ENGINEERING TRIPOS PART IIA

Friday 9 May 2003 9 to 10.30

Module 3B6

PHOTONIC TECHNOLOGY

*Answer not more than **three** questions.*

All questions carry the same number of marks.

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

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1 (a) Explain briefly why light emitting diodes are preferred to laser diodes in certain photonic applications. Describe the two main types of light emitting diode structures generally used. [40%]

(b) A light emitting diode has an operating wavelength of 650 nm, and is driven directly from a voltage source with an internal resistance of 25 ohms. If the radiative and non-radiative recombination times of the device at a temperature of 300 K are 1 ns and 2 ns respectively, and the device has an external quantum efficiency of 4%, estimate the voltage required from the source for the light emitting diode to generate an output power of 0.5 mW. [30%]

(c) Estimate the spectral bandwidth of the light emitting diode at a temperature of 300K. [15%]

(d) Comment on the temperature dependent properties of light emitting diodes. If the above light emitting diode has a characteristic temperature, T_o, of 100 K, estimate the current required for it to generate a power of 0.5 mW at a temperature of 350 K. [15%]

2 (a) Describe the main physical principles required for lasing to be achieved in a laser diode. What structural features of the device are required to ensure efficient operation? [35%]

(b) The rate equations for a Fabry-Perot laser diode may be written in the form:

$$\frac{dn}{dt} = \frac{I}{eV} - \frac{n}{\tau_s} - g(n - n_o)P$$

$$\frac{dP}{dt} = g(n - n_o)P + \frac{\beta n}{\tau_s} - \frac{P}{\tau_p}$$

(i) Explain the meaning of the different terms in the equations stating all assumptions made. [10%]

(ii) Using these equations, derive expressions for the lasing photon density and carrier concentration of the device as a function of current both below and above the threshold. Hence derive an expression for the threshold current. [35%]

(c) Describe the typical optical spectrum generated by a Fabry-Perot laser diode, and show that the mode spacing between lines can be written as $\lambda^2 /(2n_r L)$, where λ is the wavelength, n_r is the refractive index of the laser medium and L is the cavity length. [20%]

3 (a) The two most important operating wavelength ranges for optical communications are centered around 1300 nm and 1550 nm. Describe the advantages and disadvantages of operating in these ranges. Indicate, with reasons, which applications are most suitable for the two cases. [25%]

(b) An optical communications system is to operate at a data rate of 2.5 Gb s^{-1} at a wavelength of 1300 nm. The laser source has an optical bandwidth of 3 nm and launches an average power of +3 dBm into single mode fibre. The standard single mode optical fibre to be deployed has a dispersion of 2.5 $ps(nm)^{-1}(km)^{-1}$ and a loss of 0.5 $dB(km)^{-1}$ at the operating wavelength. The low noise receiver has a sensitivity of −19 dBm. Determine whether the link is a loss or dispersion limited. You may assume that the dispersion limit is reached when a single "one" is broadened to 1.5 times the bit period. [50%]

(c) A customer requires an aggregate data rate of 80 Gb s^{-1} over a 200 km single mode fibre link. Describe the technologies that would allow the optical link outlined in part (b) to be upgraded to this performance. [25%]

4 (a) Describe, using a suitable diagram, the construction of a *p+ -n* diode. [15%]

(b) Describe the key processes that limit the bandwidth of a *p+ -n* photodiode. Explain how optimizing the photodiode construction for high bandwidth would affect its responsivity and how the use of a *pin* photodiode would alleviate this problem. [20%]

(c) The front end of a receiver is to be constructed by connecting a photodiode with a capacitance of 0.8 pF to an amplifier with voltage gain of 60. The operating wavelength of the photodiode is designed to be 1550 nm and its coupling efficiency from the input optical fibre is 80%. The amplifier is to be used in transimpedance mode.

(i) Calculate the maximum value for the transimpedance resistor to allow a receiver bandwidth of 2.5 GHz. [30%]

(ii) Calculate the optical sensitivity of the receiver in dBm assuming that an electrical signal to noise ratio of 12 dB is sufficient for low error rate operation. You may assume that the thermal noise in the transimpedance resistor is the limiting noise process and that the temperature of operation is 300 K. [35%]

END OF PAPER

No answers have been received from the Examiner
for this Module