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

COLÁISTE NA h-OLLSCOILE, CORCAIGH
UNIVERSITY COLLEGE, CORK

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

OPTICAL ELECTRONICS (EE4007)

Prof. G. W. Irwin,
Prof. R. Yacamini,
Dr S. L. Prunty,
Dr A. P. Morrison.

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
Speed of light in free space = 3×10^{8} m s^{-1}

Questions follow overleaf/…

SECTION B

5. (a) Given a symmetrical slab waveguide with core refractive index 3.6 and cladding refractive index 3.55. Using the mode-chart supplied, find the propagation angles, effective refractive indices and the number of TE modes in this waveguide if the core is 1.64μm thick and the free space wavelength of propagating light is 0.82μm. Calculate also the largest thickness that will guarantee single TE mode operation at 0.82μm in this waveguide.

   (b) Describe with the aid of diagrams the operation of an electro-optic switch, listing one suitable material for its manufacture.

   (c) Describe with the aid of diagrams how a Mach-Zehnder interferometer can be used as an electro-optic modulator.

6. (a) When specifying a digital optical receiver's performance a common metric used is comparing the bit-error-rate (BER) with the received optical power. Draw a diagram that qualitatively describes the relationship between BER and received optical power. Label the main features on this diagram.

   (b) What is the maximum length a fibre system can have assuming zero dB link margin and no coupling loss if the receiver sensitivity is –32 dBm, fibre attenuation is 0.18 dB/km and the input power is 3 mW?

   (c) A digital optical receiver is sensitive enough to detect 150 photons/bit at a data rate of 2.5Gb/s and a wavelength of 1.55μm. What is the average received optical power in Watts? How many photons per bit would be received if the wavelength is changed to 1.3μm and the data rate increased to 10Gb/s? (you may assume the received optical power is the same)

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 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 +15dB. The laser chosen has an average output power of 8mW at a wavelength of 1.55μm. The sensitivity of the chosen receiver is –32dBm (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.