COMSOL Assignment (Advanced Optoelectronic Devices)

Task 1 (60%): Basic simulation setup

Set up the waveguide simulation to determine the modes (both TE / TM) of a silicon on insulator strip waveguide. The silicon layer thickness is 220 nm and the oxide (BOX) thickness is 2 µm. For task 1, assume silicon's refractive index is constant 3.47, oxide is 1.5 and wavelength 1550 nm. You are supplied with the basic COMSOL file on the Blackboard page.

1.1 Vary the waveguide width between 200 nm and 1 um and plot the mode effective refractive index, n_{eff} (for both TE and TM).
1.2 How do you tell the difference between TE and TM modes?
1.3 At what width does the waveguide become multi-moded? Note: here the second mode we are interested in is the higher order TE mode.
1.4 Change the top cladding to oxide, how does this change the width at which the waveguide becomes multi-moded?

Task 2 (40%): Dispersion calculation and four wave mixing (FWM)

For task 2, we will keep the silicon waveguide's width fixed at 500 nm and plot the mode effective refractive index for the fundamental TE mode as a function of wavelength (1.2-1.8 µm)

2.1 Assume silicon's refractive index varies according to the Sellmeier equation for the mode effective refractive index calculation:

$$n_{si}^2(\lambda) = 1 + \frac{10.6684293\,\lambda^2}{\lambda^2 - 0.301516485^2} + \frac{0.0030434748\,\lambda^2}{\lambda^2 - 1.13475115^2} + \frac{1.54133408\,\lambda^2}{\lambda^2 - 1104^2}$$

2.2 Calculate $dn/d\lambda$ and $d^2n/d\lambda^2$ for the material index. (Hint: numerical derivates are fine, no need to do this analytically. Wavelength is in microns)

2.3 Repeat the same calculation for the mode effective refractive index n_{eff} (Hint: to calculate the mode index as a function of wavelength, make sure you run the simulation with varying silicon refractive index given in the Sellmeier equation above. This problem is asking, given the material dispersion of silicon (changing refractive index as a function of wavelength), how does the mode effective refractive index for the fundamental TE mode change?

2.4 Calculate the effective mode area given by:

$$A_{eff} = \frac{(\int |E|^2)^2}{\int |E|^4}$$

2.5 What is the ratio between the effective mode area and the geometrical area (cross-section of the waveguide)? The nonlinear coefficient scales as $\gamma = {n_2\omega}/{(A_{eff}c)}$ which is why nonlinear processes become significantly enhanced in nanoscale waveguides. Comment on the final result

2.6 Suppose we want to study the degenerate four wave mixing process in this silicon waveguide with the pump wavelength fixed at 1550 nm. What are the wavelength(s) of the signal and idler photons produces in this process?

(Hint : you can ignore non-linear effects relating to the intensities of the pump, signal and idler)

Deadline : Thursday 14th March at 1pm submitted on Blackboard