ENGINEERING TRIPOS PART IIB

Thursday 28 April 2011 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

1. (a) An aperture, as depicted in Fig. 1, is illuminated with a collimated light source. Using the principles of wave propagation and diffraction, describe what will happen to the light a short distance along the z axis after the aperture plane [x, y]. Clearly state any assumptions made. [20%]

(b) Using the aperture and axes as defined in Fig.1, show how the principles of wave propagation and diffraction can be used, with suitable approximations, to prove that the far field diffraction pattern of the aperture function $A(x,y)$ is the Fourier transform of the aperture function. [30%]

(c) If the aperture was square shaped, then an array of such apertures can be arranged to form a hologram. Explain how the original aperture shape and size dictates the structure of the far field diffraction pattern of such a hologram. [30%]

(d) A hologram generated from such an array of square apertures will inevitably have unwanted and lossy repetitions of the central order. Give two ways in which the structure of the hologram might be altered in order to minimise the generation of these repetitions. [20%]

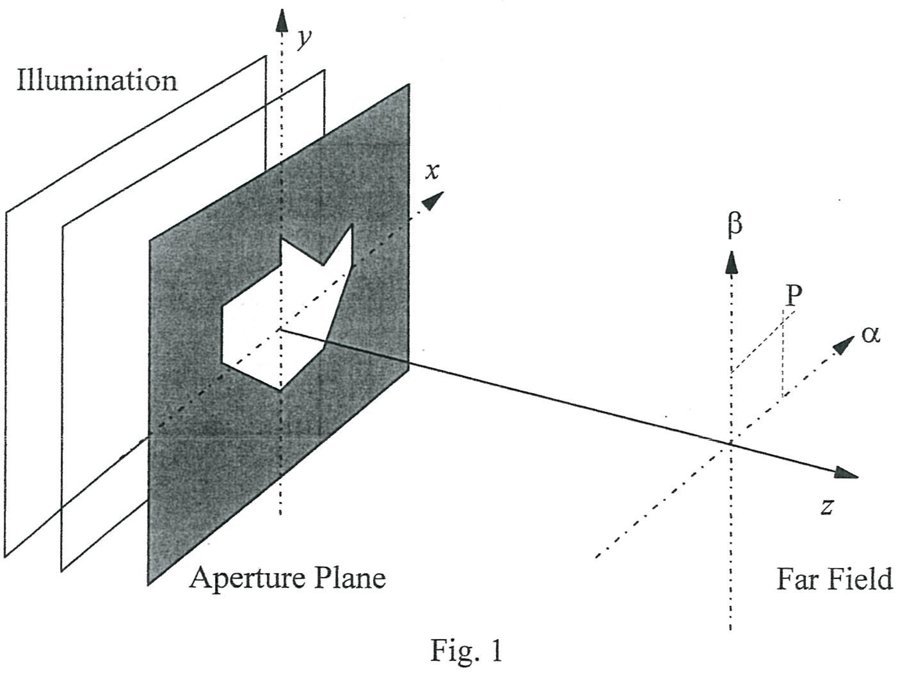

Fig. 1

2 (a) Explain how a computer generated hologram (CGH) and a lens can be used to form a replay field. Discuss the scaling of the replay field compared to pure diffraction and comment on the role of the modulation technology used to implement the CGH. [30%]

(b) A CGH is to be created to generate the replay field shown in Fig. 2. Each line is 200x2 pixels with an amplitude of unity. The resolution of the hologram is to be 512x512 pixels. Identify two different technologies that can be used to generate this replay field and sketch the target function required to calculate the CGH. [20%]

(c) The CGH in part (b) is to be fabricated with a pixel pitch of 5μm and illuminated with a 532 nm Nd:YAG laser. The replay field is then generated using a 100mm focal length singlet lens. Calculate the actual spacing of the lines in the replay field for $d = 100$ and $d = 101$ pixels, stating any assumptions made. [20%]

(d) Upon testing the CGH it was realised that the quality of the actual replay field generated experimentally was very different to that predicted. Give three reasons why this might happen and suggest possible ways to correct these problems. [30%]

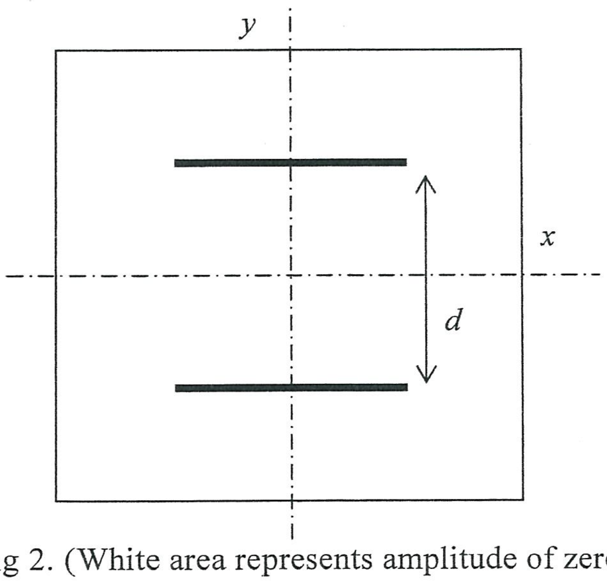

Fig 2. (White area represents amplitude of zero)

3 (a) Describe, with the aid of a suitable diagram, how two liquid crystal spatial light modulators (SLMs) can be used to create a matched filter. Identify clearly all of the elements in the system. What is the optimal function for this filter, assuming it is to be used for optical image recognition? [40%]

(b) Explain why the matched filter described in part (a) is very difficult to implement using liquid crystal technology. What sort of compromises have to be made in order to allow a ferroelectric liquid crystal (FLC) SLM to be used as a suitable filter? [40%]

(c) The matched filter is to be built using two identical FLC over silicon SLMs. Sketch a practical layout for the system and identify any modifications required by this SLM technology. What factors must be considered when choosing suitable lenses for this matched filter? [20%]

4 A company has a private and direct high-speed optical data connection to one of its clients, who are based at a different location 100 km away. The connection consists of a monomode optical fibre with a core radius of 15 μm, core index of 1.500, and a cladding index of 1.499.

(a) Describe the possible sources of dispersion in the fibre, and how this limits the maximum bit rate capable of being sent down the fibre by time-division multiplexing. [25%]

(b) Ignoring other losses in the fibre, how many secure documents (each of 1 MByte file size) can the company send to its client in 1 hour? [15%]

(c) Explain how a competitor might be able to steal data by bending the optical fibre at some point along its length. Calculate the critical radius R_C for the fibre. [20%]

(d) In a controlled experiment, it was measured that a 50% loss in optical power occurred when the fibre was wound 10 times around a rod with a radius of 10 cm. Calculate what percentage loss in optical power would be observed if the company's competitor bent the fibre through a 90° bend at a radius of 7 cm in order to steal data. [40%]

END OF PAPER