The Zenithal Bistable Device: A Liquid Crystal Display with Ultra-Low Power Consumption

Dr. C. Jones
(DERA , UK)

A Satellite Forum of ILCC 2000

ASET International Forum on Low Power Displays

July 21, 2000
KOKUYO Hall
Shinagawa, Tokyo, JAPAN

The Zenithal Bistable Device: A liquid crystal display with ultra-low power consumption

J. Cliff Jones, Alistair Graham, Guy Bryan-Brown, Emma Wood, Pete Brett

Defence Evaluation and Research Agency (DERA), St. Andrews Rd., Malvern, Worcestershire, U.K.

INTRODUCTION

The growth in use of portable electronic devices has been substantial over the past decade, driven largely by the mobile telecommunications and personal digital assistant markets. Coupled with this growth has been an increasing demand for higher levels of displayed information, without a concomitant increase in display power budget. The usual choice for such applications is the Supertwist nematic (STN) liquid crystal display, due to its low cost and reasonable degree of complexity. The type of reflective mode display presently used in mobile phones has a typical power consumption of about 0.15mW (for a 1.7” diagonal 60×24 pixel STN). The power increases with higher levels of complexity and display size; for example, a 4” diagonal 320×200 STN typically consumes about 3mW. This relationship between power and complexity proves restrictive for products such as the electronic book, where battery life is limited to several hours. In the near future, yet greater complexity will be required in products which combine the functions of the mobile phone, palm-top computer and electronic book. Display power will be a major issue for such applications.

Other important criteria for displays in portable products are weight and durability. Of course there is an indirect weight reduction associated with the battery required for low power devices. However, the greatest improvements envisaged presently is through the use of plastic substrates. As well as reducing weight significantly, this will also aid device durability significantly.

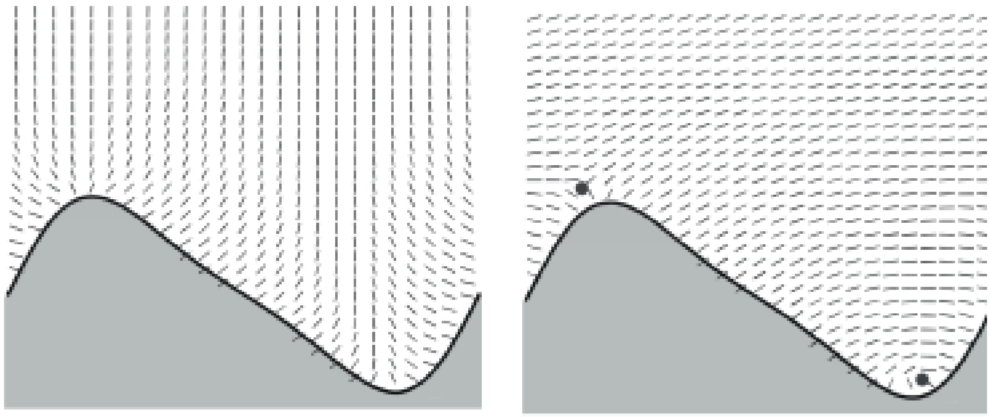
At present, much research effort is dedicated for display products that provide the attractive appearance and high degree of complexity, whilst minimising power consumption. Recently [1], highly reflective LCDs have begun to be used in portable products (eg electronic games). These combine thin film transistor (TFT) addressing to achieve the high levels of complexity, with a carefully designed micro-relief internal reflector to provide efficient usage of the ambient light. This type of device is sufficiently reflective to allow full colour operation using conventional colour filters. However, even for a 42 diagonal display the power consumption can be as high as 50mW. The use of thin film transistors is also relatively expensive and difficult to produce with plastic substrates.

THE ZENITHAL BISTABLE DEVICE, ZBD.

The approach taken in the present work is to use a novel bistable nematic displays based on grating alignment layers which is called zenithal bistable display, or ZBD™ [2]. As with other bistable liquid crystal technologies, this approach has two main advantages. Unlimited complexity is possible using passive, line-at-a-time addressing which is achieved without the need for costly, non-linear elements (such as the TFT) at each pixel. Also, the display effectively stores the image and only requires electrical input when the image changes. For applications which require infrequent updating, such as written information, this is a far more efficient method of addressing than the conventional LCD where the signal is needed constantly.

Where ZBD differs from other bistable liquid crystals is that it is based on a bistable surface alignment of the liquid crystal molecules. This leads to a number of advantages. The image is insensitive to variations of the panel, such as those caused by mechanical shock or due to temperature and cell gap changes. It also means that bistability can be added as a function to a variety of LCD geometries. For example, different properties are possible using different mono-stable surfaces opposite the bistable surface [2 – 5]. The use of gratings to achieve bistable surface alignment allows simple manufacturing techniques to be employed such as embossing. Such methods are particularly suited for fabrication of devices with plastic substrates. The control that gratings offer also allows the switching properties within each pixel to be varied readily, thereby providing a simple method for greyscale [3].

