Lab 5: Inverse taper edge coupler pt. 2

Objective:

Further explore the concept of fiber mode matching with the edge coupler

Background:

Waveguide modes represent distinct patterns of electromagnetic fields within waveguide structures, determined by factors such as geometry and material properties. Mode matching is essential for efficient energy transfer and reduced losses in optical and electromagnetic systems utilizing waveguides. It ensures alignment between the mode of the input wave and that supported by the waveguide, minimizing reflections, and enhancing performance. In optical waveguides, such as fiber optics, achieving mode matching is critical for efficient light coupling and transmission. Engineers employ techniques like beam shaping and adjusting waveguide parameters to optimize mode matching in applications like telecommunications and data transmission.

$$OI = \frac{\left|\iint_S E_1(x,y) \cdot E_2^*(x,y)\,dx\,dy\right|^2}{\iint_S |E_1(x,y)|^2 dxyd \iint_S |E_2(x,y)|^2 dxdy} \qquad (69)$$

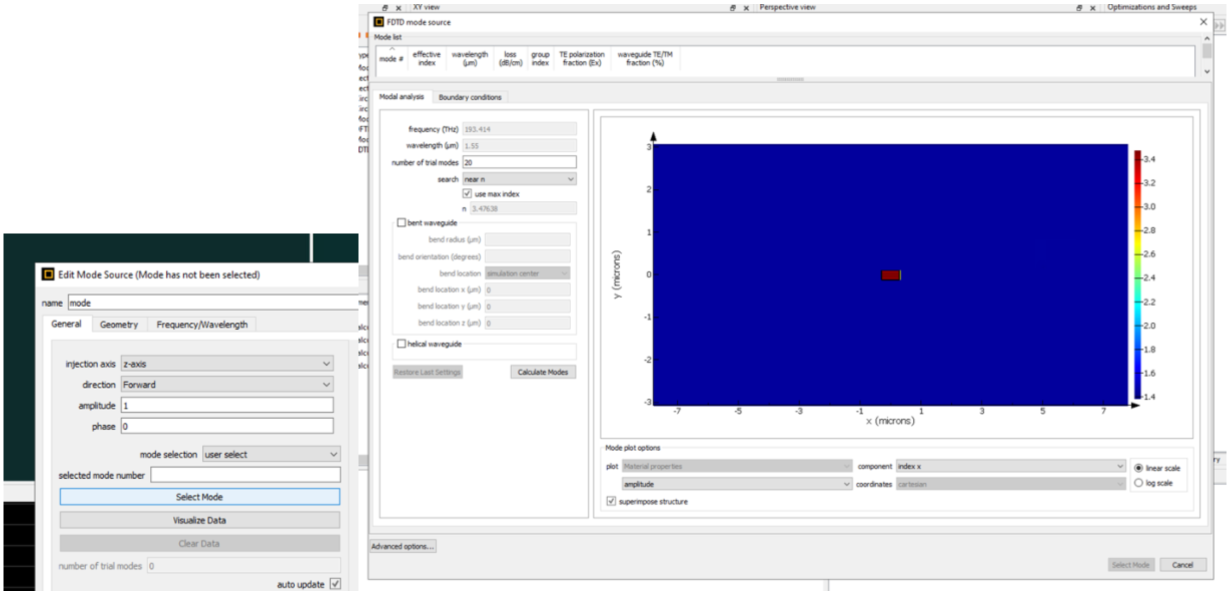
Procedure:

