<u>Optical Communications Project 2025-26</u>

Your group will be given the parameters of a step-index cylindrical fibre (n_1, n_2, a) and the wavelength of light that is to be transmitted.

The formulae and methods that you need are given in the lecture notes for lectures 3, 4 and 6.

Using the approximation that $n_1 \approx n_2$, you should attempt the following tasks working in your allocated group. You should each expect to spend about 15 hours on the project.

1. Calculate the V-parameter for the fibre.
2. Decide whether you are going to consider the {TE, TM, EH, HE} or LP modes for all of the subsequent tasks.
3. Identify all the modes that the fibre supports, and the propagation constant and effective index for each mode. Summarise the results as a table.
4. Excluding the fundamental mode (HE_{11}/LP_{01}), pick one of the modes from your table for the tasks below.
5. Plot maps in the plane perpendicular to the fibre axis of the amplitude of all three E-fields within the fibre. You will need to fix one of the *A* or *B* parameters, e.g. to unity, and use the relevant equations to calculate the other values. You can choose to do this for either the {radial, tangential, z} or {x, y, z} E-field components.
6. Plot the spatial distribution of the intensity of the mode. Under the approximation $n_1 \approx n_2$, this can be calculated (see notes for lecture 4) as $I \propto |E_x|^2 + |E_y|^2$ (or equivalently $I \propto |E_r|^2 + |E_\phi|^2$).
7. Calculate numerically the waveguide dispersion $D_w = -\frac{\lambda}{c}\left[\frac{\partial^2 n_{\mathrm{eff}}}{\partial \lambda^2}\right]_w = -\frac{\lambda}{c}\left[\frac{\partial^2 n_m}{\partial \lambda^2}\right]_w$ for the mode selected, see notes for lecture 6. For example, calculate this from the effective index calculated for three (or more) wavelengths close to the wavelength of light to be transmitted and use e.g. the central difference approximation to the 2nd derivative.
8. Now consider the fundamental (HE_{11}/LP_{01}) mode. Using the approximate formulae given in lecture 4, $b \approx \left(1.1428 - \frac{0.996}{V}\right)^2$ and $n_{\mathrm{eff}} \approx n_2 + b(n_1 - n_2)$, calculate the effective index and compare this to the value you obtained in step 3. Then numerically calculate the fraction of power carried in the core of the fundamental mode from the intensity distribution of this mode. Also calculate the fraction of power in the core using the approximate formula for $\Gamma(V)$ given in lecture 4 and compare with your numerical result.

Do come and ask questions in office hours if you need.

Think about how you can divide the work between the members of your group and agree in advance how you are going to do this.

You can use your choice of programming language to perform the calculations.

You need to submit the following via Blackboard by 2pm on Monday 8th December:

- A pdf of an A2 poster displaying a summary of your results.

- The concisely commented code that you used to perform your calculations and generate your plots.
- A max 2-page Methods document that concisely summarises the calculations and methods used in your code. This must include a statement of the contribution of each group member to the project.

Together with the relative contributions of each group member returned by all group members, we will use the Contribution Statement to adjust the individual project marks in cases where the contribution of any group member is more or less than 20% of the average. Generally, we expect that all members of a group will contribute equally and receive an equal mark.

The posters will be printed and discussed with the groups at the session at 3pm on Thursday 12th December. In this session, your group will receive feedback on your poster from the other groups.

The project will be assessed by a members of staff according to the following equally weighted criteria:

- Use of English, clarity and presentation of poster

  A good poster should be as concise as possible and avoid large blocks of text. Try and communicate what you have done as effectively as possible. Figures should be clear and all fonts should be large enough to read easily. Figures should be well labelled, and the captions should enable a knowledgeable reader to understand what is shown without referring to the main text. There should be a concise abstract and a concise summary of the key results.

- Quality of results presented in poster

  The work should be undertaken at a suitably high level and use appropriate mathematical and computational methods. The result should be described and, where appropriate, interpreted correctly.

- Clarity of commented code and Methods document

  The comments in the codes should be concise and explain in plain English (avoiding terms specific to the programming language used) what relevant lines or groups of lines achieve. The Methods document should provide a concise summary of the equations solved and the methods used to solve them. For example, you should briefly introduce the relevant equation, together with defining all symbols, and then state something like ‘Numerical solutions to equation X were found using the Python function Y which implements method Z for finding the roots of an equation’. The Methods document only needs to be as long as is required, you do not have to fill 2 pages, the 2 pages is a maximum.

The number of people in the group will be taken into account during marking.