An example of a ZBD surface is a mono-grating of suitable pitch and amplitude coated with a homeotropic layer to give two stable states with differing pre-tilts in the same azimuthal plane, as shown in figure 1. A typical grating has a pitch of about 1.0μm and an amplitude of 0.8μm. Common to all liquid crystal materials is a flexoelectric polarisation caused by the elastic deformation of the liquid crystal close to the grating surface. This allows electrical pulses of opposite polarity to latch between the high and low tilt alignment states..

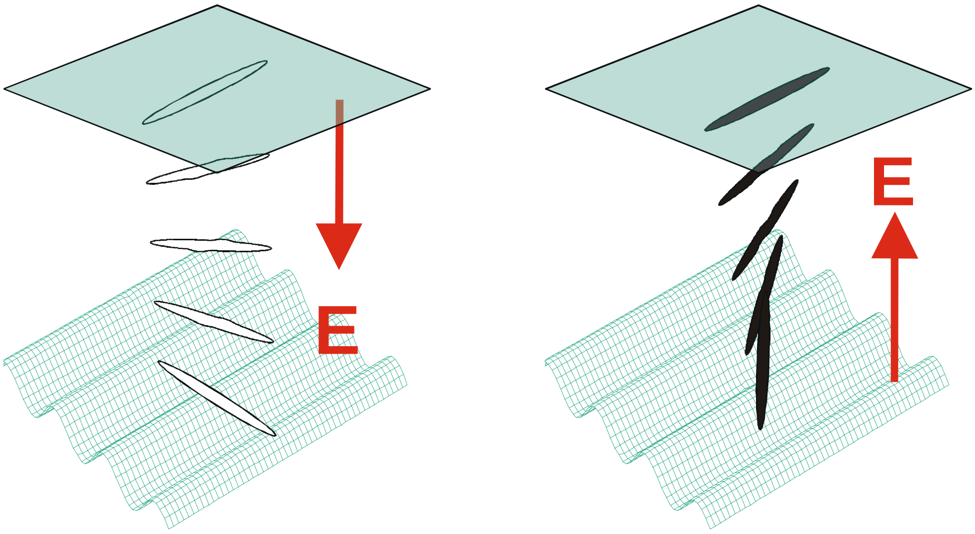


continuous state *defect state*

Figure 1: Theoretical director profiles close to a ZBD™ grating

Previously, the ZBD surface has been used opposite a simple homeotropic surface [2]. The bistable surface director configurations of figure 1 then lead to a vertical aligned nematic for the high tilt continuous state and hybrid aligned for the low tilt defect state. Such a device is very insensitive to variations of cell gap, but it requires additional optical compensation layers to achieve a wide angle of view in both vertical and horizontal viewing quadrants. Improved optical performance may be achieved using the grating opposite a rubbed polymer alignment so that in the defect state the configuration is that of a twisted nematic, whereas the continuous state has hybrid alignment, figure 2.

Between parallel polarisers these states appear black and white, respectively. This geometry retains the attractive properties previously reported for ZBD, but ensures excellent appearance in either transmissive of reflective configurations.



Twisted Nematic (Black) *Hybrid Aligned (White)*

Figure 2: *New ZBD™ Configuration.*

Figure 3 is a photograph of a reflective demonstrator of the type that might be suited for application in a mobile phone, together with the performance characteristics listed in Table 1. The panel was addressed using simple bi-polar strobe and data waveforms, in which the pixel image is dependent on the magnitude and polarity of the trailing pulse. Typical voltages required were 24V strobe (V_S) and 4V data (V_d), although significantly lower voltages have been achieved in test cells. This leads to an energy requirement for a single image update of less than 4μJ. If the image requires constant updating the power consumption would be similar to that of an STN panel. However, substantial power savings are possible where the image is updated infrequently, with images written 2 years ago still remaining unchanged on test cells in our laboratory.

