Çankaya University – ECE Department – ECE 474

2013 Spring Term

Experiment 3 : Finding beta and propagating modes of the fibre

Experiment in MATLAB is on the course webpage ece474.cankaya.edu.tr. File name is "Findingbeta_Exp3.m".

1. Copy the experiment file into the directory of your name.
2. Run the file, observe the OPs, do not record anything yet. Try to follow what is intended and what is happening
3. This experiment is intended to find the propagation constants (β) and identify the propagating modes in a step index fibre. For this purpose, the characteristic equation (CE) is written for both HE_{vm} and EH_{vm} and TE_{0m} and TM_{0m} modes. Note that the first (and in case of TM_{0m} the second as well) lines are in the original form of CE, but they create singularities due to zero crossings of Bessel functions in the denominator. Hence, they are eliminated by multiplying both sides of the equation by the Bessel function of the denominator. These are the forms used to plot both graphs .
4. In the first graph, we see in 3D the plot of CE for the selected modes. This picture helps us identify the zero crossings (zeros, m) of CE at selected v parameter for all modes in question. The second set of graphs (contour plots) display the zero crossing more clearly on a two dimensional plane and are the contour plots of the all CEs with the normalized frequency V circles added.
5. By incrementing v in the range 1 to 8 (in integer increments), find the HE_{vm} and EH_{vm} modes for V values up to 10. Identify these modes one by one and their cut-off V values, i.e. at which minimum value of V excludes them. Tabulate these results.
6. By the other CE equations (further down) in the programme, find the TE_{0m} and TM_{0m} modes for V values up to 10. Identify these modes one by one and their cut-off V values, i.e. at which minimum value of V excludes them. Tabulate these results in a separate table.
7. Find the propagation constants, and its normalized values i.e. β and β_n s following the steps given in Example 3.1 of "Notes on Fibre Propagation_Jan_2013_HTE".
8. Confirm that these propagation constants, i.e., β s, are in agreement with b_n values read from the graph in Fig. 2, also following the steps of Example 3.2.
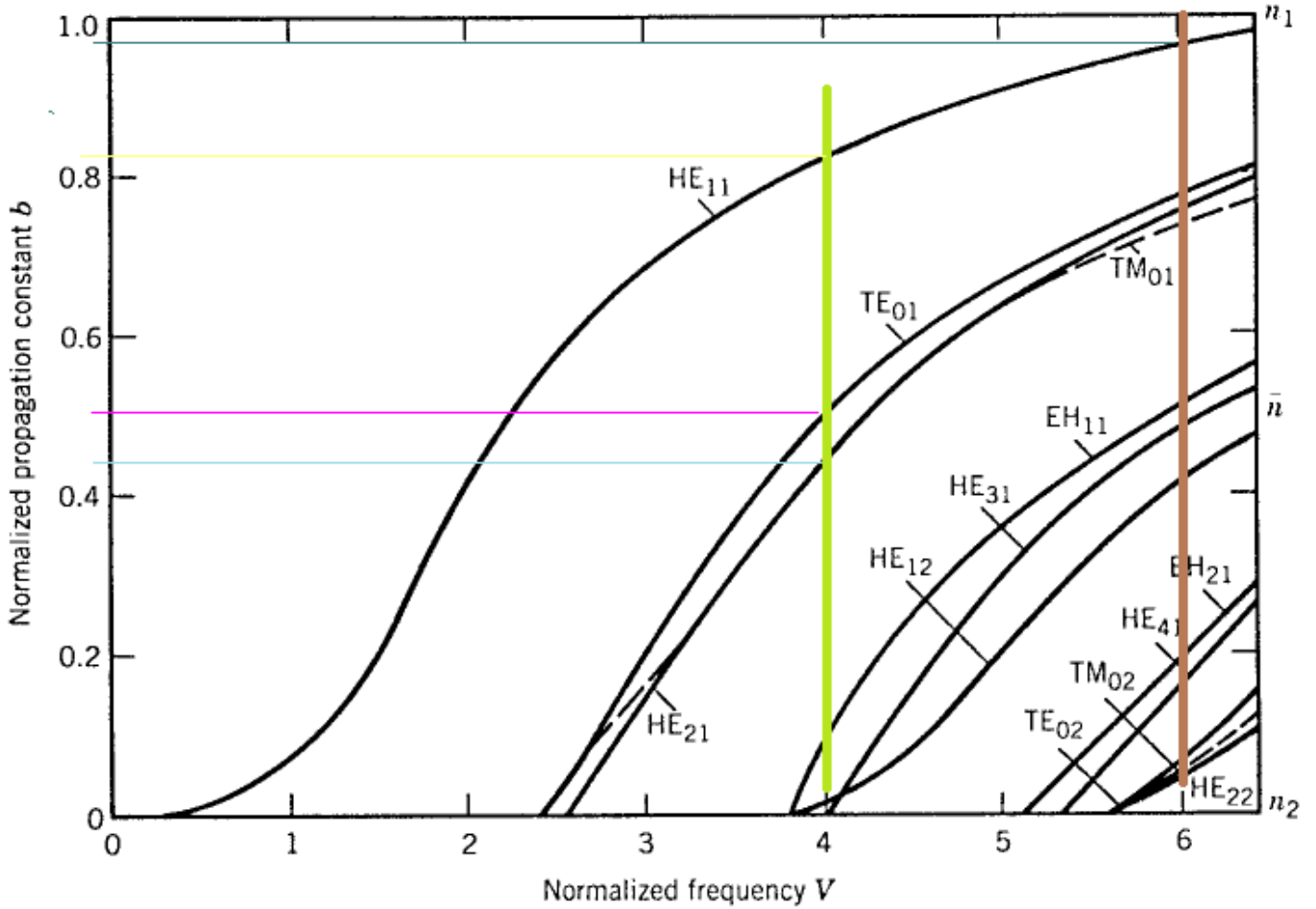9. Include your comments for the experiment