<u>Examine the modes inside of the waveguide</u>

1. Script the waveguide and fiber structures

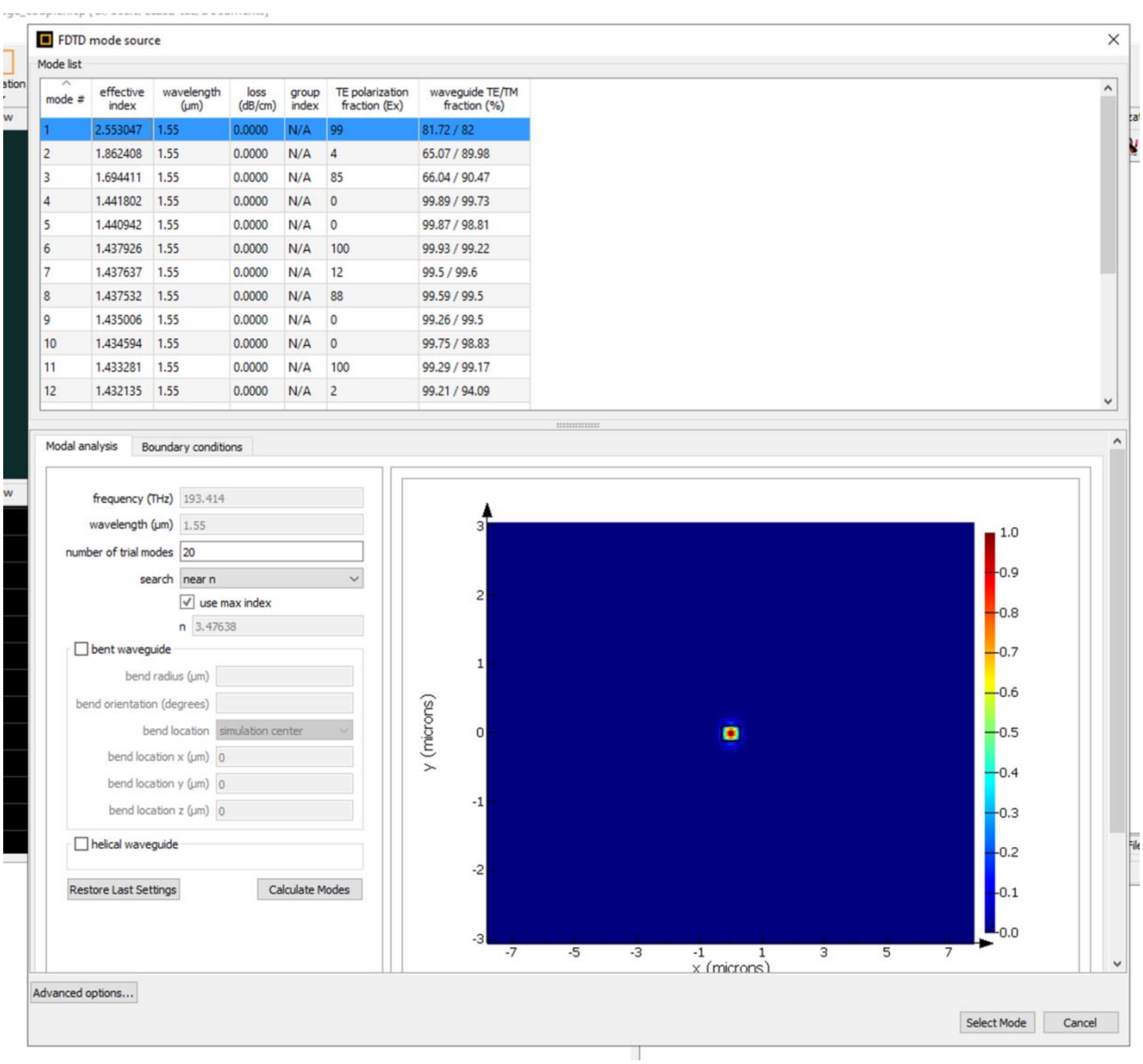
Download the updated file from bcourses, called *edge_coupler.fsp*. Since last class, I have added more variables – waveguide thickness, fiber refractive indices, and a symmetry Boolean flag.

