1.1 Figure 1 a) shows a schematic of a GaAs optical amplifier where the active region has the dimensions 110x10x2 µm, the facets to the left and right are anti-reflection coated. If 1 mA runs through the device, in which wavelength range can you expect amplification? Assume the following material parameters: band gap= 1.52 eV, intrinsic carrier concentration n_i=1.8x10^6 cm^{-3}, effective electron mass=0.07m_0, effective hole mass=0.5m_0 , refractive index = 3.6, recombination lifetime = 50 ns, temperature= 0 K.

1.2 If we remove the anti-reflection coatings in Figure 1 a) the facets get a 32% reflectivity and the amplifier turns into a laser diode. At a specific current at a temperature of 5K the gain coefficient looks like in Figure 1 b). Only mirror losses are considered but we assume that 30% of the light spills out of the gain region into the surrounding. How many longitudinal modes will lase?

1.3 For telecommunication purposes a laser diode with multiple longitudinal modes would not be ideal. Explain why and suggest a solution.

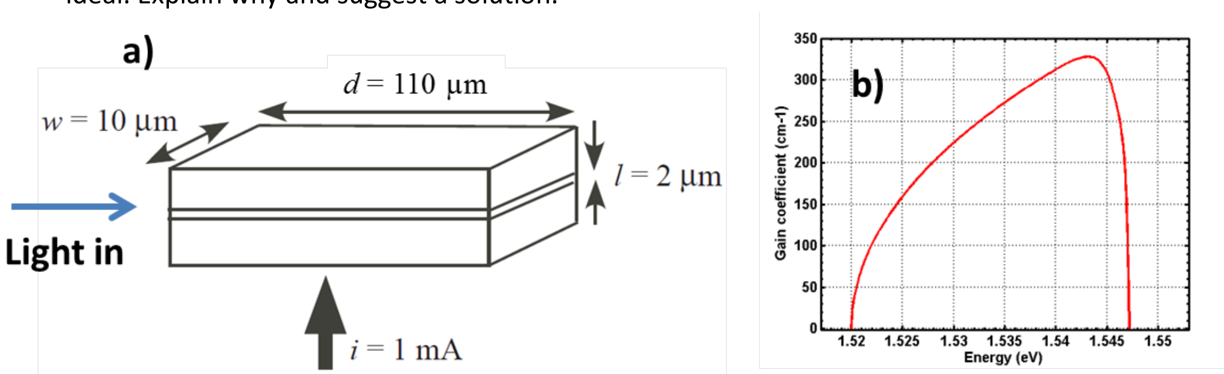


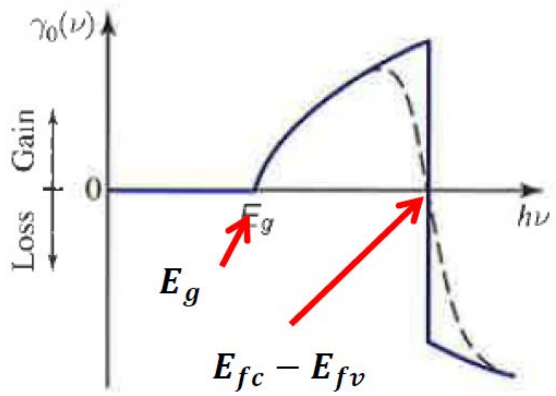
Figure 1

Solutions:

1.1

What do we need?

The gain profile looks as follows



1. We must therefore find $E_{fc} - E_{fv}$
2. This can be found if we have the carrier concentration Δn

$$E_{fc} - E_{fv} = E_g + (3\pi^2)^{2/3} \frac{\hbar^2}{2m_r} (\Delta n)^{2/3}, \qquad (17.1\text{-}11c)$$

Where m_r is the reduced mass (taking into account both effective mass of electron and holes)

$$\frac{1}{m_r} = \frac{1}{m_v} + \frac{1}{m_c}. \qquad (16.2\text{-}5)$$

3. We find Δn from the steady state condition

$\Delta n = \tau R = \frac{\tau}{e*l*d*w} * i$

Calculations:

$$\Delta n = \frac{50 * 10^{-9}}{e * 2 * 110 * 10 * 10^{-18}} * 10^{-3} = 1.4 * 10^{23} m^{-3} = 1.4 * 10^{17} cm^{-3}$$

$$m_r = \frac{1}{\frac{1}{m_c} + \frac{1}{m_v}} = \frac{1}{\frac{1}{0.07} + \frac{1}{0.5}} m_0 = 0.06 m_0$$

$$E_{fc} - E_{fv} = 1.52\ eV + (3\pi^2)^{\frac{2}{3}} \frac{\hbar^2}{2m_r} \Delta n^{\frac{2}{3}} = 1.52 eV + 0.0165 eV$$

Answer: You can expect amplification from 1.52 eV (816nm) to 1.5365 (807 nm)

1.2

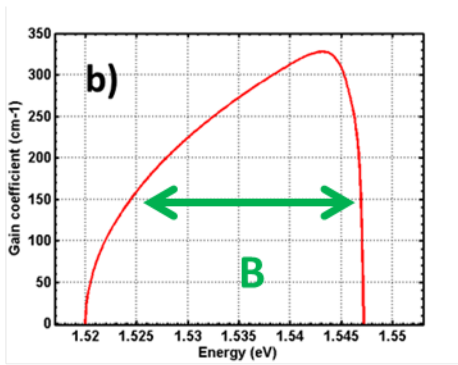
Resonator losses $\alpha_r = \frac{1}{\Gamma}(\alpha_s + \alpha_m)$

Only mirror losses are considered -> No scattering losses $\alpha_s = 0$
30% of the light spills out of the gain region into the surrounding -> only 70% in active rregion -> $\Gamma = 0.7$
Mirror losses: $\alpha_m = \alpha_{m1} + \alpha_{m2} = \frac{1}{2d} ln\left(\frac{1}{R_1 R_2}\right) = \frac{1}{2*110*10^{-4}} ln\left(\frac{1}{0.32*0.32}\right) = 104\ cm^{-1}$

➔ $\alpha_r = \frac{1}{0.7} 104\ cm^{-1} = 148 cm^{-1}$

Insert this in the figure and you get a bandwidth B=22.5 meV

$\alpha_r = 148 cm^{-1}$ ➔



Now you need to calculate the free spectral range

$$\nu_F = \frac{c}{2nd} = \frac{c}{2 * 3.6 * 110 * 10^{-6}} = 3.8 * 10^{11}\ Hz$$

➔ $h\nu_F = 1.6\ meV$
➔ Number of modes =22.5/1.6= 14 modes

Answer: 14 modes

1.3

In a fiber several different channels coexist and each has its own wavelength. This is called wavelength division multiplexing. The smaller the total linewidth of your light source, the more channels you can fit in the fiber. For that reason you would like each source to operate at a single longitudinal mode.

You can select a single mode by introducing a periodic modulation of the refractive index. The period of this modulation should be should be $q * \frac{\lambda}{2}$, where q=1,2,3…. In this way one specific wavelength, λ, experiences constructive interference in the multiple reflections and this mode is thereby selected.