Fig. 2. Graph of normalized propagation constant coped from Fig. 2.5 of Agrawal 2002.

Sample Calculation : By running the Findingbeta_Exp3.m at the settings given, we get the contour plot given in Fig. 1, i.e. the graph for TM_{0m}. From there, we take the $V = 4$ and get the intersection of this circle with the TM_{01} curve. Now following Example 3.1 and 3.2, and noting the refractive index values of core and the cladding in the given Matlab file, we proceed as follows

$$n_1 = 1.50, \ n_2 = 1.47, \ \lambda = 1.55 \ \mu\text{m}, \ u_n = 3, \ w_n = 2.6$$

$$a = \frac{V}{k\left(n_1^2 - n_2^2\right)^{0.5}} = \frac{4}{\frac{2\pi}{1.55 \times 10^{-6}}\left(1.5^2 - 1.47^2\right)^{0.5}} = 3.3 \ \mu\text{m}$$

$$\beta_n = \left(a^2 k_1^2 - u_n^2\right)^{0.5} = 19.8756 \quad \text{or} \quad \beta_n = \left(a^2 k_2^2 + w_n^2\right)^{0.5} = 19.8697 \ , \ \beta = \frac{\beta_n}{a} = 6.0124 \times 10^6$$

$$k_2 = 5.9589 \times 10^6 \ , \ k_1 = 6.0805 \times 10^6 \ , \ k_2 \le \beta \le k_1$$

$$\beta = \frac{\beta_n}{a} = 6.0124 \times 10^6$$

$$b_n = \frac{\beta/k - n_2}{n_1 - n_2} \quad \text{inserting} \quad \beta = 6.0124 \times 10^6 \ , \ n_1 = 1.50 \ , \ n_2 = 1.47 \ , \ k = \frac{2\pi}{\lambda} = 4.0537 \times 10^6$$

$$b_n = 0.44$$

The value of $b_n = 0.44$ seems to agree well with the intersection of TM_{01} found in the graph of b_n against V in Fig. 2.
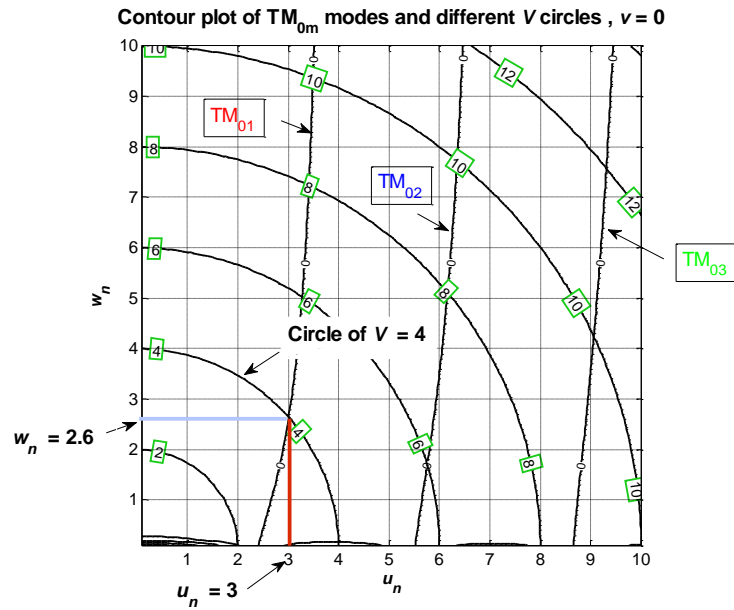
Contour plot of TM$_{0m}$ modes and different V circles , $v = 0$

Fig. 2 Graph of TM_{0m} modes obtained by running Findingbeta_Exp3.m.