Çankaya University – ECE Department – ECE 474

2014 Spring Term **April 2014**

Experiment 6 : Evaluating the performance of a fibre optic link

This experiment is intended to illustrate the attenuation and dispersion calculations of a given fibre length. From there we can deduce the amount of (minimum) optical power that has to be launched into the fibre and maximum bit rate that is achievable for this fibre. For this we benefit from midterm solutions of EEM474MT-08042013_Solutions, available on the course webpage, the Matlab m file, RefindexVcurves.m, also available on the course webpage
The given parameters of the single mode fibre and the light source are
$V = 2.2$, $\Delta = 0.004$, $L = 10$ km , $\sigma_\lambda = 0.7$ nm

Now we do a sample calculation, for this we take $\lambda_{ZD} = \lambda = 1.31$ μm from Fig. 1. By running RefindexVcurves.m, we get four figures, two of which are given in Figs. 2 and 3. By assuming that in Fig. 2, the lower curve represents the cladding refractive index, we read $n_2 = 1.447$ at $\lambda = 1.31$ μm, then by using

$$n_1 = n_2 / (1 - \Delta) = 1.4528 \tag{1}$$

From EEM474MT-08042013_Solutions, we have

$$f = \frac{c}{\lambda} = \frac{3\times 10^8}{1.31\times 10^{-6}} = 2.29\times 10^{14} \text{ Hz} \quad , \quad \omega = 2\pi f = 1.44\times 10^{15} \text{ rad/sec} \tag{2}$$

From Fig. 3, we read at $\lambda = 1.31$ μm

$$\frac{dn_{2g}}{d\lambda} = 0.001212 \ \mu\text{m}^{-1} \rightarrow \ 1212 \text{ m}^{-1} \tag{3}$$

Hence,

$$\text{Material dispersion parameter}: D_M = \frac{1}{c}\frac{dn_{2g}}{d\lambda} = 4.04\times 10^{-6} \text{ s/m}^2$$

$$= 4.04\times 10^{-6} \overbrace{\times 10^{12}}^{\text{for conversion into psec}} \overbrace{\times 10^{3}}^{\text{for conversion into km}^{-1}} \overbrace{\times 10^{-9}}^{\text{for conversion into nm}^{-1}} = 4.04 \text{ ps/km/nm} \tag{4}$$

From Fig. 5, we read $D_M \approx 3$ ps/km/nm, quite in agreement. Waveguide dispersion parameter on the other hand

$$\text{Waveguide dispersion parameter}: D_W = -\frac{2\pi\Delta}{\lambda^2}\left[\frac{n_{2g}^2}{n_2\omega} V \frac{d^2(Vb_n)}{dV^2} + \frac{dn_{2g}}{d\omega}\frac{d(Vb_n)}{dV}\right]$$

$$= -\frac{2\pi\Delta}{\lambda^2}\left[\frac{n_{2g}^2}{n_2\omega} V \frac{d^2(Vb_n)}{dV^2} - \frac{\lambda^2}{2\pi c}\frac{dn_{2g}}{d\lambda}\frac{d(Vb_n)}{dV}\right] \tag{5}$$

By reading for $V\frac{d^2(Vb_n)}{dV^2} = 0.13$ and $\frac{d(Vb_n)}{dV} = 0.97$ at $V = 2.2$ from Fig. 4, we evaluate (5) as follows

$$D_W = -\frac{2\pi\times 0.004}{\left(1.31\times10^{-6}\right)^2}\left[\frac{\left(1.462\right)^2}{1.447\times1.44\times10^{15}}\times\overbrace{0.13}^{\text{read from Fig.4}} - \frac{\left(1.31\times10^{-6}\right)^2\times1212}{2\pi\times3\times10^8}\overbrace{0.97}^{\text{read from Fig.4}}\right]$$

$$= -1.9381\times10^{-6}\ \text{s/m}^2 = -1.9381\ \text{ps/km/nm} \qquad (6)$$

From Fig. 1, we read $D_W \approx -2$ ps/km/nm.

