Exam OPTO-Electronics 01-02-2024

INSTRUCTIONS (PLEASE READ BEFORE STARTING)

Please answer in a separate paper sheet and try to write as readable as possible.

Identify properly each piece of paper with your answers and number them.

Clearly highlight your answers and in case of mistake please make sure the wrong answer is properly crossed.

Once you have finished, please double check that you have been through all the questions.

Calculators are allowed.

Formulas are provided.

No extra formulas sheet is allowed.

Useful relations:

$h = 6.626 \times 10^{-34}$ J·s,

$k_B = 1.381 \times 10^{-23}$ J/K,

temperature in Kelvin=Celcius+273.15, $q = 1.602 \times 10^{-19}$ C,

c = 299 792 458 m/s,

and $W = A^2\Omega$.

Exercise 1

Considering a declared Responsivity of 0.95 A/W at 1310 nm and a NEP of $2.66e^{-15}$ and a dark current of 2 nA.

1. Calculate the external quantum efficiency of the detector

2. Considering a bandwidth of 10 GHz what is the minimum power P1 required for an SNR of 1?

3. What is the minimum detectable optical power corresponding to the dark current?

4. Considering a load resistance of 500 ohms what is the corresponding noise current at 300K. What is your conclusion?

Exercise 2

A laser diode operates at 908 nm and has a spectral width of 50 GHz, a cavity length of 400 um and a refractive index of 3.2.

1. What is the corresponding spectral width in wavelength?

2. What is the mode spacing?

3. What is the reflection of the mirrors (considering the same reflection on both facets) of the cavity to get this spectral width?

4. How could you obtain this reflectivity?

5. Making the approximation that the output of the laser is a gaussian beam and a divergence angle 2θ of 30° what is the beam waist?

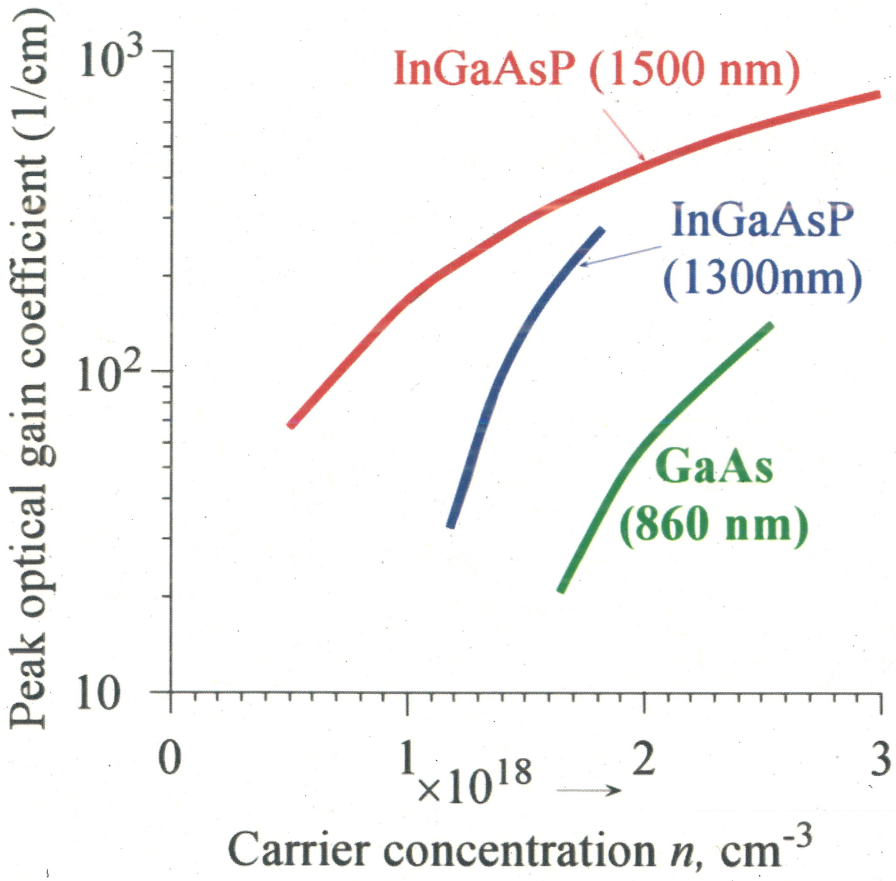
6. Considering an optical fiber with a mode field diameter of 9um what is the maximum distance at which the fiber can be put to avoid loosing too much optical power?

Exercise 3

Data Transmission

Consider a double heterostructure InGaAsP semiconductor laser operating at peak wavelength of around 1310 nm. The cavity length L ≈ 100 µm, width W ≈ 10µm, and height d ≈ 0.1 µm. The refractive index n ≈ 3.7. The loss coefficient $\alpha_s \approx 20$ cm-1 and the direct recombination coefficient $B \approx 1\times10^{-16}$ m^3 s^{-1}. Assume that the optical confinement factor is 1.

1. Find the threshold gain g_{th} considering cleaved facets and reflection from air,
2. carrier concentration n_{th} using the following graph,



3. current density J_{th}
4. the threshold current

Exercise 4

Detector and receiver noise

Consider an InGaAs pin photodiode used in a receiver circuit as in Figure 5.below with a load resistor of 27 kΩ. The total capacitance of the detector and the input of the amplifier together is 16 pF. The photodiode has a dark current of 2 nA. The incident radiation is 25 nW at 1550 nm where the responsivity is 0.8 A/W.

1. Calculate the cut-off frequency based on the RC of the circuit
2. Calculate the photocurrent
3. Estimate the total noise current using the bandwidth calculated in 1
4. Calculate the thermal contribution of the load resistor
5. Assuming that the amplifier is noiseless, calculate the SNR at 300 K