ELEC-E3210 Optoelectronics Jan 17, 2019

Exercise 1: LED's

1. a) Derive the expression of the extraction efficiency for a planar LED. b) Calculate the extraction efficiency of a surface emitting planar light diode when the refractive index of the semiconductor is 3.6. c) Calculate the extraction efficiency of a LED with a dome-shaped encapsulant if the refractive index of the encapsulant is 1.6.

2. The p and n sides of a GaAs LED have a doping concentration of 10^{18} cm^{-3}. The emission of light is caused mainly by the injection of electrons into the p-side. There is a recombination center in the active region with a time constant of 5×10^{-9} s. Assume that the lifetime of the electrons and the holes is the same and that D_e = 120 cm^2 s^{-1}, D_h = 0.01 D_e. What is the injection efficiency with bias voltage of 1 V, if the coefficient of band-to-band radiative recombination is $B_r = 7.2\times10^{-10}$ cm^3 s^{-1}?

3. Using the parameters of the previous exercise, calculate the spontaneous emission wavelength and the optical power of the LED at a bias voltage of 1 V assuming that the extraction efficiency is 10% and the surface of the diode is 1 mm^2.

4. Show that the intensity distribution of the radiation emitted by a planar LED can be expressed by the Lambertian distribution. Assume that the light source inside the semiconductor can be considered as a point source.

5. Let's consider the coupling efficiency of an LED into an optical fiber. Assume that the refractive indices of the core and cladding material of the fiber are 1.52 and 1.48, respectively. a) Light entering the fiber in angles larger than the critical angle θ_a does not couple into the traveling modes. Calculate θ_a. b) Derive an approximation for the critical angle θ_a, if the refractive index difference between the core and the cladding is small. c) Calculate the coupling efficiency into a fiber of a planar surface-emitting LED with an intensity distribution of $I = I_0 \cos\theta$ outside the LED.