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

COLÁISTE NA h-OLLSCOILE, CORCAIGH
UNIVERSITY COLLEGE, CORK

SUMMER 2002

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
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) Explain what is meant by the following:
   - (i) Modal Distortion
   - (ii) Attenuation Constant
   - (iii) Quantum well
   - (iv) Soliton propagation
   - (v) Bragg reflector

   (b) Calculate the reflection co-efficient for normal incidence at the boundary of air and a material with a refractive index of 3.2. From this calculate the reflectivity for normal incidence from this material.

   (c) Describe with the aid of diagrams the difference between s and p polarisation of light.

   (d) Calculate the Brewster angle for the material described in part (b). What happens to light incident at the Brewster angle?

7. (a) Explain the term Noise Equivalent Power (NEP) with reference to semiconductor photodetectors.

   (b) Describe the process of impact ionization as applied to avalanche photodiodes. How does this provide internal gain? What is the advantage of internal gain in the photodiode?

   (c) A p-i-n photodiode has a NEP of 1.4×10^{-12} W/Hz$^{1/2}$ and a responsivity of 0.45 A/W at 632.8 nm. The bandwidth of the photodiode is limited to 1kHz. If this photodiode is illuminated by a HeNe laser emitting 3 mW of power, at what distance will the detector no longer be able to detect the laser radiation. (you may assume that the laser is perfectly collimated and completely focused onto the detector, also assume inverse square law for beam power.)

8. (a) Describe with the aid of diagrams the (i) Quantum Well (ii) Superlattice (iii) MultiQuantum Well (MQW)

(b) Draw an idealised energy band diagram for a Graded Index Separate Confinement Heterostructure Laser diode with three quantum wells. Label each layer. List appropriate materials for each layer in the laser.

(c) An 80Å quantum well is formed from two materials with bandgap energies of 2.1eV and 1.6eV respectively. The ratio of the conduction band offset to the valence band offset for these materials is 0.45:0.55. The electron effective mass in the QW is $0.091m_0$, where m_0 is the free electron mass. If the valence band edge for the wider bandgap material is taken as the reference (zero) energy, at which energies do the quantised energy levels in the conduction band of the quantum well occur? How many discrete energy levels can be accommodated in the conduction band of this quantum well?