2. Edit the *mode* object and change the mode selection to *user select*. Click *Select Mode*

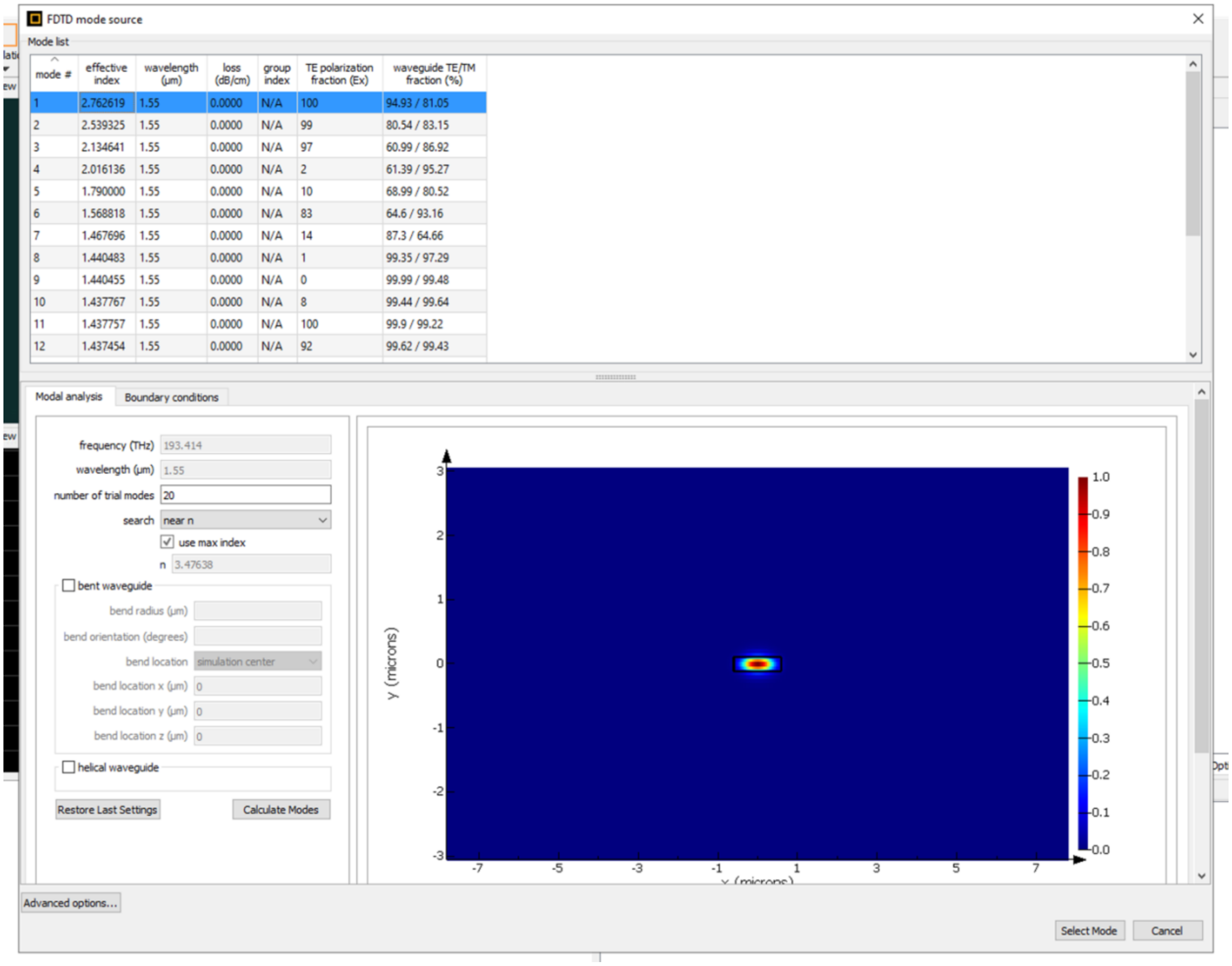


This is the Finite Difference Eigenmode (FDE) solver. According to the Lumerical website, "*the Finite-Difference Eigenmode (FDE) solver calculates the spatial profile and frequency dependence of modes by solving Maxwell's equations on a cross-sectional mesh of the waveguide*". This tool allows us to solve for all possible modes present inside the object area.

