Fibre Beat Length:

* In general, a linearly polarised mode is a combination of both the degenerate modes. As the modal wave travels along the fibre, the diff. in the refractive indices would change the phase difference between these two components and thereby the state of the polarisation of the mode. However, after certain length, referred ~~to~~ to a fibre beat length, the modal wave will produce it's original state of polarisation. This length is simply given by,

$$\boxed{L_p = \frac{2\pi}{k B_f}}$$

09/02/2020

Graded Index Fibre: (Refractive Index Profile)

$$n(r) = \begin{cases} n_1\left[1-2\Delta (r/a)^{\alpha}\right] \\ n_1(1-2\Delta)^{1/2} \simeq n_1(1-\Delta) = n_2 \quad \text{for } r>a. \end{cases}$$

?

$$\Delta = \frac{n_1^2 - n_2^2}{2n_1^2} \sim \frac{n_1 - n_2}{n_1}$$

α is the dimensionless quantity and defines the shape of refractive index profile.

For step index, $\alpha = \infty$. ($\alpha = 2$ for gradual index fibre, usually).

$$NA(r) = \begin{cases} [n^2(r) - n_2^2]^{1/2} \cong NA(0)\sqrt{1-(r/a)^\alpha}, & r \le a \\ 0 & \text{for } r > a. \end{cases}$$

Where axis NA defined as,

$$NA(0) = [n^2(0) - n_2^2]^{1/2} = (n_1^2 - n_2^2)^{1/2}$$

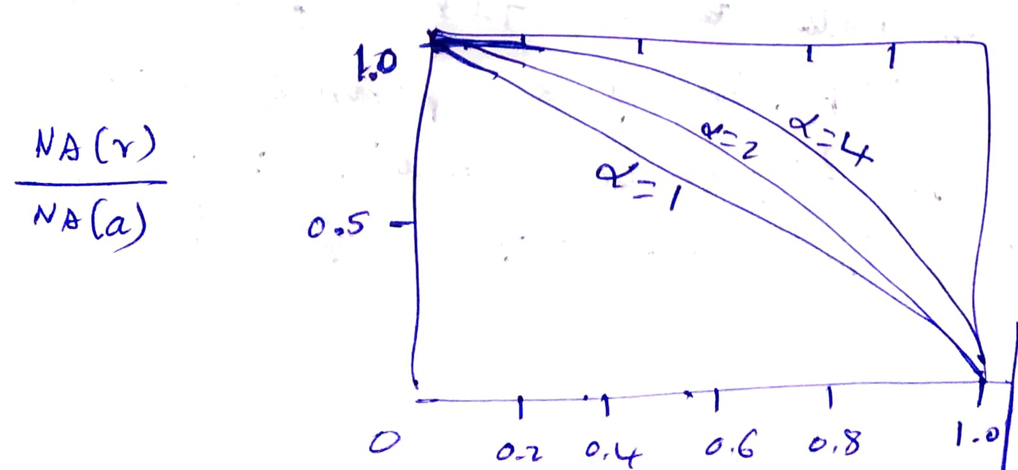
$$= n_1\sqrt{2\Delta}.$$

The number of bound modes in a graded index fiber is.

$$M_g = \frac{\alpha}{\alpha+2} a^2 k^2 n_1^2 \Delta \simeq \frac{\alpha}{\alpha+2} \cdot \frac{V^2}{2}$$

Where $k = \frac{2\pi}{\lambda}$

If $\alpha = 2$, $M_g = \frac{1}{2}\left(\frac{V^2}{2}\right)_{SIF} = \frac{M_{SIF}}{2}$ (step index fibre).



$\alpha = 2$ preferred commercially, though both 1 and 4 also available.

L_{11}(mode) of GIFs V is given by

$V = 2.405\sqrt{1+\frac{2}{\alpha}}$

Prob:

1. If we have 50 μm diam. GIF that has a parabolic reflective index of $\alpha = \sqrt{2}$. If fibre has an NA = 0.22, λ = 1310 nm, what is the total length of modes at

$$V = \frac{2\pi a}{\lambda}(NA)$$

$$= \frac{2\pi \times 25\times10^{-6}}{1310\times10^{-9}} \times 0.22$$

$$= 26.38$$

$$M = \frac{V^2}{2} = 347.95$$

$$M_g = \frac{V^2}{4} = \frac{\alpha}{\alpha+2} \times \frac{V^2}{2}$$

$$M_g = 173.975$$

---

2. Calc. the no. of modes at 820 nm and 1.3 μm in a GIF, having a parabolic index profile $\alpha = 2$. A 25 μm core radius $n_1 = 1.48$ and $n_2 = 1.46$. How does this compare to a SIF?

Chap. 3.1

Signal Degradation and losses in OF.

