PHYC 564, Laser Physics II

Spring 2021

Homework #3, Due Wed. March 3, 2021

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1.

(a) Find the transparency e-h carrier density (N_{tr}) required to just invert GaAs having E_g=1.43, m_e=0.07m_0 and m_h=0.5m_0. Assume T=300K.

(b) For a gain layer of d=1μm, calculate the steady-state current density (J_t) needed to sustain the above carrier density if the radiative recombination rate (given by BN_eN_h) is the dominating recombination mechanism where $B \cong 2\times10^{-10}$ cm^3/sec. (Note: here $N_e=N_h=N_{tr}$)

(c) Find the peak value of the gain γ, its peak wavelength λ_{peak}, and the width of the gain Δλ, if the current density is increased to $2\times J_t$.

(d) Repeat (a) and (b) for T=77 K to appreciate the temperature dependence of the threshold current of semiconductor lasers.

2.

(a) Derive an expression for the radiative recombination coefficient $B=R/N_{eh}^2$ at low injection carrier density limit (R is the radiative recombination rate) . Identify the temperature dependence. Estimate B for GaAs.

(b) Derive an expression for the mean luminescence wavelength (λ_f), and plot λ_f/λ_g as a function of temperature for GaAs (Use low carrier injection approximation). ($\lambda_g = hc/E_g$)

Use van Roosbroeck-Shockley (reciprocity) relation for luminescence power spectrum:

$$S(\nu) = \frac{8\pi n^2\nu^2}{c^2}\alpha_0(h\nu)\{f_c(1-f_v)\} \quad \text{and} \quad R = BN^2 = \int S(\nu)d\nu$$

3. Consider a symmetric optical slab waveguide shown below.

(a) For λ_0=1.5 μm (in free space), find the number of TE modes in this waveguide.

(b) What are the confinement factors (Γ) for TE_0 and TE_1 modes?