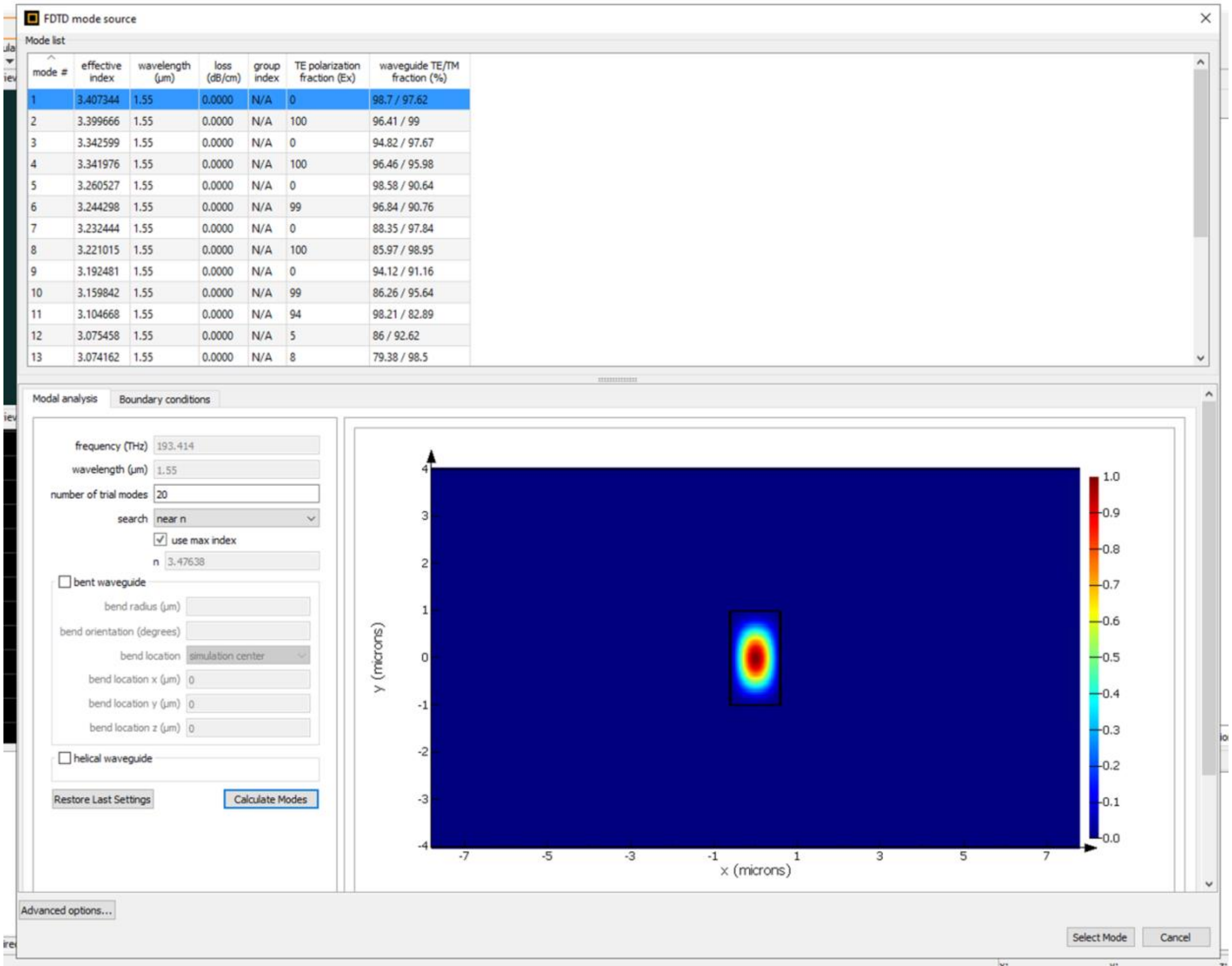
3. Calculate the modes. View a few of the 20 selections of which the FDE program solved.
    a. We can tell which modes are 'guided' by the silicon by checking the effective index. If the effective index of the mode is within the range of the cladding and core indices, then it is successfully guided.
    b. Radiative modes present in the cladding will have an effective index less than the 1.45 cladding index.



