UNIVERSITY OF CAMBRIDGE

ENGINEERING TRIPOS PART IIB

Thursday 22nd April 2004 2.30 to 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

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) Explain what is meant by the terms computer generated hologram, replay field and Fourier transform. Use a diagram to demonstrate the relationship between them in an optical system. [25%]

(b) Show that the overall structure of the replay field for a computer generated hologram is dependant on the pitch of the pixellation Δ as well as the wavelength of the illumination λ. State any assumptions made. [25%]

(c) Describe possible sources and effects of apodisation on the replay field of a computer generated hologram. Why is this a serious limitation in using computer generated holograms as optical switches? [25%]

(d) Describe the effects of repeating the computer generated hologram pattern many times on a regular grid (replication). What does this do to the effects of the apodisation? [25%]

2 (a) Describe in simple terms how both nematic liquid crystals and ferroelectric liquid crystals can be used to modulate light. What are the advantages and disadvantages of each electro-optical effect? [25%]

(b) Which of the two electro-optical effects would you use in the following applications. Explain your choices:

i) An optical correlator [10%]
ii) A single mode fibre-to-fibre optical switch [10%]
iii) An optical packet switch [10%]

(c) Sketch the basic structure of a liquid crystal over silicon spatial light modulator (SLM). How would the design of the device differ for a nematic liquid crystal versus a ferroelectric liquid crystal?

(d) Explain what is meant by a smart pixel SLM. How could such a device be used to improve the performance of an optical correlator? [20%]

3 (a) Sketch the overall layout of a binary phase only matched filter (BPOMF) using two ferroelectric liquid crystal (FLC) spatial light modulators (SLMs). Identify the key components and explain why such a correlator is difficult to align. [30%]

(b) Show that for perfect alignment of the BPOMF, the focal length of the lens must be set at

$$f = \frac{N_2 \Delta_2 \Delta_1}{\lambda}$$

where SLM1 has $N_1 x N_1$ pixels of pitch Δ_1 and SLM2 has $N_2 x N_2$ pixels of Δ_2 pitch. Why is this a serious limitation to the BPOMF? Give an example. [35%]

(c) Sketch a layout to show that three lenses can be used in place of the one in b) to remedy the problem. Show that the choice of the three focal lengths (f_1,f_2, and f_3) can be chosen using the following criterion.

$$\frac{f_3}{f_2} = \frac{N_2 \Delta_2 \Delta_1}{f_1 \lambda}$$

Find the total optical length and explain the process of choosing suitable lenses. [35%]

4 (a) Explain what is meant by the Kramers-Kronig relationship for optical materials. Why is this relationship so fundamental to the designers of optical waveguides? [35%]

(b) What are the critical optical parameters in a telecommunications single mode fibre? How do these relate to the parameters used in designing and fabricating such a single mode optical fibre. [25%]

(c) Given the waveguide structure shown in Figure 1, show that the condition for modal behaviour is given by:

$$\tan\left(kn_1 a\sin\phi - \frac{m\pi}{2}\right) = \sqrt{\frac{2\Delta}{\sin^2\phi} - 1}$$

Explain all of the variables used and state any assumptions made. [40%]

Note the phase of the Goos-Hanchen shift at the boundary is given by:

$$\Phi = -2\tan^{-1}\sqrt{\frac{2\Delta}{\sin^2\phi} - 1}$$

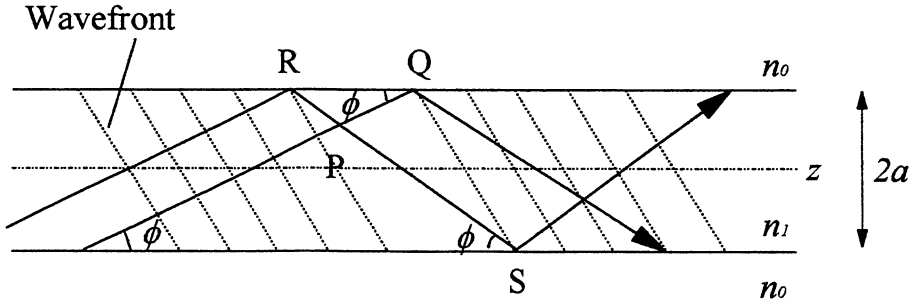

Figure 1.

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