Attenuation:

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

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

$$\log\left[\frac{P(z)}{P(0)}\right] = -\alpha_p z \log e.$$

Power Loss along a fibre.

$P(0)$ mW

$P(L) = P(0)\, e^{-\alpha_p L}$ mW

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

The parameter α_p is called fibre attenuation coeff in a units of example (1/km) or [nepers/km]

A more common unit is dB/km, that is defined by

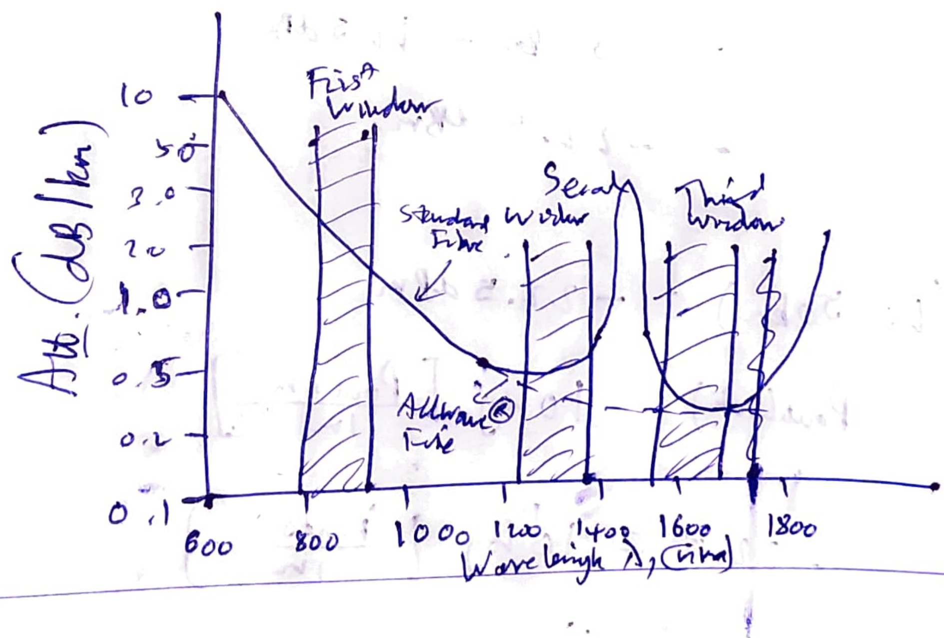
$$\alpha\,[dB/km] = \frac{10}{L} \log\left[\frac{P(0)}{P(L)}\right] = 4.343\,\alpha_p$$

$$\boxed{\alpha\,[dB/km] = 4.343\,\alpha_p\,[1/km]}$$

$$\boxed{P(L)[dBm] = P(0)\,[dBm] - \alpha\,[dB/km] \times L[km]}$$

where [dBm] or dB milliwatt is $10\log(P\,[mW])$

Ideal Attenuation vs λ curve:



Prob.

1. A 50 km long OF has an atten of 0.25 dB/km at 1550 nm. If 100 MW of power is launched into the fibre, find power emerging at fibre o/p is,

Soln $\alpha = 0.25\,dB/km$, $\lambda = 1550\,nm$, $P_{in} = 100\,MW$, $L = 50\,km$.

$$P(50\,km) = P(0)\,e^{-\alpha_p z}$$

$$= 100\,M \times e^{\boxed{-0.25\,\alpha}}$$ in dB

$$\overset{\text{dB or dBm}}{\downarrow}$$

$$P(L = 50\,km) = P(0) - \alpha \times L;$$

step 1: Convert given optical power into dB or dbm.

$$P_{in}(dB) = 10\log(100\mu W) = -40dB$$

$$P_{in}(dB) = 10\log\left(\frac{100\mu W}{1mW}\right) = -10dBm \quad (\text{milli})$$

$$P(L = 50\,km) = P_{in_{L=0}}(0)\,[dBm] - \alpha\,[dB/km] \times \underset{\substack{\uparrow \\ 50\,km}}{L}$$

$$= -10\,dBm - 0.25 \times 50$$

$$= -10\,dBm - 12.5\,dBm$$

$$= -22.5\,dBm$$

$$P_{out}(L = 50km) = -22.5\,dBm$$

$$P_{out}(50km) = 10\log\left[\frac{P_{out\,50km}}{1m}\right]$$

$$-22.5 = 10\log\left[\frac{P_{out\,50km}}{1m}\right]$$

$$10^{\left(\frac{-22.5}{10}\right)} \times 1m = P_{out\,50km}$$

$$P_{out\,50km} = 5.6\mu W.$$

L=0	L=50km
100μW	5.6μW

Chap 3.2.

Fibre Materials:

- → Glass OF
- → plastic (or Polymer) OF

oxide, fluoride, ... etc.

Char. of single mode fibers.