Spring 202 – ECE 536 Integrated Optics and Optoelectronics Homework - Set #1

Due: Friday 2/4/2022

1. Problem 1.4 in the textbook by Prof. Chuang, reproduced below for your convenience

> Plot the energy band-gap E_g versus the lattice constant for the two ternary compounds, $In_{1-x}Ga_xAs$ and $Al_xIn_{1-x}As$. Label the values for the binary compounds, InAs, GaAs, AlAs, and InP. The band-gap formulas at 300K are
>
> $$E_g(In_{1-x}Ga_xAs) = 0.36 + 0.505x + 0.555x^2$$
> $$E_g(Al_xIn_{1-x}As) = 0.36 + 2.35x + 0.24x^2.$$
>
> Show on your plot the locations (and values) of the lattice match conditions for the InP substrate.

2. (a) Calculate the band-gap wavelength λ_g for Si, GaAs, GaN, AlN, InP, and GaP at 300K. Use the band-gap energies in Appendix C and D in the text (pg. 802, 807).
   (b) Calculate the optical energy and wavenumber corresponding to the following wavelengths: 850 nm and 1.31 μm.

3. Suppose we design a quantum well structure for laser or photodetector applications using $In_{1-x}Ga_xAs$ and $Al_xIn_{1-x}As$ materials lattice matched to the InP substrate. Plot the quantum well potential profile for the conduction and valence band edges (simply considering flat band condition). The experimentally measured conduction and valence band discontinuities are about 70% and 30% of the bandgap difference (ΔE_g), respectively. Which one is the well material? You may find the band gap vs. mole fraction relations in Appendix C.3 helpful.

4. Chapter 1 of Prof. Chuang's book introduces the Fabry-Perot laser cavity on page 6.
   (a) Derive Eq. (1.2.3) and (1.2.4) for a Fabry-Perot laser with a cavity length L.
   (b) Derive the frequency spacing between two adjacent longitudinal modes.
   (c) Derive the corresponding wavelength spacing in part (b).
   (d) From the experimental data in Figure 10.11(b) on Page 425 of the text, find the wavelength spacing between two nearby Fabry-Perot modes. Can you estimate the cavity length if you assume a reasonable refractive index at 1550 nm wavelength (e.g, InP on Page 799)? Check Ref. [47] of Chapter 10 to see if your estimation of the cavity length is close to the reported value. (Hint: the introduction in Chapter 1 does not consider refractive index dependence on wavelength, that is, chromatic dispersion is not included).