ENGINEERING TRIPOS PART IIB

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Thursday 27th April 2006 2.30 - 4.00pm

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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

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1. (a) Show that the far field diffraction pattern of the aperture of amplitude A, shown in Figure 1, is given by the following expression. State any assumptions made. [25%]

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

(b) Use a simple graphical technique to derive the far field diffraction pattern of a binary amplitude (A $\in$ [0,1]) grating. State any assumptions made and estimate the efficiency of light diffracted into the first order. [25%]

(c) Using the same technique as in part (b), show how the far field diffraction pattern for a binary amplitude grating can be used to derive the far field diffraction pattern for a binary phase (A $\in$ [-1, +1]) grating. Estimate the efficiency diffracted into the first order. [25%]

(d) Explain what features of the binary phase grating or hologram affect the shape of each spatial frequency element or spot within the far field diffraction pattern. Give two reasons why this is an important factor when using binary phase gratings to steer light into waveguide structures in a telecommunications optical switch. [25%]

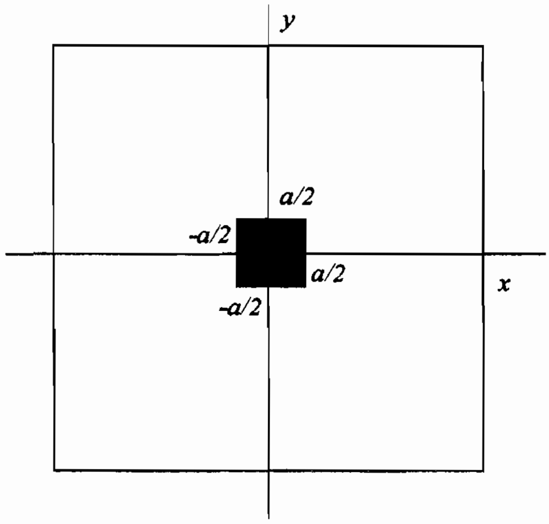


Figure 1. (The white area represents amplitude zero)

2 (a) Define the terms *retardance* and *birefringence* when referred to a liquid crystal material. What features of the liquid crystal material lead to these properties? [25%]

(b) Explain what is meant by the term surface stabilised chiral smectic C ferroelectric liquid crystal. What is the predominant feature of this class of materials and what are the switching characteristics you would expect to see in a device made with this material? [25%]

(c) A generalised Jones matrix for a waveplate at an angle $\psi$ to the vertical axis and retardance $\Gamma$ is given below. Show how a surface stabilised ferroelectric liquid crystal (FLC) pixel, with a switching angle of $\theta$, can be configured to perform binary phase modulation. Show that it is independent of $\psi$, $\Gamma$ and $\theta$. [25%]

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

(d) Explain why a normal planar aligned nematic liquid crystal material is inherently polarisation dependant. Is this also the case for a surface stabilised FLC material? [25%]

3 (a) Sketch the general functional layout of a full joint transform correlator (JTC). Explain what each component is for and how it is implemented optically. Using this functional layout, show how the principle of correlation occurs assuming a square-law non-linearity. [25%]

(b) Why is the structure of the non-linearity so important to the operation of the JTC? Describe two ways in which this non-linearity can be implemented using liquid crystal technology. [30%]

(c) What is the main limitation of this form of JTC? How can the symmetry of the optical system in part (a) be exploited to simplify the overall JTC architecture? What are the technological implications of this change? [30%]

(d) Explain briefly how a JTC could be used to implement a complex image processing task such as motion estimation of objects moving between video frames. [15%]

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4 (a) Explain, with the aid of sketches, what is mean by the terms *fan out* and *fan in* when applied to a shutter based optical switch. [25%]

(b) Sketch the basic structure of an *n* input to *n* output optical switch based on shutters or shadow logic. Define each optical component in the system and define the relationship between the number of input ports and the number of shutters required. [25%]

(c) Discuss what are the main two limits to the scalability of such a shutter-based optical switch. How important is the shutter switching speed? Name two suitable technologies which could be used for this shutter. What are their limitations? [25%]

(d) If this shutter based switch were to be used as a packet switch, then it must be capable of allowing multiple input channels to be switched to a single output channel. How could the structure of part (b) be modified to allow this? What are the repercussions on the shutter technology? [25%]

**END OF PAPER**