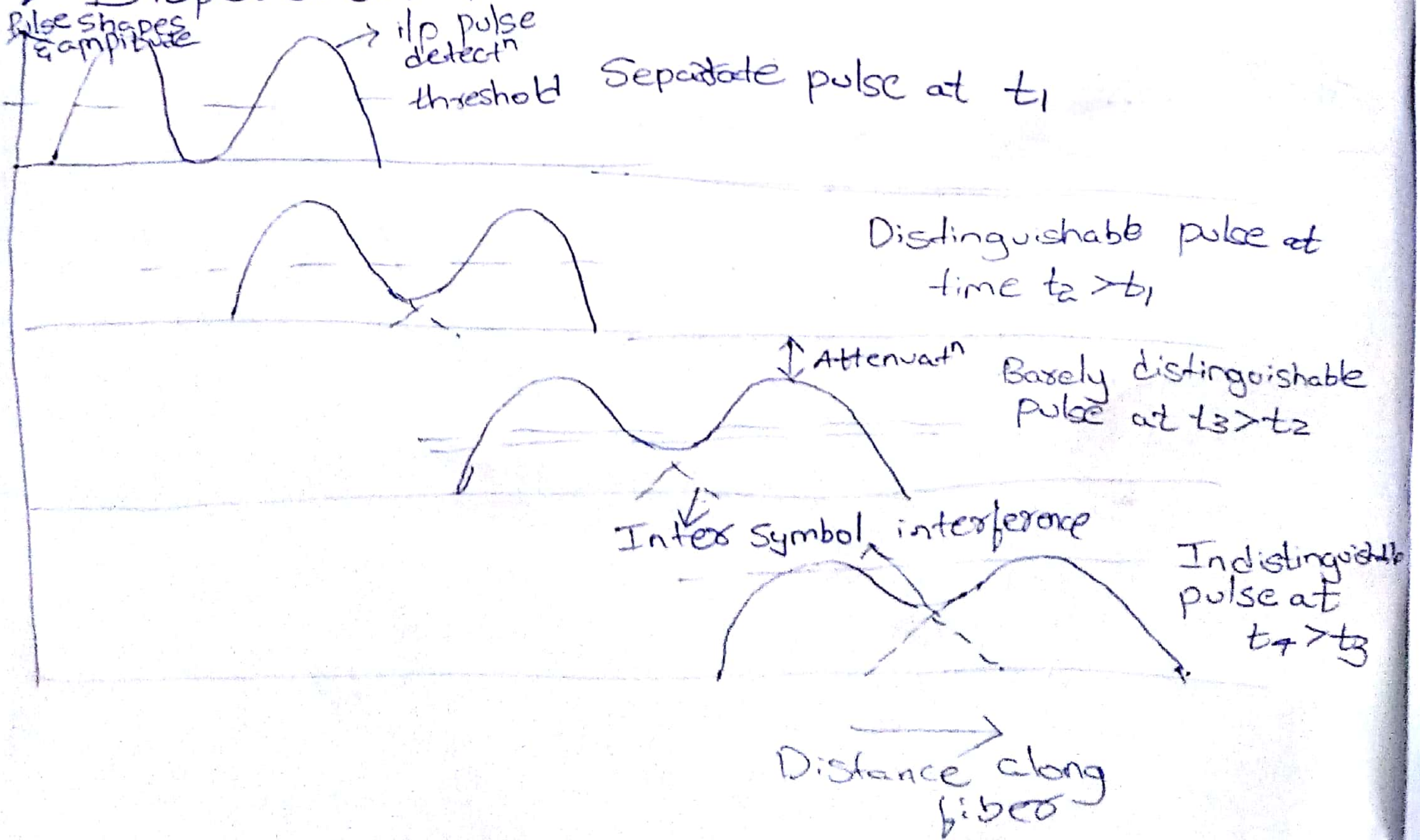
→ Dispersion



[illegible]/11/2021

2. Cal rad. of curvature R, for which no. of modes decreases by 50% in Graded Index fiber; $\alpha = 2$, $n_2 = 1.5$, $\Delta = 0.01$, $a = 25\,\mu m$ & wavelength of guided light is $1.3\,\mu m$.

