Problem:

A 6 km optical link consists of multimode step index fiber with a core refractive index of 1.5 and a relative refractive index of 1%. Estimate the delay difference between the slowest and fastest modes at the fiber output and the rms pulse broadening due to intermodal dispersion on the link. Also derive the expression involved in it.

Soln:- The pulse broadening is simply obtained from ray tracing

$$\Delta T = T_{max} - T_{min} = \frac{n_1}{c}\left(\frac{L}{\sin\phi_c} - L\right)$$

$$= \frac{L n_1^2}{c n_2}\Delta$$

Given:

$L = 6$ km

$n_1 = 1.5$

$\Delta = 1\% = 0.01$

$\therefore n_2 = 1.5 - 0.01 = 1.49$

→ The root-mean square (rms) value of the time delay is a useful parameter for assessing the effect of modal delay in a multimode fiber.

→ If it is assumed that the light rays are uniformly distributed over the acceptance angles of the fiber, then the rms impulse response σ_s due to intermodal dispersion in a step-index multimode fiber can be estimated from the expression

Lower order mode $$\boxed{\sigma_s \approx \frac{L n_1 \Delta}{2\sqrt{3}\,c} \approx \frac{L(NA)^2}{4\sqrt{3}\,n_1 c}}$$

→ Here L is the fiber length and NA is the numerical aperture. Above equation shows that the pulse broadening is directly proportional to the core-cladding index difference and the length of the fiber.

→ A successful technique for reducing modal delay in multimode fibers is through the use of a graded refractive index in the fiber core.

→ In any multimode fiber the ray paths associated with higher-order modes are concentrated near the edge of the core and thus follow a longer path through the fiber than lower-order modes (Near fiber axis).

The modal delay at the output of a graded index fiber that has a parabolic ($\alpha = 2$) core index profile.

Higher order mode $$\boxed{\sigma_s = \frac{L n_1 \Delta^2}{20\sqrt{3}\,c}}$$

For

Lower order [Slowest mode].

$$\sigma_s = \frac{L n_1 \Delta}{2\sqrt{3}\, c} = \frac{6 \times 1.5 \times 0.01}{2 \times \sqrt{3} \times 3 \times 10^5}$$

$$\boxed{= 86.62 \text{ ns}}$$

For Higher order

[Fastest mode]..

$$\sigma_s = \frac{L n_1 \Delta^2}{20\sqrt{3}\, c} = \frac{6 \times 1.5 \times (0.01)^2}{20 \times \sqrt{3} \times 3 \times 10^5}$$

$$= \frac{0.0009}{103.92 \times 10^5} = 0.00866 \times 10^{-8} \text{ s}$$

$$\boxed{= 86.6 \text{ ps}}$$

problem:

Consider two silica fibers that are doped with 6 % and 18 % mode fractions of GeO_2, respectively. Compare the ultraviolet absorptions at wavelengths of 0.7 μm and 1.3 μm.

soln:-

$$\alpha_{uv} = \frac{154.2\, x}{46.6\, x + 60} \times 10^{-2} \exp\left(\frac{4.63}{\lambda}\right)$$

(a) For the fiber with $x = 0.06$ and $\lambda = 0.7\ \mu m$

$$\alpha_{uv} = \frac{1.542(0.06)}{46.6(0.06)+60} \exp\left(\frac{4.63}{0.7}\right)$$

$$= \frac{0.09252}{62.796} \exp(6.614)$$

$$= 1.47 \times 10^{-3} \times 745.45$$

$$\boxed{= 1.095 \approx 1.10 \text{ dB/Km}}$$

(b) For the fiber with $x = 0.06$ and $\lambda = 1.3\ \mu m$

$$\alpha_{uv} = \frac{1.542(0.06)}{46.6(0.06)+60} \exp\left(\frac{4.63}{1.3}\right)$$

$$= 1.47 \times 10^{-3} \times 35.21$$

$$\boxed{= 0.0239 \approx 0.024 \text{ dB/Km}}$$

(c) For the fiber with $x = 0.18$ and $\lambda = 0.7\ \mu m$

$$\alpha_{uv} = \frac{1.542(0.18)}{46.6(0.18)+60} \exp\left(\frac{4.63}{0.7}\right)$$

$$= \frac{0.27756}{68.388} \exp 6.614$$

$$= 4.058 \times 10^{-3} \times 745.67$$

$$\boxed{= 3.025 \approx 3.03 \text{ dB/Km}}$$

(d) For the fiber with $x = 0.18$ and $\lambda = 1.3\ \mu m$

$$\alpha_{uv} = \frac{1.542\,(0.18)}{46.6\,(0.18) + 60} \exp\left(\frac{4.63}{1.3}\right)$$

$$= 4.058 \times 10^{-3} \times \exp 3.561$$

$$= 4.058 \times 10^{-3} \times 35.21$$

$$\boxed{= 0.142\ dB/km}$$

problem

Compute the total intermodal, intramodal and total dispersion for a fiber having fiber length 1 km, line width 50 nm, intermodal and intramodal dispersions 5 ns/km and 80 pcs/km Respectively.

soln

$$\text{Total dispersion } \Delta t = \sqrt{\Delta t^2_{modal} + \Delta t^2_{ch}}$$

Intermodal or modal dispersion $\Delta t_{modal} = L \times 5\ ns/km$
$= 5\ ns$

Intramodal or chromatic " $\Delta t_{ch} = L \times 80\ ps/km \times 50\ nm$
$= 4000\ ps = 4\ ns$

$$\Delta t = \sqrt{5^2 + 4^2} = \sqrt{41} = 6.4\ ns$$

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