Exam

"Basics of Opto-Electronics"

27/06/2024

Official duration: 2 hours

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 at the end of the questionnaire or a separated sheet.
No extra formulas sheet is allowed.

Useful relations:

$h = 6.626\times10^{-34}$ J·s,
$k_B = 1.381\times10^{-23}$ 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

Timing jitter is the fluctuation in the arrival time of a data bit at the reciever with respect to the clock. There are many sources of timing jitter, one of which is fluctuation in wavelength of the laser source due to temperature fluctuations. Suppose you have a laser where the emission wavelength changes with temperature with a **slope 0.5 nm/°C** about a nominal value of 1.55 μm, and the temperature control unit is accurate **to about 1 °C,** meaning that the temperature randomly fluctuates within this range.
The fiber has a dispersion parameter of **M=10 ps/nm·km** and a length of 25 km.

1. What is the spread in pulse arrival time $\Delta\tau$ due to timing jitter?
2. What is the maximum bit rate as limited by this timing jitter, assuming NRZ modulation (B_{NRZ}=0.7/jitter)
3. If the laser has a spectral width of 1 nm, then what is the maximum bit rate as limited by both timing jitter and chromatic dispersion?
4. If you had to double the length of the fiber to 50 km what could be the strategies to improve the system

Exercise 2

A l=1.31 μm communications system is operated at B=2.5Gb/s.

1. Calculate the receiver sensitivity for an InGaAs pin receiver with η=70% quantum efficiency, a bandwidth Δf=0.7**B**, a load resistance R_L=500 ohms, and an electronic amplifier noise figure of 6 dB (noise is multiplied by 4) Assume that the receiver is at room temperature and the dark current is Id=0
2. Assume then a dark current Id=10nA
3. Calculate in both the previous cases the minimum Power that can be received at the receiver
4. Calculate the loss limited distance for an average launched power of 7 dBm and fiber attenuation of 0.3dB/km

Exercise 3

A 200 km , 5Gb/s communication link consists of four spans and three optical amplifiers.
The initial transmitted power is 0 dBm and the fiber loss is 0.25 dB/km.
Assume the receiver bandwidth 0.7B and the responsivity 0.8 A/W. The operating wavelength is 1.55μm.

1. What is the total loss due to propagation?
2. What is the optimal gain (that compensates exactly the loss for each span) for maximum SNR?
3. Consider a dark current of 0, calculate the power received before each amplifier and the noise in a photodiode (equivalent to the final one) due to the incoming power, estimate the SNR
4. Considering that each amplifier is affecting the SNR by a noise figure of 4 dB (the signal after the amplifier as an SNR-4dB), what is the final SNR at the receiver?

Exercise 4

In the following multiple choices questions, there are 5 possible answers, where one or **more** may be reported as correct. Please write down the one you think are correct and justify your answer.

i) Which of the following are properties of a light-emitting diode (relative to laser diodes)?

a) longitudinal modes

b) high beam divergence

c) temporal coherence

d) emission at telecom wavelengths

e) low cost

ii) A laser diode with source spectral width $\Delta\lambda = 2$ nm at $\lambda_f = 1.55$ μm has a spectral width in frequency $\Delta\omega$ of:

a) 250 GHz

b) 387 kHz

c) 2.43 rad/μs

d) 1.57 rad/ps

e) not listed

iii) If you wanted to detect light at wavelengths $\lambda = 1.31$ μm and $\lambda = 1.55$ μm with a heterojunction pin photodiode, then which combination of bandgap energies for the i and pn regions would work?

a) i: Wg = 0.75 eV, pn: Wg = 1.35 eV

b) i: W_g = 0.89 eV, pn: W_g = 1.35 eV

c) i: Wg = 0.69 eV, pn: Wg = 1.12 eV

d) i: W_g = 0.89 eV, pn: W_g = 0.75 eV

e) i: W_g = 1.12 eV, pn: W_g = 0.69 eV