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

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

$$= \frac{2}{4}\left(1.515 \times 1381 \times 10^{-23} \times 25 \times 10^{-6}\right)^2 0.01$$

$$= 1.367 \times 10^{-57}$$

$\Rightarrow 0.01 n_1 = n_1 - 1.5$

$-0.99 n_1 = -1.5$

$n_1 = 1.515$

$$N_{eff} = N_\infty \times \frac{50}{100} = \cancel{6.836 \times 10^{-58}} \qquad \frac{N_{eff}}{N_\infty} = \frac{1}{2}$$

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

$$\frac{1}{2} = 1 - \left(\frac{2+2}{2 \times 2 \times 0.01}\right)\left[\frac{2 \times 25 \times 10^{-6}}{R} + \left(\frac{3}{2 \times 1.5 \times \frac{2\pi}{1.3 \times 10^{-6}} \times R}\right)^{2/3}\right]$$

$$\frac{1}{2} = 1 - 100\left[\frac{50 \times 10^{-6}}{R} + \frac{1.442}{3.46 \times 10^{-8}\, R^{2/3}}\right]$$

$$= 1 - 100\left[1.729 \times 10^{-12} R^{1/3}\right.$$

$$\frac{1}{2} = 1 - 100\left[\frac{50 \times 10^{-6}}{R} + \frac{1.7376 \times 10^{-5}}{R^{2/3}}\right]$$

$$\frac{1}{2} = -\left[\frac{5 \times 10^{3}}{R^{2}} + \frac{1.737 \times 10^{17}}{R^{2/3}}\right]$$

$$0.125 = -\left[\frac{125 \times 10^{9}}{R^3} + \frac{5.241 \times 10^{51}}{R^2}\right]$$

$$\cancel{-0.125 = \frac{R^{2} \times 125 \times 10^{9} + R^{3} \times 5.241 \times 10^{51}}{R^5}}$$

15.625×10⁹   6.551×10⁵⁰

$$\cancel{-R^{3} = R^{2}\,10^{12} + R(4.193 \times 10^{52})}$$

$\Rightarrow$

$$\cancel{-0.125 = \frac{125\times10^{9}}{R^3} + \frac{5.241\times10^{51}}{R^2}}$$

$$\cancel{\Rightarrow R^2(125\times10^{9}) + R^3(5.241\times10^{51}) + 0.125R^5 = 0}$$

$$\cancel{125\times10^{9} + R(5.241\times10^{51}) + R^3(0.125) = 0}$$

~~Neff~~

2.

$$N_{eff} = N_\infty\left\{1 - \frac{\alpha+2}{2\alpha\Delta}\left[\frac{2a}{R} + \left(\frac{3}{2n_2kR}\right)^{2/3}\right]\right\} \; ; \; k = \frac{2\pi}{\lambda} = 4.83\times10^{6}$$

$$N_{eff} = N_\infty \times \frac{50}{100} \Rightarrow \frac{N_{eff}}{N_\infty} = \frac{1}{2}$$

$$\therefore \frac{1}{2} = 1 - \frac{2+2}{2\times2\times0.01}\left[\frac{50\times10^{-6}}{R} + \left(\frac{3}{2\times1.5\times4.83\times10^{6}\,R}\right)^{2/3}\right]$$

$$0.5 = 1 - 100\left[\frac{50\times10^{-6}}{R} + \frac{3.499\times10^{-5}}{R^{2/3}}\right]$$

$$-0.5 = -\left[\frac{500\times10^{-5}}{R} + \frac{3.499\times10^{-5}}{R^{2/3}}\right]$$

$$0.5\times10^{5} = \frac{500}{R^1} + \frac{3.5}{R^{2/3}}$$

$$50\times10^{3} = \frac{500R^{2/3} + 3.5R}{R^{5/3}} \times \cancel{\frac{R^3}{R^3}}$$

$$= \cancel{\frac{500R^2 + 3.5R^4}{R^5}}$$