ENGINEERING TRIPOS PART IIB

Thursday 26th April 2007 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) Explain the effects that the pixel pitch (Δ) of a hologram, the number of pixels (N x N) and pixels shape affects its replay field. How does the focal length f of a positive lens and illumination wavelength λ affect it as well? Use an example of a one dimensional grating and state any assumptions made. [30%]

(b) Starting with a single pixel, use a simple graphical technique to demonstrate the structure of the replay field of the hologram shown in Figure 1. Calculate the spacing of the first order peaks of the pattern generated. Assume the same parameters as in part (a). [40%]

(c) Explain how a hologram or grating can be used to control the wavelength of light in the replay field. Give two different applications where this function could be useful. [20%]

(d) Is it possible to use a hologram or grating to control both position and wavelength at the same time? Explain your conclusion. [10%]

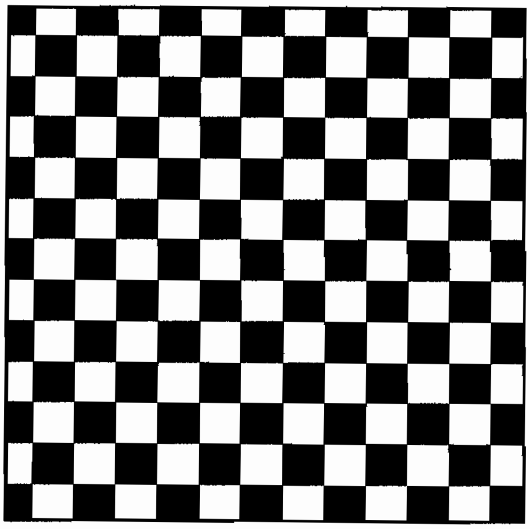

Figure 1. (black = +1, white = -1)

2 (a) Sketch the basic structure for a matched filter and explain its function given an input image *s(x,y)* and reference image *r(x,y)*. Explain how the effectiveness of the matched filter is evaluated and explain why it is not practical to implement such a system in the real world. [25%]

(b) Show how a binary phase only matched filter can be constructed using two transmissive spatial light modulators and explain how the filter is generated. What sort of technology could be used for the modulation function on each spatial light modulator? [25%]

(c) If both spatial light modulators are 256x256 devices with 40μm pixel pitch illuminated by a 633nm laser, derive and calculate the focal length of the Fourier transform lens. Why is this a limiting factor in the design of the binary phase only matched filter? [25%]

(d) Given the system designed in part b) suggest two possible ways of improving the size of the optical system. Describe the process of how the required optical elements would be selected for the better of the two designs. Estimate some typical figures which might generate a suitable solution. [25%]

3 (a) Sketch a diagram to show how a ferroelectric liquid crystal (FLC) can be used to create an intensity modulator. Assuming a FLC with a switching angle of θ and birefringence Δn, calculate the optimal conditions for intensity modulation for a pixel of thickness d at a wavelength of λ. [25%]

(b) Given the calculation made for the intensity modulation in part (a), what will the contrast ratio be for such an FLC modulator? Give three distinct reasons why this contrast ratio figure is never actually achieved in a real device. [20%]

(c) Show how a binary intensity modulator such as the one described in part (b) can be used to make a reconfigurable optical switch. Define the main function of the different components within the switch. [30%]

(d) How does the contrast ratio of the ferroelectric liquid crystal intensity modulator effect the overall performance of the optical switch of part (c)? What other performance parameter of the liquid crystal modulator is important in this switch architecture? Could you improve on a ferroelectric device? [25%]

4 Figure 2 shows the cross-sectional area of an optical waveguide with dimensions a by b. The electric and magnetic field components are given by:

$$\mathbf{E}(x,y,z,t) = \mathbf{i}E_x(x,y,z,t) + \mathbf{j}E_y(x,y,z,t) + \mathbf{k}E_z(x,y,z,t)$$
$$\mathbf{H}(x,y,z,t) = \mathbf{i}H_x(x,y,z,t) + \mathbf{j}H_y(x,y,z,t) + \mathbf{k}H_z(x,y,z,t)$$

(a) Briefly describe how you can obtain six equations relating the six components of the electric and magnetic fields that will be propagated along the waveguide. [10%]

(b) Show that for a long optimised waveguide that the following relationship can be generated,

$$-\gamma H_x - \frac{\partial H_z}{\partial x} = j\omega\varepsilon_0 n^2 E_y$$

where γ is the wave propagation constant, ε_0 is the permittivity of free space and n is the refractive index of the waveguide material. State any assumptions made. [50%]

(c) Explain what is meant by the terms TE and TM modes in the context of this waveguide structure. [15%]

(d) Sketch the two dimensional intensity profile in a cross section (x,y) of the waveguide shown in Figure 2 for the TE_{22} mode. Mark clearly the direction of the magnetic field vector. [25%]

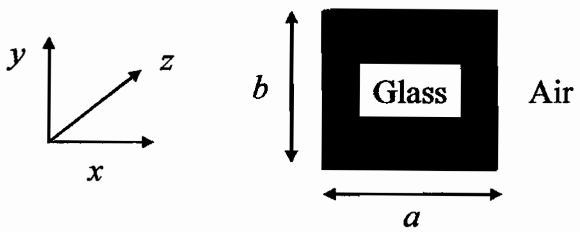

Figure 2.

END OF PAPER