4. Change the waveguide to be 1.2 µm wide. Calculate the modes again.

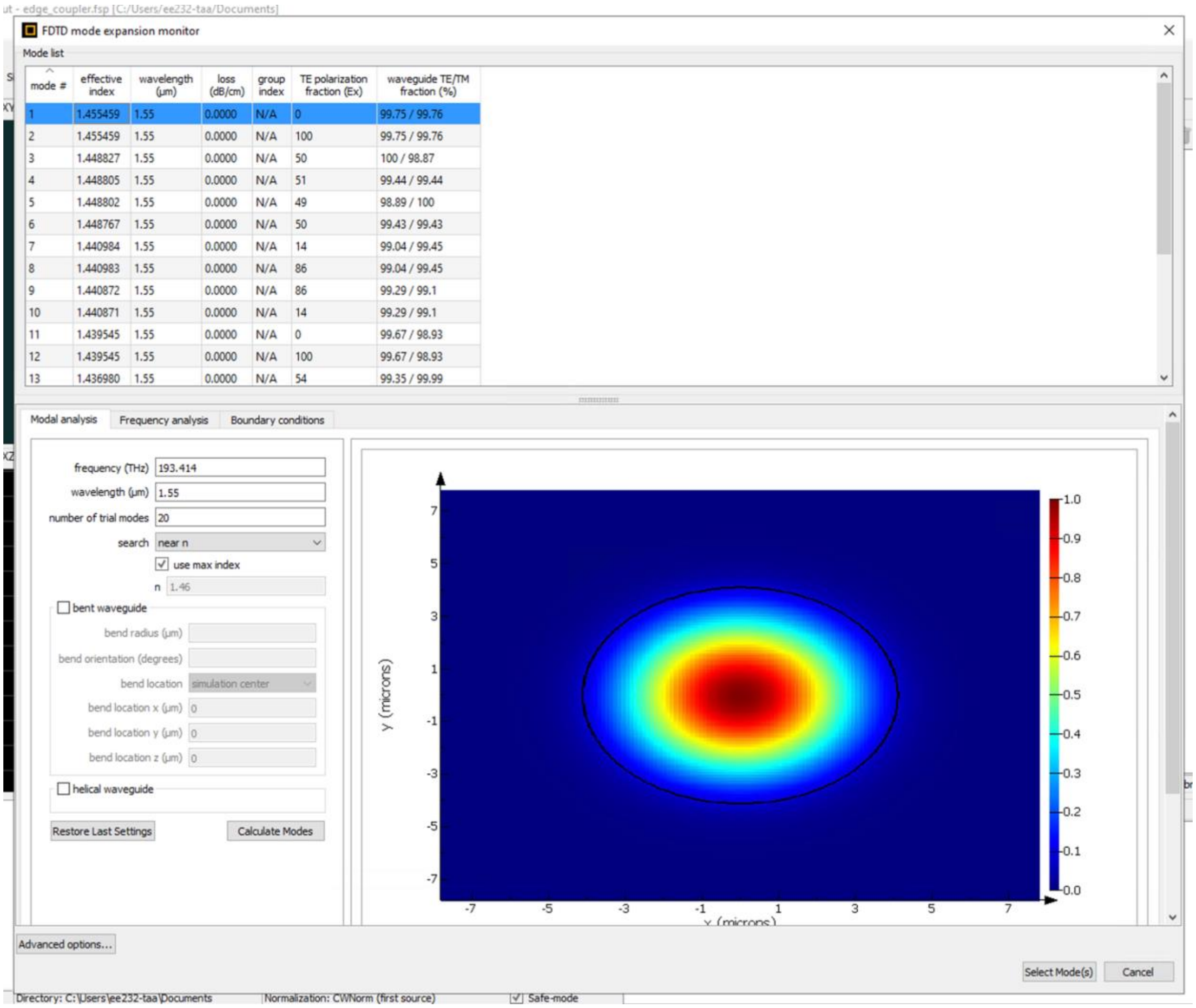


5. Finally, change the waveguide thickness to 2.0 µm and calculate the modes again.

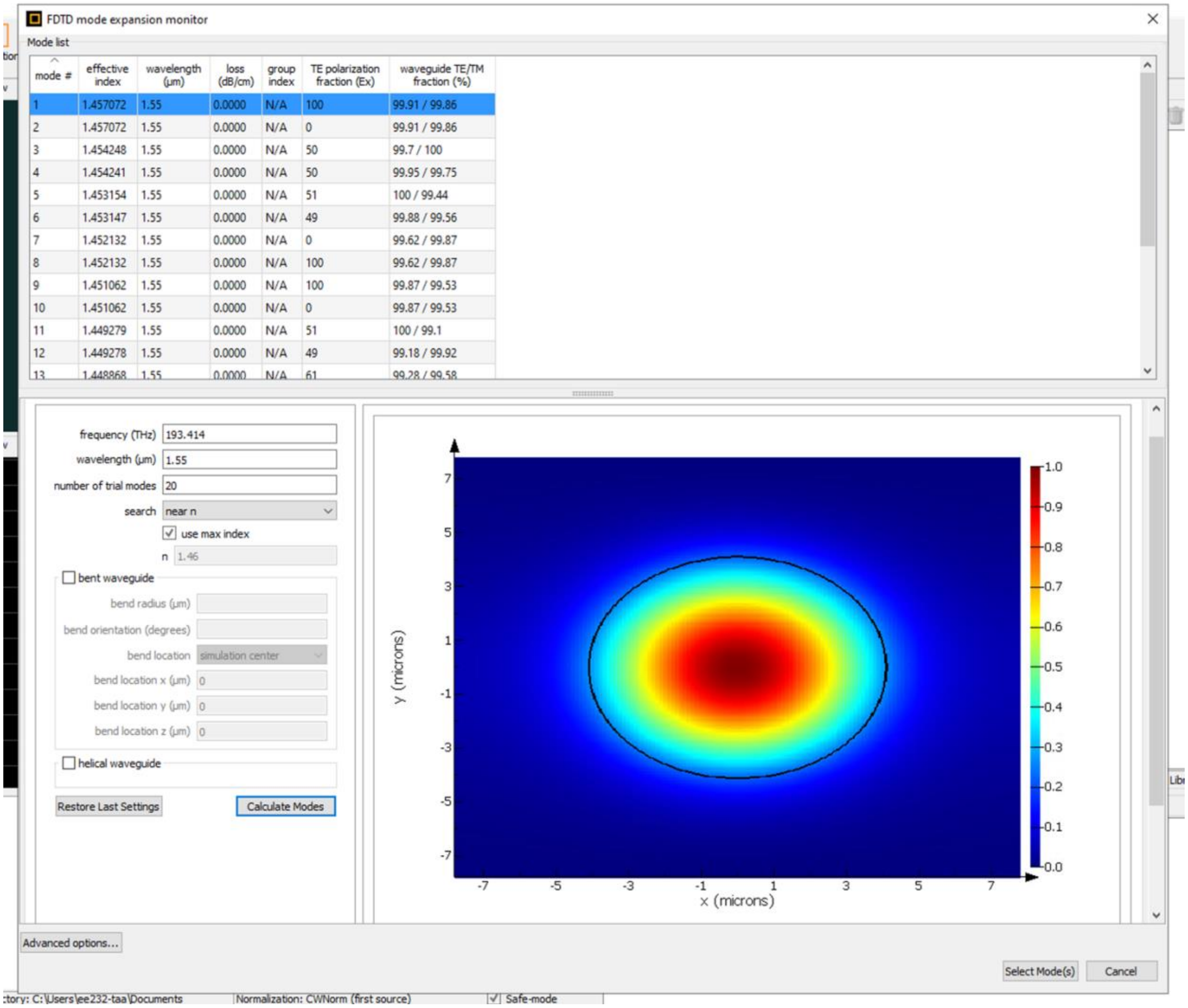


<u>Examine the modes inside of the optical fiber</u>

1. Set the *n_core* to 1.46 and *n_cladding* to 1.44. Edit *fiber_mode_expansion* and user select the mode on the *Mode Expansion* tab. Calculate the modes.



2. Change *n_cladding* to 1.455. Calculate the modes again.



<u>Optimize the edge coupler design:</u>

1. Set *n_core* to 1.46813 and *n_cladding* to 1.45392.

Waveguide Width Sweep:

1. Add new sweep in "Optimizations and Sweeps" tab
2. Add waveguide_width as parameter. Sweep from 0.05 to 0.35 µm.
3. Add T as a result and run the sweep

<u>Benchmark the design:</u>

Bandwidth Estimation

1. Enter the optimized result for waveguide_width
2. Change lambda_start to 1.31 µm and run the simulation
3. View the result

Follow-up questions:

1. How would the mode selection process change if you were using metal boundary conditions instead of PML? What about symmetrical boundaries?
2. Compare and contrast the performance of the edge coupler and the grating coupler. If you were a professional SiPh designer, what considerations would go into your selection process?
3. What is the expected 'fabrication tolerance' of the edge coupler? I.e. what are design factors that can change with the fabrication process, and how does that impact performance? What about with the grating?
4. We've only simulated the end of the edge coupler – later, we will simulate the taper structure, or how the waveguide gets to this design thickness. What design parameters go into creating a waveguide taper?