OLLSCOIL NA h-ÉIREANN, CORCAIGH
THE NATIONAL UNIVERSITY OF IRELAND, CORK

COLÁISTE NA h-OLLSCOILE, CORCAIGH
UNIVERSITY COLLEGE, CORK

SUMMER 2001

B.E. DEGREE (ELECTRICAL AND ELECTRONIC)
HIGHER DIPLOMA IN PHYSICS

OPTICAL ELECTRONICS (EE4007)

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3 HOURS

The use of approved calculators is permitted.

FIVE QUESTIONS TO BE ANSWERED, AT LEAST TWO FROM EACH SECTION.
USE SEPARATE ANSWER BOOKS FOR EACH SECTION

Physical Constants:
Free electron mass, $m_0 = 9 \times 10^{-31}$ kg
Planck's constant, $h = 6.624 \times 10^{-34}$ J s
Electronic charge, $q = 1.6 \times 10^{-19}$ C
Boltzmann's constant, $k_B = 1.38 \times 10^{-23}$ J K^{-1}
Room temperature = 300 K

Questions follow overleaf/…

SECTION B

5. (a) List five advantages of optical fibre over normal copper twisted pair or coaxial transmissions lines.

   (b) Draw a schematic representation of a point-to-point optical link, labeling each major component.

   (c) A point-to-point optical fibre link is to be designed between Cork and Dublin (distance 260 km). The desired link margin is +10dB. The laser chosen has an average output power of 5mW at a wavelength of 1.55μm. The sensitivity of the chosen receiver is –30dBm (this includes all collection losses). Modulation loss and fibre coupling loss may be taken as a total of 5.8dB. The single mode fibre used for the link has an attenuation of 0.28dB km^{-1} at 1.55μm. Erbium doped fibre amplifiers are to be used to boost the optical signal. These amplifiers come in 5 m lengths and will provide 5 dB gain. How many of these EDFAs will be required to ensure the desired link margin? Where would they be placed? You may assume that fibre dispersion and non-linearity are insignificant, also assume fibre splice loss to be 0.15dB. All fibre ends are properly terminated with low reflection loads.

6. (a) Explain what is meant by the following:
   (i) Modal dispersion
   (ii) Material dispersion
   (iii) Refractive index
   (iv) Critical angle
   (v) Numerical aperture

   (b) A symmetrical slab waveguide has refractive indices of 2.8 and 2.4 for the core and cladding respectively. What is the critical angle?

   (c) Using the previous symmetrical slab waveguide what is the largest thickness that the core can be to guarantee single-mode operation at 850 nm?

   (d) Draw the mode pattern for TE_0, TE_1, TE_2 and TE_3 for a symmetric slab waveguide.

7. (a) Explain the importance of lattice matching in semiconductor laser growth.

   (b) Show using diagrams the physical effect compressive strain and tensile strain has on a mismatched epi-layer. Is the epi-layer lattice constant greater or smaller than that of the substrate for tensile strain to occur?

   (c) Draw E-k diagrams for Ge, Si and GaAs. Use a parabolic band approximation and label the L, Γ and X minima, the HH band, LH band and SO band for each.

   (d) Explain why GaAs is more efficient at radiative recombination compared to Si or Ge.

   (e) List suitable semiconductor materials for light emission at wavelengths around 650 nm, 780 nm, and 1300 nm. (one of each).

8. (a) List five differences between Light-emitting diodes (LEDs) and Laser diodes.

(b) What peak emission wavelength is to be expected from an LED having an active region with a band-gap of 2.4 eV? Draw the spectral output if $\Delta\lambda$ = 20 nm.

(c) Describe how an indirect band-gap material, such as GaP, can be used to make a light-emitting diode.

(d) A GaAs/AlGaAs LED has an activation barrier of energy E_d = 0.6 eV to long-term degradation. If the prefactor in the Arrhenius equation describing the degradation rate is C = 250 $hour^{-1}$, find the time after which the ouptut radiant power will fall to half its initial value, assuming room temperature operation.