ENGINEERING TRIPOS PART IIB
ELECTRICAL AND INFORMATION SCIENCES TRIPOS PART II

Friday 25 April 2003 2.30 to 4.00

Module 4B10

OPTOELECTRONIC TECHNOLOGY

*Answer not more than **three** questions.*

All questions carry the same number of marks.

*The **approximate** number of marks allocated to each part of a question is indicated in the right margin.*

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

1 (a) Describe one technique used to grow bulk InP or GaAs crystals suitable for use as optoelectronic device substrates. Explain why it is important to assess the crystals prior to epitaxial layer growth, and provide notes on the types of test that may be carried out. [35%]

(b) Describe the metal-organic vapour phase epitaxy (MOVPE) system for growing epitaxial layers on InP wafers providing diagrams to illustrate your answer. List advantages and disadvantages of this technique when compared with liquid phase epitaxy (LPE) and molecular beam epitaxy (MBE). [35%]

(c) It is proposed to fabricate buried heterostructure diode lasers. Explain the growth steps that are required for these devices and how the choice of growth technique affects the achieved device structure. [30%]

2 (a) Briefly describe the operation and structure of a diode laser amplifier, stressing how it differs from a conventional diode laser. List the most critical properties that the amplifier must exhibit for applications in optical communication systems. [40%]

(b) The electron rate equation as applied to diode laser amplifiers may be written as

$$dn/dt = (I/eV) - n/\tau_s - \Gamma g(n - n_o)L/E$$

Explain the meaning of the terms, indicating what assumptions are made.

Hence derive an equation for the steady state gain of the amplifier as a function of drive current and input optical power. Describe how the gain changes at high input optical powers. [40%]

(c) A laser diode amplifier has a gain constant of 3×10^{-16} cm^2, a confinement factor of 0.06 and a carrier relaxation time of 3 ns at a wavelength of 1.5 microns. What is the saturation optical intensity of the device? What steps can be taken to maximize the saturation power of such a device and what trade off exists in terms of the amplifier performance? [20%]

3 (a) Describe what factors determine the spectral performance of a Fabry Perot diode laser, indicating why it is often multimode in form. Explain how the spectrum may be influenced by optical feedback into the device. [40%]

(b) What factors determine the temperature dependence of the peak emission wavelength of a Fabry Perot laser diode? A 1.5 μm Fabry Perot laser has a cavity length of 300 μm and a waveguide effective refractive index of 3.2. If the temperature change required for the peak gain wavelength to shift from one mode spacing to the next is 20 °C, calculate the refractive index variation with temperature if the typical gain spectrum shifts by 0.3 nm/°C. [40%]

(c) A distributed feedback (DFB) laser is constructed using the same wafer structure as that used for the Fabry Perot laser of part (b). What would be the shift in wavelength of the DFB laser over a 20 °C temperature range? [20%]

4 (a) Describe the structure of a heterostructure pin photodiode, contrasting its features with that of a homojunction device. How does the choice of photodiode material depend on the structure used? Illustrate your answer by providing a cross section of a typical heterostructure device. [40%]

(b) Describe in detail how the photodiode may be optimised to ensure that low capacitance is achieved and to achieve maximum possible speed. What penalties are paid for high-speed performance? [20%]

(c) It is proposed to use a photodiode with a quantum efficiency of 80% at a wavelength of 1.3 microns to detect a 10 GHz RF sinusoidal signal. If the transit time of the device is 10 ps, and the overall chip capacitance is 0.2 pF, what average optical power must be incident on the photodiode if it is to generate a peak-to-peak voltage of 1 mV across a 50 Ω load resistance? [40%]

END OF PAPER