Version TDW/3

EGT3
ENGINEERING TRIPOS PART IIB

Wednesday 23 April 2014 9.30 to 11

Module 4B20

DISPLAY TECHNOLOGY

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.*

Write your candidate number ***not*** *your name on the cover sheet.*

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed
Engineering Data Book

You may not start to read the questions printed on the subsequent pages of this question paper until instructed to do so.

1 (a) Liquid crystal displays (LCDs) and many other optical systems can be expressed using Jones matrices. Define (using suitable variables) the basic structure of a Jones matrix for linearly polarised light and then show how it can be enhanced for circularly polarised light. Using their respective Jones matrices, define the optical function of a half waveplate (with its extraordinary axis parallel to the *y* axis) and a vertical linear polarisor. [30%]

(b) Using the same Jones matrices defined in part (a), calculate the transmitted amplitude of a vertically polarised light beam which is normally incident upon a half waveplate which is between a vertical and a horizontal pair of linear polarisors. The waveplate extraordinary axis is set at 45^{o} relative to the *y* axis. Sketch the overall optical system and show the changes in polarisation state as the light passes through each element. [25%]

(c) When designing a new type of LCD, one of the most difficult parameters to control is the viewing angle of the display. Explain how Jones matrices can be used to help solve this problem. How would a Jones matrix, such as that used for a half waveplate, be modified to compensate for light passing through it at different angles? How can this be used to generate an isocontrast map for the LCD? [25%]

(d) What other optical analysis technique might be useful for calculating the viewing angle of an LCD? Explain how this technique might also be used to compensate for other undesirable viewing characteristics. [20%]

2 (a) One of the biggest evolutionary steps in the liquid crystal display (LCD) industry was the twisted nematic (TN) pixel structure. Sketch the overall structure of a TN showing the liquid crystal molecular alignment in the on and off states. Explain how this structure can be used to create contrast in the TN LCD and explain why this structure was so much better than previous LCD electro-optical effects. [30%]

(b) One of the ways of enhancing the performance of the TN LCD is to increase the twisting element to create the supertwist nematic (STN) pixel structure. Using sketches of the transmission versus voltage curves for the TN and STN pixels, explain what improvement is gained by the extra twist and the relevance of the Alt-Pleshko limit. What are the main drawbacks of the STN architecture in a LCD? [25%]

(c) A further improvement on both the TN and STN LCD was the development of the vertically aligned nematic (VAN) architecture. Explain the basic structure of this architecture and how it impacts the choice of liquid crystal material. [25%]

(d) One of the key parameters in the performance of a modern LCD, which has evolved from the TN to the VAN, is the response time of the liquid crystal electro-optical effect. Why is this response time so critical to the performance of the LCD? List two possible applications where further enhancement in response time is required. [20%]

3 (a) Describe the two main matrix addressing schemes for organic light emitting diode (OLED) displays. Highlight clearly the operating principle of each scheme and discuss their relative strengths and weaknesses. [25%]

(b) Briefly explain the pixel design and architectural considerations for high-resolution, stable OLED displays and how they differ from a traditional liquid crystal pixel design. [25%]

(c) Explain what is meant by the gate overdrive voltage in an OLED display backplane and describe how it accounts for the threshold voltage shift.

With the aid of sketches, show how the overdrive voltage depends on the efficiency of the OLED. [25%]

(d) Tabulate the benefits and trade-offs of placing the OLED in the source or drain of the drive thin film transistor (TFT) for both top and bottom emission architectures. [25%]

4 (a) One of the most successful technologies in the projection displays market is the digital micromirror device (DMD) from Texas Instruments. Sketch the basic pixel structure of this device and explain how it can be used to modulate incident light. What is the main limitation of this technology? [30%]

(b) How can the limitation in part (a) be rectified in order to produce greyscale images? Are there any drawbacks with the use of this technique when displaying colour images? Explain your answer carefully in terms of the human visual system. [30%]

(c) One of the most popular methods of generating colour images within a DMD based single chip projector is to use a colour wheel. Use a simple sketch of the projector to show where the colour wheel would be located. What is the DMD frame rate and colour wheel rotation speed required to project a 50Hz frame rate, 8 bit greyscale colour video using a RGBRB colour wheel? [20%]

(d) What modifications would be required to convert a DMD based single chip projector into a three dimensional cinema system, viewed with passive glasses? How would this modification affect the operation of the colour wheel? [20%]

END OF PAPER

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