The University Of Sheffield.

Data Provided: None

Maxwell's Equations

$\nabla \times \mathbf{E} = -\delta \mathbf{B}/\delta t$ $\quad$ $\nabla \times \mathbf{H} = \delta \mathbf{D}/\delta t$

$\nabla \bullet \mathbf{D} = 0$ $\quad$ $\nabla \bullet \mathbf{B} = 0$

$\mathbf{D} = \varepsilon_0 \mathbf{E}$ $\quad$ $\mathbf{B} = \mu_0 \mathbf{H}$

Operator Identity – $\nabla \times (\nabla \times \ ) = \nabla(\nabla \bullet \ ) - \nabla^2$

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Autumn Semester 2007-2008 (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. Derive vector expressions to show that the E-field of a monochromatic electromagnetic wave can be described by a one-dimensional wave equation, stating all assumptions made. **(5)**

b. Describe the physical factors which give rise to chromatic dispersion in silica glass, defining all terms used. **(3)**

c. Sketch the chromatic dispersion of a typical single-mode fibre indicating the origin of key features. **(5)**

d. A single mode fibre has a dispersion coefficient of 20 ps/(nm.km) at 1550nm. A fabry-Perot laser of 1nm spectral linewidth is used to transmit a 1:1 amplitude modulated bit stream at 1GBit/s. Describe methods to transmit a 10GBit/s signal over the same distance. **(7)**

2. a. Describe the operating principle of a wavelength division multiplexed link, using diagrams if required. Indicate the requirements placed upon the components in such a system. **(7)**

b. The bit error rate of a system can be described by an error function of the receiver signal Q-factor. Describe the receiver Q-factor in terms of the probability function for a system with no power in a logical "0", using diagrams if necessary. Describe what is meant by an extinction ratio penalty, and the reason for a finite extinction ratio in a high speed link. **(6)**

c. Explain possible sources of cross-talk in a dense wavelength division multiplexed network, indicating their origin and effect on system performance. **(7)**

3. **a.** Figure 1 shows the current – optical power characteristics for an InP based bulk hetero-junction laser operating at 1.55µm. Discuss the relative strength of all possible optical processes for photons traversing the optical cavity, and the gain within the cavity as the current is increased from 0 to 40mA. **(4)**

b. Sketch the possible band structure of such a device under zero and forward bias. Indicate the Fermi-level or quasi Fermi-levels, and possible materials. **(5)**

c. This laser is shown schematically in Fig.2, assuming the cavity has an internal loss of 20 cm^{-1}. Calculate the threshold modal gain for the laser. **(3)**

d. Given the material gain $g_{material} = An$, where n is the carrier density, calculate A assuming the carrier lifetime is 1 ns at lasing carrier densities. **(4)**

e. Describe strategies for reducing the threshold current for such a laser. **(4)**

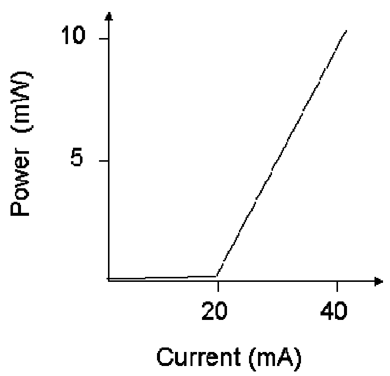

Figure 1

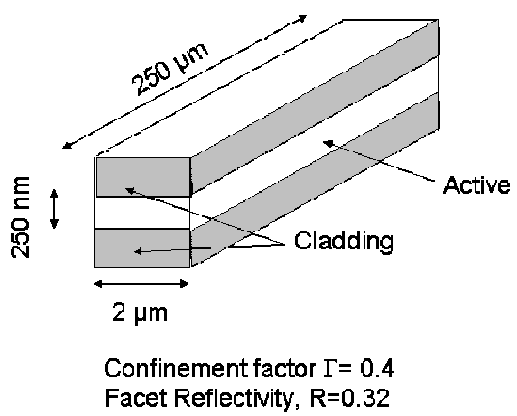

Figure 2

4. **a.** Describe, using diagrams if necessary, the effect of increased temperature on the operating characteristics of a semiconductor laser and describe the effects of a varying laser temperature on system bit error rate. **(4)**

b. Describe, using diagrams if necessary, the effect of increased temperature on the response of a p-i-n photodiode and describe the effects of varying photodiode temperature on system bit error rate. **(4)**

c. Describe rate equations for the photon density and carrier density within a laser cavity, describing all terms. Derive steady state solutions to these equations. **(8)**

d. With reference to these equations, describe the effect of spontaneous emission into the lasing mode for a laser operated above threshold. **(4)**

RAH / PJP