ENGINEERING TRIPOS PART IIB

Thursday 22nd April 2010 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.

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

tdw03

1. (a) Show that for a single square aperture of dimension a and transmissive modulation A, the image formed in the far field (u, v) will have the form

$$F(u,v) = Aa^2 \text{sinc}(\pi a u)\text{sinc}(\pi a v) .$$

At what distance from the aperture do we know we have formed this image? [30%]

(b) Using the far field result for a square aperture derived in part (a), show with simple sketches how we can estimate the structure of the far field diffraction pattern for the aperture shown in Fig. 1. [30%]

Hence explain why the aperture shape is important to the structure of the far field diffraction pattern. [10%]

(c) Extend your analysis from part (b) to show what the replay field of a chequerboard structure displayed in binary phase on a spatial light modulator with square pixels would look like. Identify the key features in the resulting image. [30%]

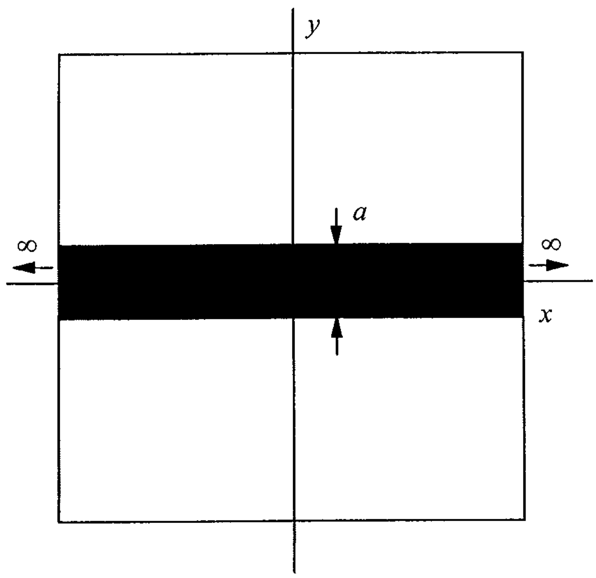

Fig. 1

2 (a) Explain what properties and structures of a ferroelectric liquid crystal (FLC) allow it to be used to modulate a coherent light source such as a laser. What sort of modulation can be achieved? Under what conditions will that modulation be restricted to purely binary states? [40%]

(b) Use Jones matrices analysis to show how an FLC can be used to generate binary phase modulation. What are the optimal parameters for the FLC cell to give maximum performance? [20%]

The Jones matrix for a generalised retarder with retardation Γ and orientation ψ, with respect to the y axis, is given by:

$$\begin{pmatrix} e^{-j\Gamma/2}\cos^2\theta + e^{j\Gamma/2}\sin^2\theta & -j\sin\left(\frac{\Gamma}{2}\right)\sin(2\theta) \\ -j\sin\left(\frac{\Gamma}{2}\right)\sin(2\theta) & e^{j\Gamma/2}\cos^2\theta + e^{-j\Gamma/2}\sin^2\theta \end{pmatrix}$$

(c) A transmissive FLC based spatial light modulator is to be designed for use in a 4 x 4 telecommunications single mode to single mode optical fibre switch. Sketch the layout of the switch identifying key components. How will the use of an FLC modulator limit the performance of the switch? [40%]

3 (a) Describe how a single binary phase hologram can be used to control different wavelengths from a coherent optical source. What is the main limitation of this technique in the context of a long distance telecommunications application? Suggest a technique that could be used to overcome this limitation and explain how it might be implemented. [40%]

(b) With the aid of a simple sketch, show how the concept outlined in (a) can be used to create a tuneable fibre laser suitable for use in a long distance telecommunications network. Explain the role of each element in the system and discuss the potential advantages of such a laser. [40%]

(c) Do you think it is possible to make a single computer generated hologram that is capable of manipulating both the spatial and wavelength properties of light simultaneously? Use the example of a combined wavelength and space switch in a long distance telecommunications network to illustrate your answer. [20%]

4 (a) Draw diagrams illustrating the results from an electromagnetic model of light propagation in a two dimensional slab waveguide which predicts the electric field amplitude variation across its thickness for the TE_0, TE_1, TE_2 and TE_3 optical modes. [20%]

(b) Explain what is meant by "intermodal dispersion" and how it occurs in optical fibres. Explain also why this cannot occur in fibres with a radius smaller than a critical value. Give three ways in which intermodal dispersion can be minimised. [20%]

(c) A multimode optical fibre has core radius 50 µm, core refractive index of 1.50 and a cladding refractive index of 1.51. By considering intermodal dispersion only, what is the maximum temporal pulse broadening (in seconds) that can result in this fibre after travelling a distance of 100 km. What is the maximum acceptable length over which data rates of 150 Mbits/s can be sent? [20%]

(d) Explain how bending the fibre of part (c) can give rise to further optical losses. What is the critical bending radius for this fibre? [25%]

(e) Briefly describe four other possible sources of loss in the fibre of part (c) [15%]

END OF PAPER