The University Of Sheffield.

Data Provided: Speed of light in vacuum

$c = 3 \times 10^8$ m/s

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Autumn Semester 2010-2011 (2 hours)

EEE6041 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.** Draw a schematic diagram of a Fabry-Perot laser consisting of InP cladding layers and a bulk InGaAsP active and grating layers. Indicate;

I. The active region

II. p and n-cladding regions.

III. The metal contacts

IV. The facets and any coatings

V. The ridge structure **(6)**

b. The net modal gain of a laser is approximated to be linear in current. Transparency is obtained at 10 mA whilst a gain of 100 cm^{-1} is obtained at 60 mA. The facet reflectivity of both facets (R) are equal and is 0.3.

Calculate the threshold current for lasers of length 200 μm and 300 μm. **(8)**

c. By considering the rate of change of carrier density of a laser modulated from zero carrier density (J=0) to above threshold (J>Jth) derive the turn-on delay for a laser as a function of J. **(6)**

2. **a.** Describe, using diagrams if necessary, the effect of increasing temperature on the current – output power characteristics of a semiconductor Fabry-Perot laser.

Explain the origin of these changes.

Describe the effect of these changes on system bit error rate in an optical communications system. **(6)**

b. For a p-i-n photodiode, describe the key impact of increasing temperature with regard to system bit error rate in an optical communications system. What can be done to maintain a constant bit error rate if the receiver temperature is increased? **(4)**

c. Explain the operating principles of an erbium doped fibre amplifier (EDFA) with regard to the energy levels of Er3+ and how such a fibre is optically excited.

Describe sources of noise when these components are used in a fibre optic link..

Describe the advantages and disadvantages of an EDFA compared to a semiconductor optical amplifier. **(10)**

3. **a.** Describe the effect of dispersion on an amplitude modulated optical pulse. **(2)**

b. Explain, with the aid of diagrams if necessary, the origins of intermodal dispersion in multi-mode fibre.

Derive an expression for this dispersion.

Estimate the maximum bit-rate distance product for a fibre with a core refractive index of 1.5 and cladding index of 1.48, stating all assumptions. **(8)**

c. Describe the origins of chromatic dispersion in single-mode fibre.

Sketch the typical spectral dependence of dispersion in standard single-mode fibre, describing all features.

How does this dependence influence the choice of optical transmitter in an optical communications link? What impact does the minimum in absorption at 1550nm have upon this choice? **(10)**

4. **a.** A new laser is being developed for 10 GBit/s fibre-to-the-home applications. The emission wavelength is specified to be 1.27 μm where single-mode fibre has a dispersion coefficient of -2 ps/(km.nm) and an attenuation of 0.5 dB/km. The transmitter will have an average power of 10 dBm, the receiver power needed for the specified bit error rate is -25dBm. A margin of 20 dB is required within the system. With regard to dispersion, a maximum pulse broadening of 40% of the bit slot is permitted.

Calculate the maximum transmission distance with regard to loss in the system.

Calculate the maximum transmission distance with regard to dispersion as a function of transmitter line-width. **(8)**

b. Comment on the choice of laser for this application for 10 km and 30 km link lengths. **(4)**

c. A coarse wavelength division multiplexed version of this system is also proposed. Briefly describe the operating principles of a CWDM system.

Comment on the transmitter needed to operate such a system at 10 GBit/s **(8)**

RAH/MMDS