Midterm

ECE 227B

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Name_____

(40 points)

1. An edge emitting laser uses a single InGaAs quantum well. The lasing wavelength is at 950 nm, the threshold current is 1 mA, the active and the modal volumes are 10 and 300 μm^3, respectively, the modal index and the group index are 3.5 and 4, respectively, the injection efficiency is measured to be 0.8, and the threshold inversion factor n_{sp} = 1.6. By making measurements from the back surface of the chip and factoring in appropriate geometrical corrections, the total spontaneous emission power spectrum at and above threshold is found to be as in Figure 1. Do not use any other data.

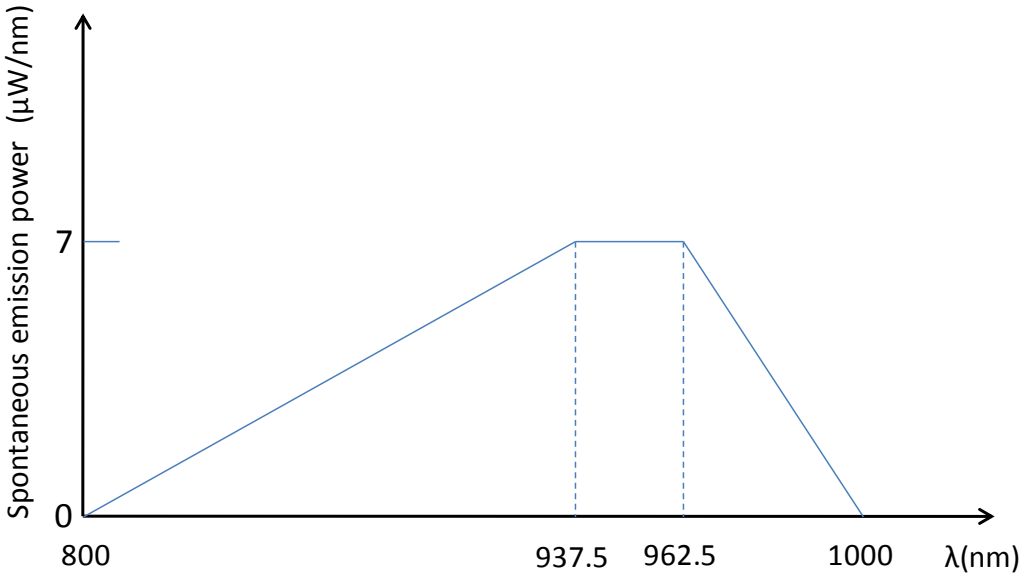

Figure 1 - Total spontaneous emission power spectal density versus wavelength

a) What is the radiative efficiency η_r?
b) What is the spontaneous emission rate per unit energy per unit active volume at 950nm?
c) What is the optical mode density?
d) What is the threshold modal and material gain for the TE mode?
e) What is the spontaneous emission factor β_{sp}?

(15 points)

2. InGaAs/AlGaAs quantum well material from Figure A8.6 was used to fabricate lasers with the lowest transition wavelength of λ= 985 nm. Assume that the parabolic approximation can be applied close to the bottom of the band edge, and that the matrix element for the TE gain is $|M_T|^2 = 0.6|M|^2$, and zero for the TM gain. Assume that the refractive index of InGaAs is 3.
    a) Determine the reduced density of states
    b) Determine the value of g_{max}

(45 points)

3. Etched air post VCSELs have been fabricated in two different materials: one on a GaAs substrate lasing at 850 nm, the other on InP lasing at 1550 nm. Both have diameters of 4 μm. The GaAs device's active region consists of four 8nm wide quantum wells; the InP device has an active region consisting of six 6 nm unstrained quantum wells – both characterized by the numbers in the Tables 4.4 and 4.5. The etch has proceeded through the active regions of both devices, resulting in surface recombination velocities of 5×10^5 and 5×10^3 cm/s, respectively, for GaAs and InP devices. VCSEL mirrors are constructed in such a way that the one-pass threshold gain of the active regions in both cases is 1%, including the enhancement factor of 1.8.
   a) What are the surface recombination currents for the two cases assuming uniform carrier distributions?
   b) What are the total threshold currents assuming Auger recombination coefficients of 2×10^{-30} and 6×10^{-29} cm^6/s, respectively for GaAs and InP cases?

   Now we assume that the operating temperature has increased by 50 K. This has resulted in an increase in the surface recombination, the radiative and the Auger currents. We assume Auger threshold energy 10% higher that the energy gap, an increase of J_{tr} by 10%, and a decrease of g_{0J} by 10% in both cases. The cavity losses have remained the same.

   c) What are the new surface recombination currents for both cases at the increased temperature?
   d) What are the new total threshold currents for both cases?