ENGINEERING TRIPOS PART IIB

Tuesday 24 April 2007 9.00 to 10.30

Module 4B17

PHOTONICS OF MOLECULAR MATERIALS

*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.*

There are no attachments.

STATIONERY REQUIREMENTS
Single-sided script paper
Graph Paper

SPECIAL REQUIREMENTS
Engineering Data Book
CUED approved calculators allowed

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

(TURN OVER)

1. (a) Describe the molecular order characteristic of the nematic phase of a liquid crystal. Surface induced alignment may be planar or homeotropic in a nematic film. Explain the differences between these two forms of alignment and discuss how they may be produced. [30%]

(b) Describe how a twisted nematic device works and discuss briefly why planar surface alignment is of importance in such a display device [30%]

(c) Discuss the parameters that influence the dynamic response time, τ, of a twisted nematic device and give the key equation linking τ to these parameters. Explain, briefly, the reason why there is a delay in the optical response after the application of an external field. What response time would be required for a directly driven TV display fabricated from a 1280 column by 1028 line dot matrix array? How would this array be driven and why would you prefer active matrix addressing? [40%]

2. (a) Describe the molecular order characteristic of a smectic side chain liquid crystal polymer. If such a material is to be used as the storage medium for optical image recording, i.e. a road map display, describe an apparatus suitable for recording and viewing such images in a polymer film. [40%]

(b) Explain the molecular processes involved in selective writing and erasure of a given pixel of an optical image recorded on such a polymer film. [30%]

(c) A 100 mW laser diode is to be modulated to write linear tracks 100μm long and 5μm wide in a 20μm thick dyed polymer film at a speed of 5 ms^{-1}. Assuming 80% of the laser energy is absorbed, calculate:

(i) the required duration of the laser pulse, and

(ii) the local temperature increase produced in the track.

You may assume that the dyed liquid crystal polymer has a density of 120 kg m^{-3} and a specific heat of 60 x 10^3 J kg^{-1} K^{-1}. [30%]

3. (a) Describe the molecular arrangement typical of a chiral nematic (cholesteric) liquid crystal. If such a material is aligned by surface forces to give a planar texture, discuss the properties of light reflected from it. In your description differentiate between effects found when light is incident normally and obliquely. [40%]

(b) Describe how a chiral nematic film may be used to construct a microscopic laser cavity. Discuss the operating principles of such a laser and describe the main features of the output light, in terms of the liquid crystalline properties, assuming the laser is driven by nanosecond light pulses. How would you differentiate between laser and other forms of light emission? Describe how you could tune the wavelength output of the laser and give typical data. [60%]

4. (a) In Landau theory the behaviour of a ferroelectric liquid crystal may be described by a free energy density expansion in one dimension as

$$F(P_s, T, E) = -E + g_0 + \frac{g_2}{2} P_s^2 + \frac{g_4}{4} P_s^4 + \cdots$$

where P_s is the polarisation, E is the applied electric field, T is the temperature and g_n are temperature dependent coefficients. Use this expression to derive a relationship between P_s and T for a second order phase transition. Define any parameters used in your derivation. [40%]

(b) Describe the principles of operation of a surface stabilised ferroelectric liquid crystal (SSFLC) device based on birefringence effects. [30%]

(c) Given that the light transmission through an SSFLC device is given by

$$I_t = I_0 \sin^2(4\theta) \sin^2(\pi \delta n d / \lambda),$$

where I_o and λ are the incident intensity and wavelength, respectively, θ is the tilt angle, δn the birefringence and d is the cell thickness. Calculate the birefringence needed for a) a $\lambda/4$ waveplate and b) a $\lambda/2$ waveplate if $d = 2\mu$m and $\lambda = 600$nm. What is the optimum value of θ? [30%]

5. (a) Dichroic dyes may be incorporated in so-called dye-guest-host (DGH) liquid crystal devices. Describe the principles of operation of a polariser free DGH electro-optic device based on the nematic phase. Why would this device be wavelength specific? [40%]

(b) A DGH nematic device has a peak absorption at 550nm with a dichroic ratio 15:1. Sketch the absorption curves for the "on" and "off" states of the device and calculate the orientational order parameter, S, of the dyed nematic material. [30%]

(c) Explain how the DGH effect might be used to construct a light emissive display. In your explanation discuss the parameters that affect the device performance. [30%]

END OF PAPER