The University Of Sheffield.

Data Provided:

Speed of light, $c = 3.00\times10^{8}\ ms^{-1}$

The Boltzmann constant, $k_B = 1.38\times10^{-23}\ JK^{-1}$

The Planck constant, $h = 6.63\times10^{-34}\ Js$

Electron charge, $e = 1.60\times10^{-19}\ C$

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Autumn Semester 2012-13 (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** Describe and explain the following concepts using a semiconductor as an example.

i) Spontaneous emission

ii) Stimulated emission

iii) Population inversion **4.5**

b Describe and explain the operation mechanisms of the following devices with regard to light emission and absorption processes.

(i) Laser diode

(ii) Optical amplifier

(iii) Light emitting diode **4.5**

c A GaAs/AlGaAs double heterostructure Fabry-Perot laser diode has an active region thickness of 1 μm. The refractive indices of GaAs and AlGaAs are 3.6 and 3.58 respectively. The cavity length is 100 μm; an internal loss, α_i, is assumed 100 cm^{-1}. Assume the optical confinement related constant C to be $8\times10^{7} m^{-1}$

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

(ii) Calculate the optical confinement factor.

(iii) Calculate the threshold gain coefficient if the end mirrors are both as-cleaved.

(iv) Calculate the length of cavity which has the same threshold gain as that calculated in (iii), if one end-mirror is coated to produce a reflectivity of 0.90. **8**

d Explain how you would modify the laser diode in order to reduce the threshold current. **3**

2 **a** Briefly describe the operation mechanisms for the following photo-detectors.

(i) Photoconductor

(ii) PIN Photodiode

(iii) Avalanche photodiode **6**

b Describe which kind of photo-detector is best for the following applications.

(i) Low-noise

(ii) High gain

(iii) Large bandwidth **3**

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 to be 1×10^{4} cm^{-1}.

(ii) Explain how you would modify the photodiode in order to further improve the external quantum efficiency **7**

d For an InGaAsP/InP avalanche photodiode, the quantum efficiency is 80% for detecting 1.3 μm radiation. When an incident optical power is 1.0 μW, the output current is 20 μA. Calculate the multiplication factor of the avalanche photodiode. **4**

3 **a** (i) Describe and explain the optical loss mechanisms in a silica fibre.

(ii) Describe the spectral dependence of optical loss as a function of wavelength.

(iii) Describe and explain the best optical windows for an optical communication system using a silica fibre. **6**

b Describe and explain the optical dispersion mechanisms in a single mode silica fibre. **3**

c Describe the effects of optical loss and optical dispersion on transmitted optical signals in a silica fibre. **4**

d Consider a single-mode fibre link with a fibre loss of $\alpha = 0.2$ dB/km. A Fabry-Perot laser with an optical power of 3 dBm is used as the transmitter. A photodetector receiver with a detection limit of -35 dBm is used as the receiver. 10 optical connectors each with an optical loss of 0.3 dB and two optical splices each with a 0.1 dB loss are used. Furthermore, a EDFA with a gain of 10 dB is used as an optical amplifier. A power margin of 10 dB is required.

(i) Calculate the maximum optical loss allowed for the optical fibre used.

(ii) Briefly describe and explain the operation mechanism of EDFA.

(iii) Calculate the maximum transmission distance with regard to loss in the system. **7**

4 **a** Derive an expression for numerical aperture (NA) for a multiple mode optical fibre, and comment on how to increase NA. **5**

b Describe and explain the formation mechanism of optical mode in a waveguide using a ray optics model. **5**

c For a planar waveguide, the refractive index of the core layer is 1.468; and the refractive index of the cladding layer is 1.477.

(i) Calculate the numerical aperture assuming that the waveguide is used in the air.

(ii) Calculate the maximum number of optical modes if the waveguide with a core-layer thickness of 100 μm is designed to operate at a wavelength of $\lambda = 1.3$ μm. The phase change due to reflection is ignored.

(iii) Explain how you would design the waveguide in order to reduce the number of optical modes.

(iv) Calculate the maximum thickness of the core layer, which still allows you to achieve a single optical mode operating at $\lambda = 1.3$ μm. **10**

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