For total dispersion and fibre bandwidth, maximum bit rate that can be offered with $L = 10$ km and $\sigma_\lambda = 0.7$ nm

$$\delta T = \left(D_M + D_W\right)L\sigma_\lambda = DL\sigma_\lambda = 10\times2.1\times0.7 = 14.7\ \text{ps}$$

$$B_t = \frac{1}{\delta T} \simeq 68\ \text{GHz : Total bandwidth offered over 10 km}$$

$$C_t \simeq B_t = 68\ \text{Gb/s : Total capacity offered over 10 km} \qquad (7)$$

At $\lambda_{ZD} = \lambda = 1.31\ \mu$m, from Fig. 5, we read $\alpha = 0.35$ dB/km., we have

For SNR calculations, we benefit from (4.1.11) of the Attenuation and dispersion in fibres_March 2013_HTE, hence

$$T_a\left(\text{absolute temprature}\right) = 273 + 20 = 293\ ^0\text{K}$$

$$S_n\left(f\right) = \frac{kT_a}{2} = \frac{1.38\times10^{-23}\times293}{2} = 2.0217\times10^{-21}\ \text{J : Two side noise spectral density}$$

$$P_n = 2S_n\left(f\right)B_t = 2\times2.0217\times10^{-21}\times68\times10^9 = 3.05\times10^{-10}\ \text{W} = 2.75\times10^{-4}\ \mu\text{W: Noise power}$$

$$\text{For SNR}\left(\text{at receiver}\right) = 30\ \text{dB},\ \frac{P_r}{P_n} = 2.75\times10^{-4}\ \mu\text{W}\times10^3 = 0.275\ \mu\text{W} \ \rightarrow\ -35.6\ \text{dBm}$$

$$\text{Minimum power to be launched into the fibre } P_t = P_r + \alpha\times L = -32.1\ \text{dBm} \ \rightarrow\ 0.616\ \mu\text{W} \qquad (8)$$

Exercise : Repeat the above calculations for

- $V = 2,\ V = 2.4$
- $V = 2.2,\ \lambda = 1.2\ \mu\text{m},\ \lambda = 1.4\ \mu\text{m},\ \lambda = 1.5\ \mu\text{m}$

Compare your results with those in Fig.1, write your comments on the variation of dispersion with wavelength, fibre capacity and minimum power to be launched into the fibre.
Note that f in (2) will change as λ changes.

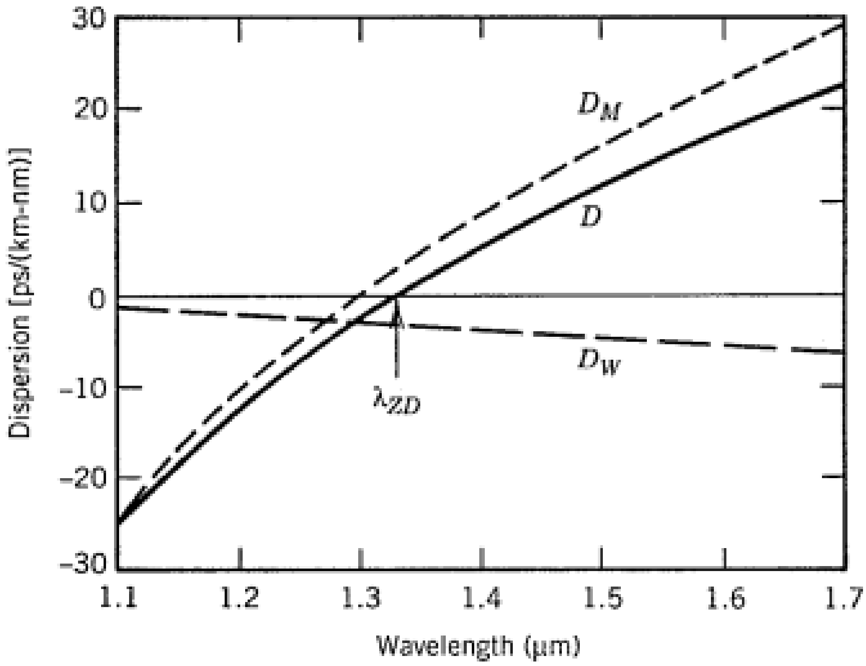

Fig. 1 Curves of D, D_M and D_W, showing the position of λ_{ZD} (Fig. 2.10 of Agrawal).

