The University Of Sheffield.

Data Provided:

Speed of light, $c = 3.00\ x10^{8}\ ms^{-1}$

The Boltzmann constant, $k_B = 1.38x10^{-23}\ JK^{-1}$

The Planck constant, $h = 6.63\ x10^{-34}\ Js$

Electron charge, $e = 1.60\ x10^{-19}\ C$

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Autumn Semester 2011-12 (2.0 hours)

EEE6041 Optical Communication Devices and Systems

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 Sketch and explain the spectral dependence of attenuation as a function of wavelength for a silica fibre. Describe the origins of optical loss. **2**

b **(i)** Describe the origins of dispersion in a single mode silica fibre; **(ii)** explain the advantage of using a laser diode as a transmitter over a light emitting diode. **3**

c Considering an optical communication system using a single-mode silica fibre, describe the effects of attenuation and dispersion on a pulse amplitude modulated optical signal. **2**

d Consider a single-mode fibre link operating at 1.5 µm with a fibre loss of $\alpha = 0.4$ dB/km. The fibre used has a dispersion coefficient of 2 ps/(km.nm). A Fabry-Perot laser with a spectral linewidth of 2 nm is used as the transmitter. The transmitter will have an average power of 2 mW. The receiver requires that the minimum number of photons per bit (N_p) is 1000. A power budget margin of 10 dB is required within the system. The system is designed for a data rate of 2.5 Gbit/s. A maximum pulse broadening of 50% of the bit slot is permitted for the dispersion.

(i) Calculate the maximum optical loss allowed for the system.

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

(iii) Calculate the maximum transmission distance with regard to dispersion in the system. **10**

e Comment on how to modify the above system in terms of transmitter and receiver in order to increase the link length. **3**

2 **a** Describe how a waveguide guides light and explain what the optical mode is, using the given slab waveguide (very long length compared to its width) as shown in Figure 1, where n_1: the refractive index of the core layer; n_2: the refractive index of the cladding layer; d is the thickness of the core layer.

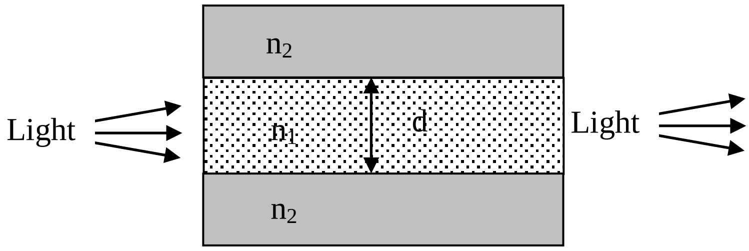

Figure 1

4

b Derive an expression for the number of optical modes based on ray optics, using the above given slab waveguide. **8**

c Calculate the maximum number of lateral optical modes using the slab waveguide given as above. d = 85 μm; n_1= 1.490; n_2 =1.470. The waveguide is designed to operate at a wavelength of λ = 1.5 μm. The phase change due to reflection is ignored. **4**

d Explain how you would modify the waveguide in order to reduce the number of optical modes. **4**

3 **a** Describe what is meant by

i) Spontaneous emission
ii) Stimulated emission
iii) Population inversion **9**

b An InGaAsP Fabry-Perot laser operating at a wavelength of 1.3 μm has a cavity length of 400 μm. The refractive index of InGaAsP is 3.39. Assuming ideal optical confinement and an internal loss, α_i, of 10 cm^{-1}.

(i) Calculate the mirror loss expressed in cm^{-1}, if the laser facets are both as-cleaved.

(ii) Calculate the percentage reduction in threshold current if one of the laser facets is coated to produce 80% reflectivity? Assume gain is linear in injection current.

(iii) Explain how you would modify the laser diode in order to further reduce the threshold current. **11**

4 **a** Considering a photoconductor, (i) define a photocurrent gain (Γ); (ii) explain how the device or material parameters affect the photocurrent gain. **4**

b For a n-type GaAs photoconductor with a length 30 μm, the minority-carrier recombination time τ=90 ns; electron mobility μ_e=7000 cm^2/V.s; and hole mobility μ_e=400 cm^2/V.s.

(i) Calculate the photocurrent gain if the applied bias is only 4.5V.

(ii) Sketch and explain the photocurrent gain as a function of the applied bias **6**

c Considering an $In_{0.53}Ga_{0.47}As$-based pin photodiode, the $In_{0.53}Ga_{0.47}As$ active region is 1 μm thick, and the optical window reflectivity is 0.4.

(i) Calculate the quantum efficiency of the device if it is used for detection of 1.3 μm radiation. Assume the absorption coefficient of 1×10^4 cm^{-1}.

(ii) Explain how you would modify the photodiode in order to further improve the external quantum efficiency. **6**

d **(i)** Briefly describe the operation principle of an avalanche photodiode; **(ii)** Briefly explain the origins of limits in the performance of an avalanche photodiode **4**

TWANG/RAH