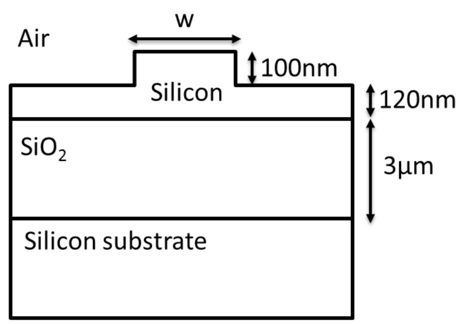
HW #3
Due April 20 (Wed) in Prof. Wu's office, 511 SDH

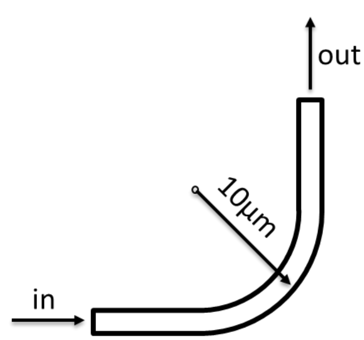
1. Silicon photonic rib waveguide

In discussion we studied the silicon photonic ridge waveguide in detail. Another waveguide that is frequently used in silicon photonics is the rib waveguide or partially-etched waveguide in which the silicon layer is not completely etched away. For the rib waveguide shown in the figure below:



Rib waveguide
(side-view)

a. Using Lumerical MODE, plot the effective index of each guided mode versus rib width from w = 0.1 to 1.2 μm at λ=1.55μm. Properly identify each mode as TM or TE. Note: the guided modes should be confined primarily to the rib and not extend out into the silicon slab.
b. For what width (w) is the rib waveguide single mode?
c. We often need to introduce a bend into the waveguide to re-direct the waveguide into a different direction. Following https://kb.lumerical.com/en/pic_passive_bent_waveguide_analysis.html, find the loss (in units of dB) for the single mode rib waveguide in a 10μm radius bend (direction of waveguide changes by 90°)



Top-view

Use the built-in material Si (Palik) for silicon and assume the index of SiO_2 is 1.48.

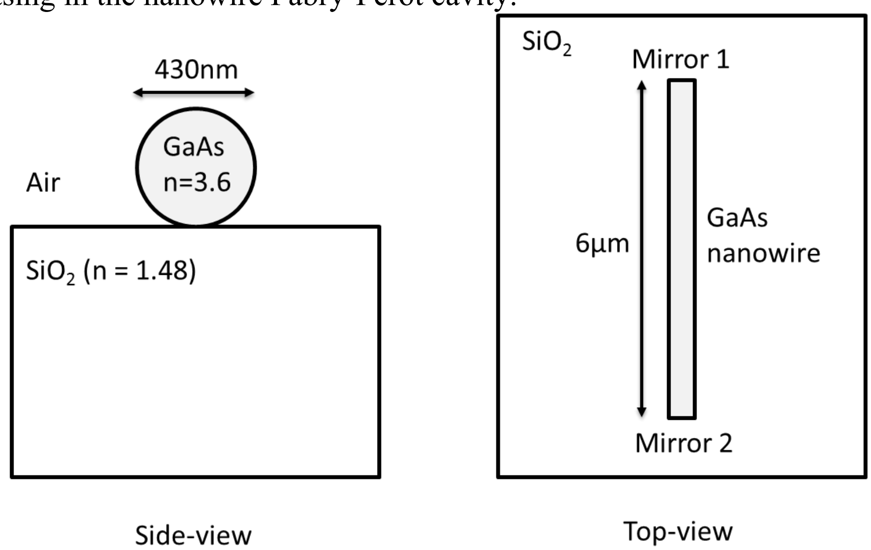
2. Grating coupler design

In this problem we will design a silicon photonic grating coupler at λ=1.55μm.

a. Using hand analysis, what is the grating period needed such that the diffraction angle is 10°? (you can make a reasonable assumption about the effective index of the guided mode).
b. Using the Lumerical FDTD file gratingCoupler.fsp on bcourse, plot the simulated in-coupling efficiency between 1500 and 1600nm using the results in part a. Use the fiber mode source and assume a grating etch depth of 100nm.
c. Run a sweep to optimize the grating period. Plot the in-coupling efficiency as a function of wavelength for each sweep point. What is the optimized grating period?
d. Run a sweep to optimize the position of the fiber. Plot the in-coupling efficiency as a function of fiber position. What is the optimized fiber position?

3. GaAs nanowire laser

In this problem we will analyze the properties of the nanowire laser system shown below. A GaAs nanowire (gain medium) is laying horizontal on a SiO_2 substrate. The nanowire behaves as a simple Fabry-Perot cavity: the two ends of the nanowire will behave like mirrors and guided optical modes within the nanowire will be reflected back and forth (similar to the ZnO nanowire laser we analyzed in discussion). If the gain in the GaAs nanowire exceeds the mirror loss then we can observe lasing in the nanowire Fabry-Perot cavity.



a. The nanowire is large enough to support multiple guided modes. We will assume that lasing will occur in the fundamental mode. Find the effective index and confinement factor of the fundamental mode at 870nm (bandgap of GaAs) using Lumerical MODE.
b. Using Lumerical FDTD, find the reflectivity of the nanowire end at 870nm and calculate the threshold gain assuming negligible internal loss. How does the reflectivity compare to normal incidence at an infinitely large GaAs-air interface?
c. Calculate the carrier density needed to achieve the threshold gain at a wavelength of 870nm. Assume bulk GaAs semiconductor at room temperature and consider only the electron to heavy-hole transition.

d. This nanowire laser system was previously experimentally studied (http://www.nature.com/nphoton/journal/v7/n12/abs/nphoton.2013.303.html). For a similar nanowire dimension, the authors found that the room temperature threshold gain was 1820 cm^{-1}. Why might your threshold gain value be different than what the authors experimentally measured (provide 2-3 reasons)?