The University Of Sheffield.

Data Provided: speed of light, $c = 3 \times 10^8$ ms^{-1}

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Autumn Semester 2006-2007 (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. Describe the effects of chromatic dispersion and attenuation on the distance an optical signal made up of amplitude modulated bits may be transmitted down a single-mode silica fibre. **(4)**

b. A fibre optic link is to be created to operate at 1 GBit/second using amplitude modulated pulses with 1:1 mark:space ratio. A Fabry-Perot laser and a p-i-n photodiode are to be used as the transmitter and receiver, respectively. The transmitter and receiver have identical operating characteristics except their operating wavelength may be either 1.35 or 1.55 um.

The Fabry-Perot laser has spectral linewidth of 5nm and launch power 2dBm. A p-i-n diode, which requires a receiver power of -20dBm for both at this bit-rate, is the receiver. A power budget margin of 15dB is required for the system. The dispersion and loss characteristics for the single-mode fibre to be used in the system at 1.35 um and 1.55 um are tabulated below.

Operating Wavelength (μm)	Dispersion (ps/(nm.km)	Attenuation (dB/km)
1.35	1	0.4
1.55	15	0.2

Determine the operating wavelength which will give the maximum link length and state whether the system is loss or dispersion limited in this case. State all assumptions made. **(10)**

c For the same link length as obtained in part (b) for a 1 GBit/second signal, discuss methods to transmit a 10GBit/sec signal. **(6)**

2. **a.** A multimode fibre optic cable of length L, consists of a core of refractive index n, and diameter D. The cladding has a refractive index of n(1-Δ). Show that the pulse broadening due to intermodal dispersion is given by;

$$\partial t = \frac{Ln\Delta}{c(1-\Delta)}$$

where c is the speed of light in vacuum. **(5)**

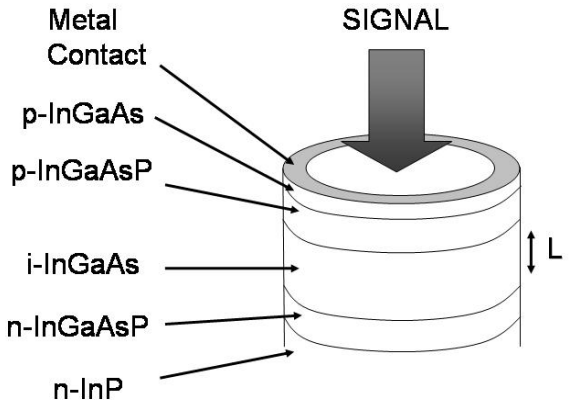
b. Considering data in the form of a 1:1 mark:space amplitude modulate bit with bandwidth B, derive an expression for the maximum link length, stating all assumptions made. **(5)**

c. For a 20 MBit system, where n=1.5, Δ=0.01, what is the maximum link length? **(2)**

d. i) Describe the operating principles of a wavelength division multiplexed (WDM) link. **(5)**

ii) Briefly describe two crosstalk mechanisms possible for such a link. **(3)**

3. **a.** The structure of a p-i-n photodiode is shown schematically below.



Draw the band-structure of this device under operation, indicating the quasi Fermi-levels and the direction of the signal light. Sketch the current-voltage characteristics of such a device under illumination, and without illumination. Briefly describe the key features of this graph. **(8)**

b. Describe design considerations for the thickness L, of the intrinsic region for both high responsivity, and high speed operation of the device. **(6)**

c. Describe how the responsivity of this device could be improved. **(6)**

4. **a.** Describe light absorption and emission processes in a semiconductor and explain the process by which gain is achieved in the active region of a laser diode. **(6)**

b. Explain why single longitudinal and transverse modes are desirable in lasers for optical communications applications. Describe methods to achieve these. **(4)**

c. Using diagrams if necessary, describe the response of a laser to a step change in current when it is operated above threshold. **(4)**

d. The relaxation oscillation frequency of a laser ω_0 is given by;

$$\omega_0^2 \propto \frac{\frac{dg}{dn} \cdot N_{photon}}{\tau_{photon}}$$

Where *dg/dn* is the differential gain, N_{photon} is the number of photons within the mode, and τ_{photon} is the photon lifetime.

Describe strategies, and limitations in maximising the direct modulation rate for such a laser. **(6)**

RAH / PJP