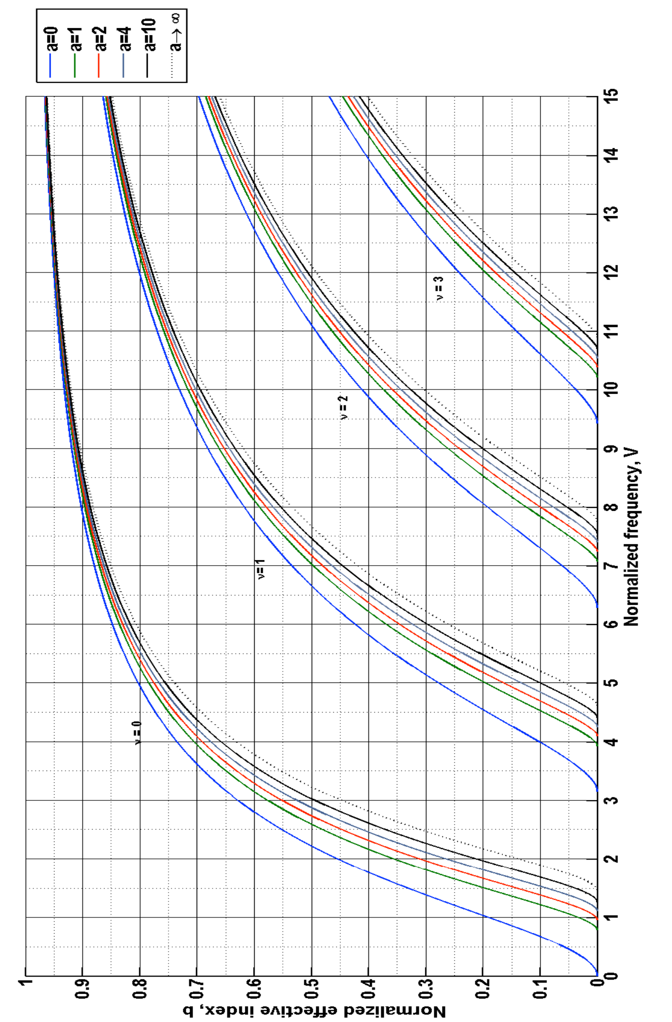
Hands on exercises on Lectures by Prof. Lipson July 2016 Campinas Sao Paulo

1. **Waveguide design: (a)** Consider a single mode slab waveguide with a core index of 1.5, a cladding index of 1.4 and an effective index 1.42. The wavelength of guiding is 1 micron. Should you decrease or increase the wavelength to help decrease the losses due to roughness in the fabrication? **(b)** Now neglect losses due to fabrication. For this waveguide, for a particular bending radius the losses are 0.2 dB/cm. Would you decrease or increase the wavelength to decrease these bending losses?

2. **Surprising effects on resonator losses:** consider a ring resonator coupled to a single bus waveguide. Kippenberg et al reported this year (2016) in CLEO that the intrinsic Q (actual propagation losses in the ring as opposed to losses due to evanescent coupling from the ring to the waveguide) increase when the ring is brought in proximity to the bus waveguide. Provide at least two possible explanations on why this could be the case. How would you test these hypotheses?

3. **Decoupling propagation losses from absorption (bulk) losses:** Lets say you are putting together a CAD for extracting 1. the absorption losses and 2. the scattering losses. You will extract these two parameters by fabricating several SiN/SiO2 ring resonators with the same dimensions, each coupled to a single bus waveguide with different dimensions. You are free to vary the width of the bus waveguide (only) as well as to taper it (ie no need for the waveguide to be uniform in width as light propagates). Assume all the waveguides behave as slab waveguides. 1. What are the different widths of the bus waveguides that you should choose in order to extract the two losses? 2. If the intrinsic Q of the ring coupled to the narrowest waveguide is 1M at 1.5 micron wavelength, and the intrinsic Q of the ring coupled to the widest waveguide is 100,000, estimate roughly (using the normalized parameters and back of the envelope calculations) the absorption and scattering losses. Make sure to write down all your assumptions. *Note: this method for extracting the scattering losses is being used currently by William Ji, a graduate student in Lipson's lab.*

4. **Using higher order modes to engineer dispersion** Plot the approximate waveguide dispersion for the second order mode and for the first order mode of a SiN/SiO slab waveguide that supports 3 modes (in a given polarization) between 1.4 micron and 1.5 microns. B. Now consider a waveguide that supports N modes. If the first order mode is in the normal dispersion regime what shall N be so that the second order mode is in the anomalous regime? (hint: use normalized parameters and the notes from prof. Gaeta's lecture on dispersion). Make sure to write down all your assumptions. *Note this idea of using higher order modes to engineer dispersion was just demonstrated a month ago by Felipe Barbosa who just finished his postdoc in Lipson's lab*



$$V = \pi m = hK_o\sqrt{n_f^2 - n_s^2}$$

$$b = \left(n_{eff}^2 - n_s^2\right)/\left(n_f^2 - n_c^2\right)$$

$$a = \left(n_s^2 - n_c^2\right)/\left(n_{eff}^2 - n_s^2\right)$$ a = assymetry