Assume room temperature for all questions unless specified otherwise.

1. Answer the following questions concisely. Show your calculations.

   a) The visible spectrum is from 380 to 740 nm in wavelengths, what are the corresponding photon energies in eV?

   b) A green laser pointer has 1 mW output power at 532 nm wavelength, and a beam diameter of 1 mm. How many photons are emitted per second?

   c) A 10 Gbit/s optical link with 1240 nm wavelength receiver has a sensitivity of –20 dBm. How many photons must be received per bit? [Note: dBm is a measure of power in dB scale relative to 1 mW, e.g., 1 dBm = 1 mW, -10 dBm = 0.1 mW, -20 dBm = 0.01 mW].

   d) For a slab waveguide with high-index (n = 5) core and cladding (n = 3), what is the maximum core thickness for the waveguide to support only one TE mode at 1 μm wavelength?

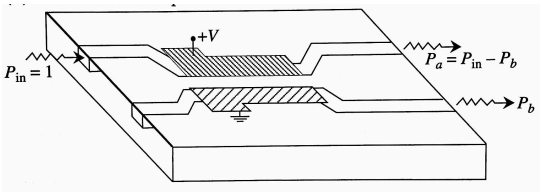
2. Consider a direct-bandgap semiconductor with a bandgap energy of 1 eV, an electron and a hole effective masses of 0.1 m_0 and 0.4 m_0, respectively, where $m_0 = 9.1 \times 10^{-31}$kg is the free electron mass.

   a) A 1.2-eV photon absorbed by the semiconductor generates an electron-hole pair, what is the kinetic energy of the electron?

   b) Under a steady state bias, the electron and the hole concentrations are both 3x10^{18} cm^{-3}. Find the electron quasi-Fermi level in reference to conduction band edge, E_C.

   c) An infinite quantum well with 10-nm width is formed with this semiconductor. Under the same electron and hole concentrations as in b), find the electron quasi-Fermi level in reference to the first quantized state, E_{e1}.

3. A directional coupler switch is shown on the right. The two waveguides are identical, and their effective refractive indices can be varied by electro-optic effect: $n_{eff}(V) = 0.001 \cdot V$. The coupling coefficient between the waveguides is 10 cm^{-1}. The optical wavelength is 1 μm. Assume all components have no loss.



   a) How do we achieve 100% transmission in Cross state, i.e., all light from P_{in} appear in P_b?

   b) What should be the length of the coupler section (in cm)?

   c) What is the switching voltage, i.e., the voltage needed to change the switch state?

   d) If the coupling coefficient of the fabricated coupler turns out to be 11 cm^{-1}, what is the insertion loss and crosstalk of the Bar and Cross states, respectively, using the bias you found in Part c)?