Çankaya University – ECE Department – ECE 635

Questions

1) A single mode fibre with $V = 2.2$, $n_1 = 1.46$, $\Delta = 0.4$ percent is operated at wavelength of $\lambda = 1.55\ \mu\text{m}$. Find the core radius so that the single mode condition is not violated. For this fibre, calculate the propagation constant, find the percentage of power propagating in the core. Evaluate and plot the NA of the same single mode fibre.

Solution : According to (2.5) of ECE 635_Notes on Fibre Propagation_Jan 2013_HTE, n_2 of the fibre is given by

$$n_2 = n_1(1-\Delta) = 1.46\times(1-0.4\times10^{-2}) = 1.4542 \tag{1.1}$$

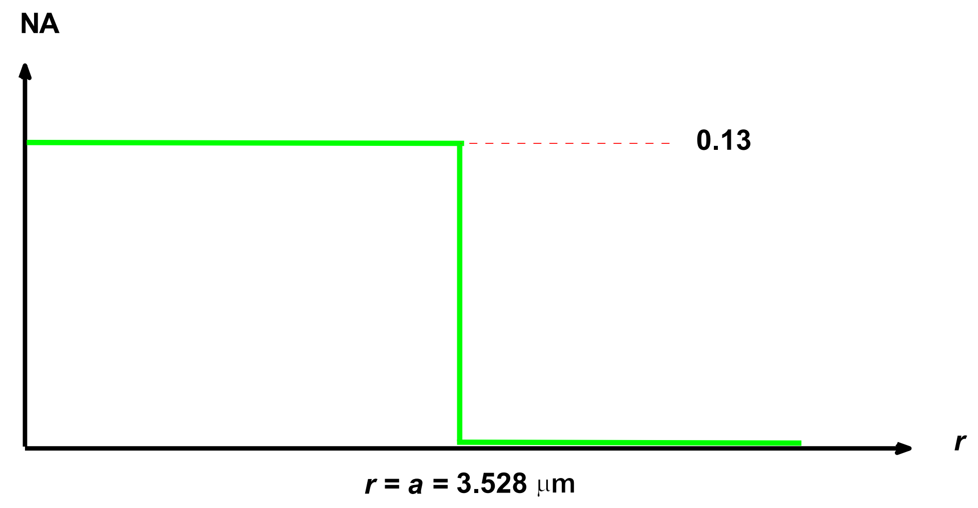
Then from (3.21) of the same notes, fibre radius is calculated from

$$a = \frac{V}{k\left(n_1^2 - n_2^2\right)^{0.5}} = \frac{V}{\frac{2\pi}{\lambda}\left(n_1^2 - n_2^2\right)^{0.5}} = \frac{2.2}{\frac{2\pi}{1.31\times10^{-6}}\left[(1.46)^2 - (1.4542)^2\right]} = 3.528\ \mu\text{m} \tag{1.2}$$

From (2.4) of the same notes, NA is evaluated and plotted as shown below

$$\begin{aligned} &n_2 = n_1(1-\Delta) = 1.46\times(1-0.4\times10^{-2}) = 1.4542 \\ &\text{NA} = \sin(\theta_{0c}) = n_1\sin(\theta_c) = \left(n_1^2 - n_2^2\right)^{0.5} = \left[(1.46)^2 - (1.4542)^2\right]^{0.5} = 0.13 \\ &\theta_{0c} = \sin^{-1}(\text{NA}) = 7.47^0 \end{aligned} \tag{1.3}$$

The related plot can be found in Fig. 1.1.



For percentage of power propagating in the core, from (4.4) of ECE 635_Notes on Fibre Propagation_Jan 2013_HTE, we get

$$\Gamma_c = \frac{P_{core}}{P_{total}} = 1 - \exp\left(-\frac{2}{w_s^2}\right) = 1 - \exp\left[-\frac{2}{\left(0.65 + 1.619V^{-1.5} + 2.879V^{-6}\right)^2}\right] = 0.7671 \qquad (1.4)$$

By making the suitable arrangements in the m file Findingbeta_Exp0.m, we get the plot of following V circles for the given fibre parameters.

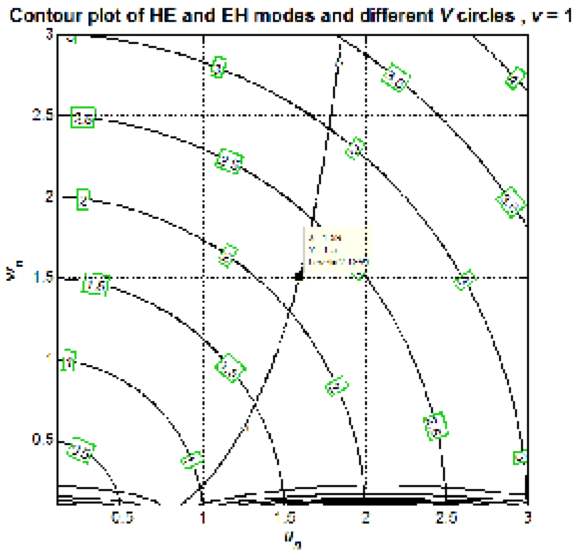


Fig. 1.2 Contour plots of the CE for HE and EH modes and the associated V circles.

From Fig. 1.2, we estimate the approximate location of the $V = 2.2$ and mark the corresponding intersection $u_n = 1.5,\ w_n = 1.59$. Subsequently using (3.21)

$$\beta_n = \left(a^2k_1^2 - u_n^2\right)^{0.5} = 20.826 \quad \text{or} \quad \beta_n = \left(a^2k_2^2 + w_n^2\right)^{0.5} = 20.8577$$

$$\beta = \frac{\beta_n}{a} = 5.9031\times10^6 \quad , \quad k_2 = 5.8948\times10^6 < \beta < k_1 = 5.9184\times10^6 \qquad (1.5)$$

Exercise : With the above settings find the propagation constants of TE_{01}, TM_{01} and prove that they will not propagate in this single mode fibre.

2) Answer the following questions as **True** or **False.** For the **False** ones give the correct answer or the reason. For the **True** ones, justify your answer.

a) Single mode fibre is obtained by observing the V , i.e., normalized frequency value for TE_{01} and TM_{01} : True, for single mode operation, we select V to be below the roots of TE_{01} and TM_{01} at $w_n = 0$.

b) In graded index fibres, ray propagation takes place according to Fermat's principle : True, according to (2.1) of ECE 635_Notes on Propagation in GI fibres_Feb 2013_HTE.

c) In single mode fibres, rays can be classified as meridional and skew : False. In single mode fibres, radius of the core is comparable in size to the wavelength of the light source, so the mode theory applies, thus propagation cannot be described in terms of rays. It is only in multimode fibres where radius of the core is much larger than the wavelength of the propagating light.

d) In single mode fibres, part of the electric field of the TE_{01} mode, propagates in the core : The part about TE_{01} mode propagation is false, since in single mode fibre, the HE_{11} mode propagates, but part of it extends into cladding as well.

e) In single mode fibres, multimode dispersion is absent: True, in single mode fibres, intermodal dispersion, arising from the existence of many modes is absent