ENGINEERING TRIPOS PART IIB

Thursday 24 April 2008 2:30 - 4.00pm

Module 4B11

PHOTONIC SYSTEMS

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

All questions carry the same number of marks.

*The **approximate** percentage 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

SPECIAL REQUIREMENTS
Engineering Data Book
CUED approved calculator 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

1. (a) Describe how a lens can be used to generate a replay field in a free space optical system. Explain the advantages and also the disadvantages of doing this in an optical system such as an optical correlator. Explain how the limitations of using a lens can be minimised.

How does the replay field change with the choice of lens and wavelength of light. [35%]

(b) Derive an expression to calculate the physical size of the first order when a 200mm focal length lens is used to form the Replay Field in a holographic projector based on a 1280x1280 pixel binary phase only spatial light modulator (SLM) with 13μm pitch pixels using the three primary wavelengths of 412nm, 532nm and 635nm.

Explain why this is a potential problem in the projector. [30%]

(c) Give two ways in which the problem indicated in part b) could be remedied. Explain what the advantages and disadvantages of each solution might be in a real holographic projector. [35%]

2 (a) Describe, using the theory of Jones matrices, how polarised light is propagated. Include definitions of *linear*, *circular* and *elliptically* polarised light in your explanation. [35%]

(b) Use the properties of Jones matrices to show that the generalised Jones matrix P of a polarisor at an angle ψ is given by:

$$P = \begin{pmatrix} \sin^2\psi & -\frac{1}{2}\sin 2\psi \\ -\frac{1}{2}\sin 2\psi & \cos^2\psi \end{pmatrix}$$

State clearly any assumptions made. [15%]

(c) Show how Jones matrices can be used to derive the optimal conditions for binary amplitude modulation using a ferroelectric liquid crystal with cell thickness d, switching angle θ and birefringence Δn, at a wavelength λ. The generalised form of an optical retarder with retardance Γ at an angle ψ is as follows: [50%]

$$W = \begin{pmatrix} e^{-j\Gamma/2}\cos^2\psi + e^{j\Gamma/2}\sin^2\psi & -j\sin\frac{\Gamma}{2}\sin(2\psi) \\ -j\sin\frac{\Gamma}{2}\sin(2\psi) & e^{j\Gamma/2}\cos^2\psi + e^{-j\Gamma/2}\sin^2\psi \end{pmatrix}$$

3 (a) Sketch the basic layout for a *joint transform correlator* (JTC) based on a square law non-linearity and describe how it can be used to recognise objects within images. Clearly identify all of the parts in the system and describe how they could be implemented using real optical components. [30%]

(b) Fig. 1 show the input plane for a square law based non-linearity JTC. Calculate the positions of the correlation peaks in the output plane. Draw a sketch of the lower half of this output plane and comment on its structure in terns of how well the correlator would perform the task set by the input plane of Fig. 1. [40%]

(c) Explain why the non-linearity is a key element in the performance of the JTC. Describe how the performance of the JTC can be improved by changing the non-linearity and list two possible technologies which could be used to implement it. [30%]

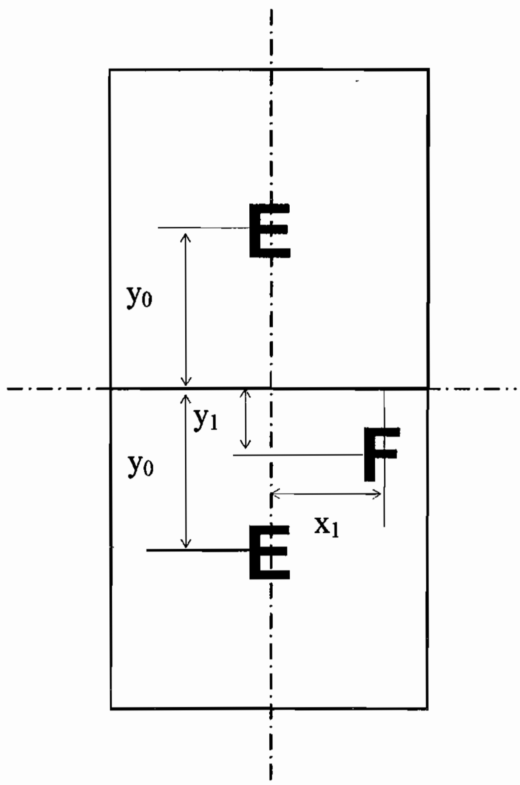

Fig. 1

4 (a) Fig. 2 shows a beam of light travelling from glass (refractive index n_1) into the air (refractive index n_2).

(i) Calculate the angle θ_i, at which the transmitted beam of light will disappear. [10%]

(ii) The amount of energy transmitted into the air, E_t depends on the incident angle θ_i. What other factor may affect the amount of energy transmitted into the air? [15%]

(iii) Other than Snell's law, what conditions must be satisfied at the boundary between the medium and the air? [10%]

(b) (i) With a sketch of the wavelength versus attenuation plot for silica glass, explain the mechanisms behind its absorption spectra. Clearly indicate the location of the 1300nm and 1500nm wavelengths. [20%]

(ii) Silica glass is used to fabricate both single mode and multimode fibres. Describe briefly all of the stages required in order to fabricate a single mode fibre suitable for an optical telecommunications network. [30%]

(iii) Give two factors which will greatly affect the quality and performance of the single mode fibre fabricated with the processes described in (b) (ii) above. [15%]

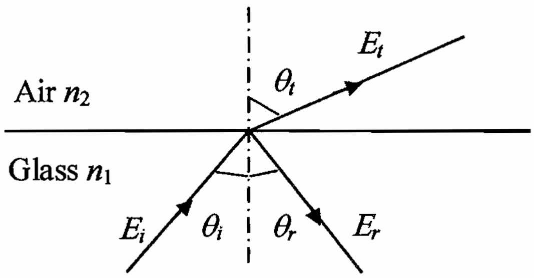

Fig. 2

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