Exam OPTO-Electronics 17-01-2024

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,

$kB = 1.381 \times 10^{-23}$ 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

Consider a multimode fiber with a core diameter of 100 μm, core refractive index of 1.4750, and a cladding refractive index of 1.4550 both at 850 nm. Consider operating this fiber at $\lambda = 850$ nm.

(a) Calculate the V-number for the fiber and estimate the number of modes.

(b) Calculate the wavelength beyond which the fiber becomes single mode.

(c) Calculate the numerical aperture.

(d) Calculate the maximum acceptance angle.

(e) Calculate the modal dispersion $\Delta\tau$ and hence the bit rate $\times$ distance product.

Exercise 2

Calculate the total dispersion and the overall net dispersion coefficient when a 900 km transmission fiber with D_{ch} = +15 ps nm^{-1}.km^{-1} is spliced to a compensating fiber that is 100 km long and has D_{ch} = –110 ps nm^{-1} km^{-1}.

What is the overall *effective* dispersion?

Exercise 3

Data Transmission

A communication system uses the previous receiver at 1550 nm with a data rate of 2.5 GB/s.

The transmitter has a spectral linewidth of 0.5 nm.

1. Calculate the SNR for an incoming power of 10uW for a noise level of 20 nW.
2. Considering that the receiver is connected to a fiber with loss of 0.2 dB/km what is the length of the fiber knowing that the input power is 1 mW at the beginning of the fiber?
3. If the fiber has a dispersion of -18ps/nm.km, will the system work?
4. If no, can you comment on how to achieve that?
5. What is the minimum length of a possible compensating fiber with a dispersion 100ps/nm.km?
6. Repeat the reasoning of a data rate of 10 GB/s and a laser linewidth of 0.025 nm.

Exercise 4

Fabry-Perot optical resonator in gas lasers

Consider an idealized He-Ne laser optical cavity.

Taking $L = 0.6$ m, $R_1 = R_2 = 0.99$,

(a) calculate the separation $\Delta\lambda$ of the modes in wavelength and the *spectral width* $\delta\lambda$.

(b) Considering a Gaussian mode field output of diameter $2w_0$ equal to 0.1 mm what is the expected far field divergence angle. Hint: the output is red

(c) What would be the spot diameter after 1 m and 10 m

Exercise 5

InGaAsP-InP Laser

Consider a FP InGaAsP-InP laser diode that has an optical cavity of length 250 microns. The peak radiation is at 1540 nm and the refractive index of InGaAsP is 3.7. The internal cavity losses (α_s) is 30

cm^{-1}. The optical gain bandwidth (as measured between half intensity points) will normally depend on the pumping current (diode current) but for this problem assume that it is 2 nm.

(a) What is the mode integer m of the peak radiation?

(b) What is the separation between the modes of the cavity?

(c) How many modes are there in the cavity?

(d) What is the reflectance at the ends of the optical cavity without any coating (faces of the InGaAsP crystal)?

(e) Considering a coating on the facets, what should be the period to get a peak reflection at 1540 nm?

(f) Calculate the linewidth if the reflection is now 0.9 and 0.95

Exercise 6

Bandgap and photodetection

(a) Determine the maximum value of the energy gap which a semiconductor, used as a photoconductor, can have if it is to be sensitive to yellow light (600nm).

(b) A photodetector whose area is 4×10^{-2} cm^2 is irradiated with yellow light whose intensity is 5 $mW.cm^{-2}$. Assuming that each photon generates one electron-hole pair, calculate the number of pairs generated per second.

(c) From the known energy gap of the semiconductor GaAs (E_g = 1.42 eV), calculate the primary wavelength of photons emitted from this crystal as a result of electron-hole recombination. Is this wavelength in the visible?

(d) Will a silicon photodetector be sensitive to the radiation from a GaAs laser? Explain why?