HW #7
Due Dec. 5 (Tuesday) in class

1. Consider a DH edge-emitting laser with the following parameters:

   Optical gain: $g(N,S) = \frac{g'(N - N_{tr})}{1 + \varepsilon S}$, where $g' = 2\text{x}10^{-16}$ cm^2, $N_{tr} = 10^{18}$ cm^{-3},

   the gain compression factor $\varepsilon = 10^{-16}$ cm^3

   Intrinsic loss α_i = 10 cm^{-1}

   Laser width = 1 μm
   Laser cavity length = 200 μm
   Thickness of active layer = 0.1 μm
   Confinement factor of active region = 50%
   Facet reflectivity = 30% for both facets
   Internal quantum efficiency η_i = 100%

   Assume the total carrier lifetime at threshold = 1 nsec
   Laser wavelength = 1240 nm
   Effective refractive index = 3

   a. Find the threshold gain and photon lifetime
   b. Find the photon density at 1 mW output power (from both facets)
   c. Find the relaxation oscillation frequency at 1 mW output power
   d. Find the K factor of the laser (express your answer in nsec).
   e. Express the damping in terms of the K factor, plot the small-signal frequency response of the laser, i.e., $10 \cdot \log(|H(\omega)|^2)$, at three output levels: (i) 1 mW, (ii) 10 mW, (iii) 100 mW.

2. A surface-illuminated p-i-n photodiode has an absorption coefficient of 10^4 cm^{-1} and an area of 100μm x 100μm. The surface of the photodiode is AR-coated to allow 100% transmission. Assume the internal quantum efficiency of the absorption layer is 90%. The photodetector is connected to a 50Ω impedance. The electron velocity is 10^7 cm/sec, and the hole velocity is $2\text{x}10^6$ cm/sec.

   a. If the thickness of the absorption region is W, find the expression for the transit time and the RC time.
   b. What is the expression for the overall bandwidth of the p-i-n?
   c. What is the maximum bandwidth one can achieve for this p-i-n? What is the condition for the maximum bandwidth?
   d. What is the total external quantum efficiency for the p-i-n in Part (c), i.e., under the condition of maximum bandwidth.

3. A SAM-APD has a 2-μm long absorption region and a 0.5-μm long multiplication region. The absorption coefficient of the absorption region is 10^4 cm^{-1}, while the multiplication region is made of a wide-bandgap material with an electron impact ionization coefficient of 5×10^4 cm^{-1} and a hole impact ionization coefficient of 5×10^3 cm^{-1}. The surface of the APD is

anti-reflection coated so the reflection is 0%. The electron velocity is 10^7 cm/sec, and the hole velocity is $2x10^6$ cm/sec.

a. What is the responsivity of the APD for 1.55-μm light? (Note: responsivity includes the effect of gain).
b. What is the bandwidth of the APD?
c. What is the noise figure of the APD?
d. What is the receiver sensitivity (defined as the minimum received optical power to reach a signal-to-noise ratio of 1000) of the APD at 1 Gbit/sec? Express your answer in dBm. The APD is connected to a 50Ω resistor.