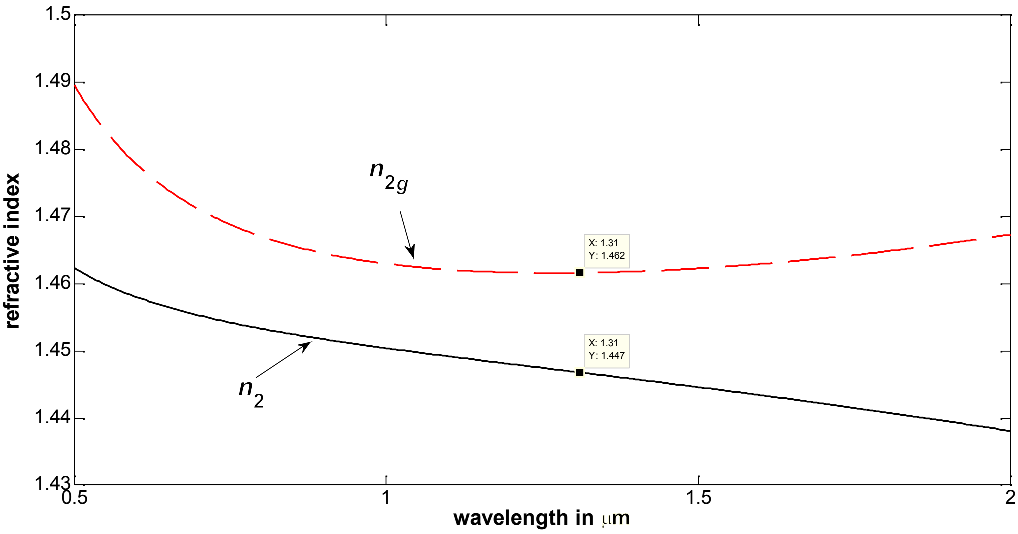

Fig. 2 Variation of refractive index with wavelength (from RefindexVcurves).

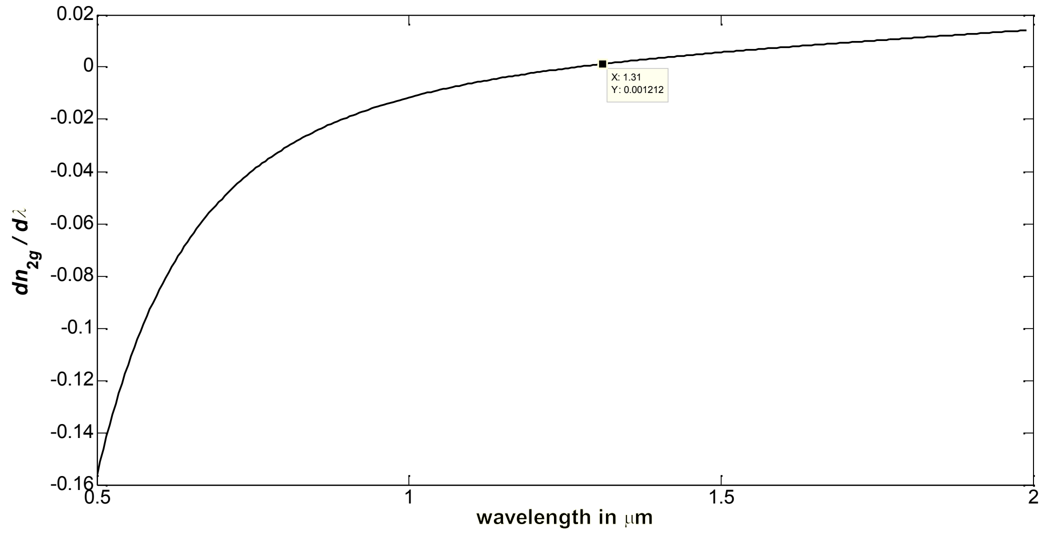

Fig. 3 The derivative of n_{2g} with respect to wavelength (from RefindexVcurves).

