The University Of Sheffield.

Data Provided:

Speed of light, $c = 3.00 \times 10^{8}\ ms^{-1}$

The Boltzmann constant, $k_B = 1.38 \times 10^{-23}\ JK^{-1}$

The Planck constant, $h = 6.63 \times 10^{-34}\ Js$

Electron charge, $e = 1.60 \times 10^{-19}\ C$

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Autumn Semester 2008-2009 (2 hours)

Optical Communication Devices and Systems 6

Answer **THREE** questions. **No marks will be awarded for solutions to a fourth question.** Solutions will be considered in the order that they are presented in the answer book. Trial answers will be ignored if they are clearly crossed out. **The numbers given after each section of a question indicate the relative weighting of that section.**

1. **a.** i) Describe the origin of dispersion in multi-mode fibre optic cable.

ii) Derive the dispersion per unit length for a step-index multimode fibre, stating clearly all assumptions made. **(6)**

b. Two points are linked by a step–index multimode plastic fibre which has a dispersion coefficient of 100 ns/km and loss of 200 dB/km. A laser diode, with launch power 5 dBm, is amplitude modulated with a 50:50 mark:space ratio. For all data rates the receiver requires a minimum receiver power of -55 dBm to operate at a bit error rate (BER) of 10^{-9}.

Assuming no margin with regard to the power budget, calculate the maximum link lengths for data rates of

i) 0.1 GBit/s.

ii) 1 GBit/s

iii) 10 GBit/s.

For each length indicate the limiting factor to transmission distance. **(10)**

c. Describe possible methods to increase the transmission distance for each data rate in the system described in part (b). **(4)**

2. **a.** i) Describe the losses associated with a passive coupler

ii) Determine the longest distance power budget for n passive couplers making up a linear bus.

iii) Define the losses associated with a star coupler

iv) Describe the power budget for a star network, describing the advantages of a star network over a bus network.

v) Explain how the disadvantages of the linear bus topology may be overcome

vi) Give a common application of a bus optical network. **(12)**

b.

	Launch Power (dBm)	Modulation Rate (GBit/S)	Linewidth (nm)	Peak Wavelength (nm)
Vertical Cavity Surface Emitting Laser	2	10	~1	850nm
Fabry Perot Laser Diode	10	10	~5	1300nm
Distributed Feedback Laser Diode	10	10	0.001	1550nm

The table details key operating parameters for a range of transmitters.
Describe briefly;

i) The choice of materials for each type of component.

ii) The origin for the different line-widths of the sources.

iii) Typical link lengths and network applications for each of the laser components. **(8)**

3. **a.** Describe what is meant by

i) Fundamental absorption,

ii) Spontaneous emission,

iii) Stimulated emission,

and define factors influencing the transition probabilities in each case. **(6)**

b. The threshold current of a quantum well laser diode of length 300 μm is 8 mA, while for an identical device with cavity length of 400 μm a threshold current of 9.75 mA is obtained. The device has as-cleaved facets (R=0.32), an active region width of 2 μm, a linear current density - modal gain relationship, and an internal loss, α_i, of 5 cm^{-1}.

i) Calculate the current density-gain characteristics of the laser material

ii) Hence calculate the transparency current density.

iii) Calculate the threshold current for a 250 μm long device with one as-cleaved (R=0.32) and one high reflectivity (R=1) facet. **(12)**

iv) If the maximum modulation rate is relaxation oscillation limited, discuss which of the three chips is likely to exhibit the highest maximum modulation rate. **(2)**

4. **a.** A photodiode used as the receiver in a fibre-optic link consists of an InGaAs region of length L sandwiched between n-doped InP and p-doped InP. Describe the design considerations in choosing L. **(6)**

b. For a photodiode the shot noise (σ_{shot}) and thermal noise (σ_{therm}) may be approximated to;

$$\sigma^2_{shot} = 2q\,(I+I_{dark})\Delta f$$

$$\sigma^2_{therm} = (4k_BT/R_L)\,F_N\,\Delta f$$

Where q=electron charge, I = photocurrent, I_{dark}= dark current, Δf = bandwidth (RC limited), k_B=Boltzmann's constant, T = temperature, R_L =load resistance, F_N =Amplifier noise figure. For such a photodiode operating at 1550nm, assume 5GHz bandwidth, 70% quantum efficiency, 1 μA dark current, 0.6pF junction capacitance and a 3dB amplifier noise figure. The receiver is illuminated with 2 mW of optical power. Determine;

i) The noise currents due to shot noise, and

ii) The noise currents due to thermal noise.

iii) The signal to noise ratio. **(9)**

c. Discuss strategies to improve the signal to noise ratio. **(5)**

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RAH