HW #7

Due November 30 (Wed) in the **IN Box at 261M Cory**

1. A distributed Bragg reflector (DBR) with a grating coupling coefficient of κ and length of L = 100 μm. Assume the end facet of the grating is perfectly anti-reflection (AR)-coated. The grating reflectivity is defined as the field reflection coefficient at the interface of the grating and the input waveguide. Assume the average refractive indices are the same for the waveguide and the grating section so there is no reflection due to index discontinuity. All the reflection comes from the DBR. The Bragg wavelength is 1550 nm, and the effective refractive index of the waveguides is 3.5.
    a. Find the relation between $\delta = \frac{2\pi n}{\lambda} - \frac{\pi}{\Lambda}$ and the deviation of wavelength from the Bragg wavelength $\Delta\lambda = \lambda - \lambda_{Bragg} = \lambda - 2n\Lambda$.
    b. Plot the magnitude (absolute value) and phase of the field reflectivity of the DBR versus $\Delta\lambda$ for the following three values of κ. The unit for $\Delta\lambda$ should be nm, and the range should be from -15 nm to +15nm.
        i. $\kappa = 50$ cm^{-1} ,
        ii. $\kappa = 200$ cm^{-1} ,
        iii. $\kappa = 400$ cm^{-1} .
    c. For each curve in Part b), calculate and mark the wavelength deviation $\Delta\lambda_\kappa$ that corresponds to $\delta = \pm\kappa$. As we discussed in lecture, the width of the reflection band is approximately $-\kappa \to \kappa = 2\kappa$ for strong gratings (i.e., large κ). For the three κ values, which one(s) can be considered strong grating? What are the values of κL product? (*Hint: use the relation you find in Part a*).

2. A quantum well vertical cavity surface-emitting laser (VCSEL) has the following parameters:

    Optical gain: $g(N) = g_0 \ln(N/N_{tr})$, where g_0 = 2000 cm^{-1}, N_{tr} = 10^{18} cm^{-3}

    Intrinsic loss α_i = 5 cm^{-1}

    Laser area: 1x1 μm^2,

    Effective cavity length = 1 μm

    Active region with 3 Quantum wells, each with thickness = 10 nm, located in the middle of the cavity at the peak of the optical standing wave

    Facet reflectivity = 99.95% for the bottom DBR, and 99.5% for the top DBR

    Internal quantum efficiency η_i = 100%

    Assume the total carrier lifetime at threshold = 1 nsec

    Laser wavelength = 1240 nm

    a. Find the threshold gain of the VCSEL.
    b. Find the threshold current and external quantum efficiency *from the top emission only*.
    c. Construct the L-I curve for up to 3 times threshold current.

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

   Optical gain: $g(N,S)=\dfrac{g'(N-N_{tr})}{1+\varepsilon S}$, where g' = 2x10^{-16} cm^2, N_{tr} = 10^{18} cm^{-3}, and 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.