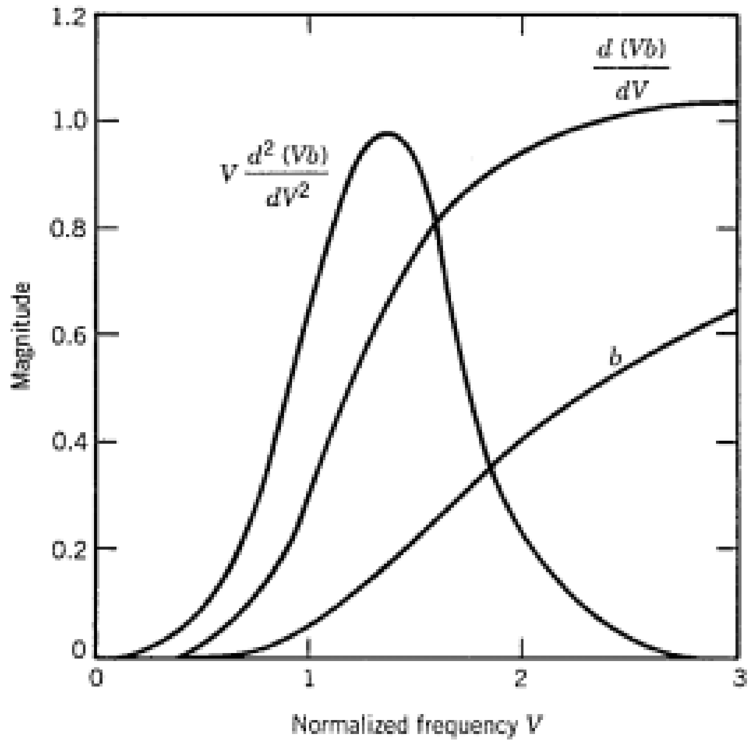

Fig. 4 Variations of b_n, $\frac{d(Vb_n)}{dV}$ and $\frac{d^2(Vb_n)}{dV^2}$ with V. Note that in our notation b is b_n (Fig. 2.9 of Agrawal).

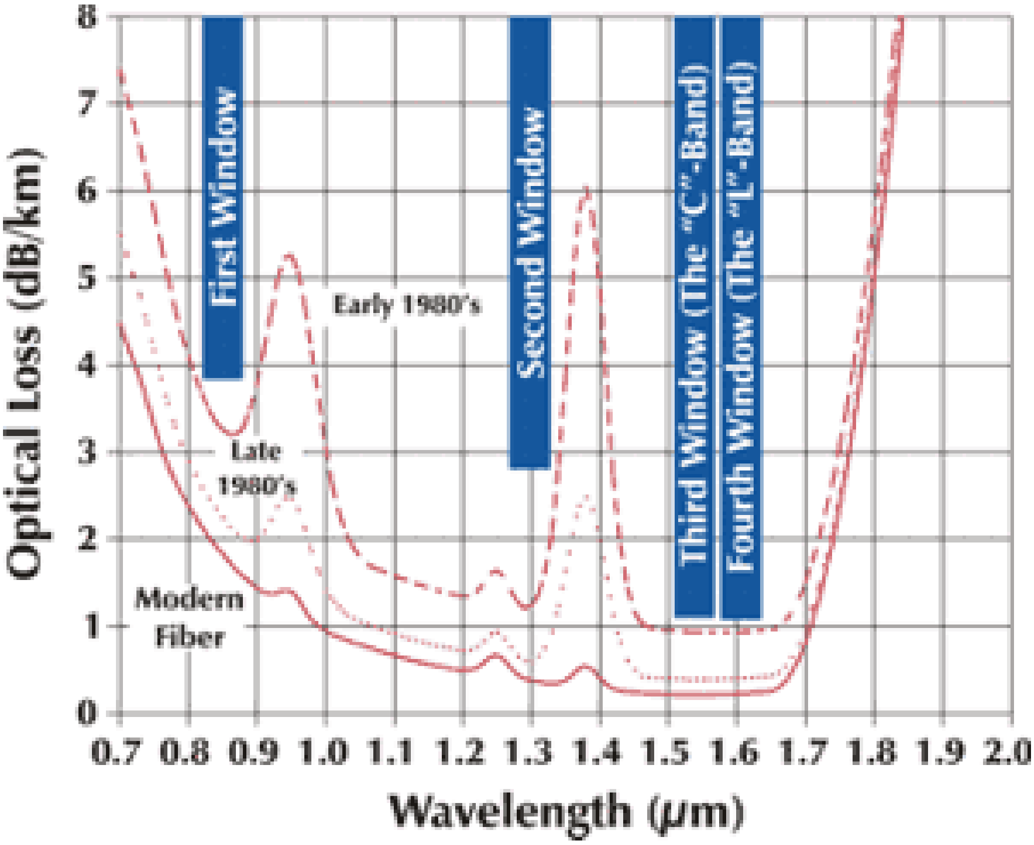

Fig. 5 Variation of fibre attenuation with wavelength.