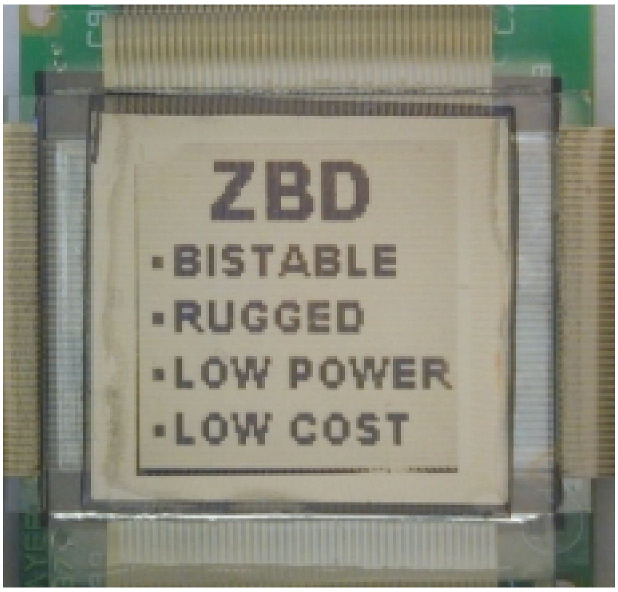


Figure 3: *Photograph of the un-powered 2” diagonal 90 × 83 reflective ZBD.*

Size	2cm × 2cm
Complexity	90 × 83
Addressing	$24V_S \pm 4V_d$
Contrast	Pixel: 40 : 1 Panel: 15 : 1
Reflectivity	150% that of commercial STN
Frame time	60ms
Update energy	4 μJ
AA battery life at 1Hz update (including driver power)	≈ 1000 hour
Image storage	> 2 years

Table 1: Performance of ZBD™ Demonstrator

The addressing window is shown in figure 4. This illustrates that faster operation is possible by increasing the magnitude of the strobe voltage, for example to avoid flicker during update for complex images. Line address times of 40μs has been achieved with 35V pulses. This need not be too costly in terms of power consumption which is dominated by the data voltage through terms in V_d^2/τ (where τ is the line address time). Multiplexing data as low as 2V is possible, allowing exceptionally low power even for images with continuous update, although the addressing window is then narrowed. Figure 4 shows that a wide addressing window is possible for data voltages available with standard STN driving circuitry. Such wide operating conditions allows the same waveform to be used for a range of temperatures, or local variations. For applications that require low voltage addressing, 10ms line address times occur with 10V strobe pulses.

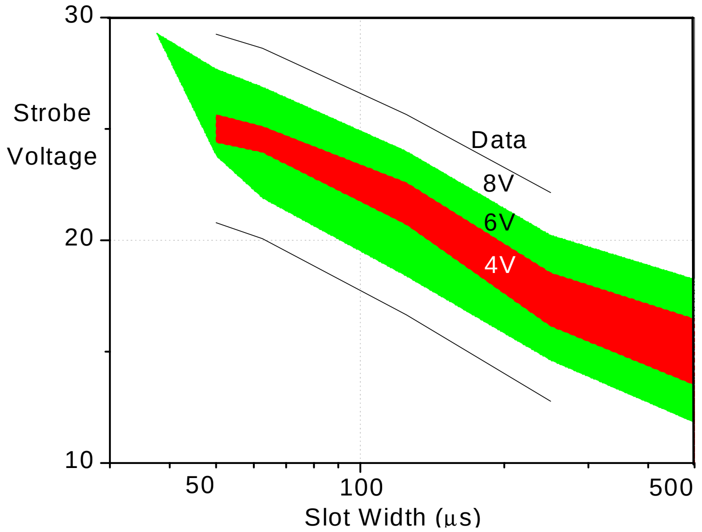


Figure 4: Multiplex addressing window for different levels of strobe for the ZBD demonstrator operating at 25°C.

CONCLUSIONS

Increasing display complexity in portable products will necessitate dramatic improvements to power consumption without compromising image quality. Not only is this possible with ZBD, but the technology is readily adaptable to manufacture with plastic substrates at relatively low cost. Such devices represent an exciting opportunity for future display markets.

REFERENCES

1. Y. Itoh, S. Fujiwara, N. Kimura, S. Mizushima, F. Funada and M. Hijikigawa, (1998) “Influence of rough surface on the optical characteristics of reflective LCD with polarizer” SID 98 Digest, p221 – 224.
2. G.P Bryan-Brown, C.V. Brown, J.C. Jones, E.L Wood, I.C. Sage, P. Brett and J. Rudin, (1997) “Grating aligned bistable nematic device”, *Proceedings of SID 97*, **28**, pp37-40, Boston.
3. J.C. Jones, E. L. Wood, G.P. Bryan-Brown and V.C. Hui, (1998) “Novel configuration of the zenithal bistable nematic liquid crystal device”, *Proceedings of SID 98*, **29**, pp858-861, Anaheim, 1998
4. G.P. Bryan-Brown, E.L. Wood and J.C. Jones, (1998) “Optimisation of the zenithal bistable nematic liquid crystal device (ZBD)”, *Procceedings of the 18th International Displays Research Conference, Asia Display 98*, 33.3, pp1051-1054, Seoul.
5. J.C. Jones, G. P. Bryan-Brown, E.L. Wood, P.Brett, A. Graham and J.R. Hughes (2000) “Novel Bistable Liquid Crystal Displays Based on Grating Alignment”, *Proceedings of SPIE*, **3955**, 84 – 93.
6. E.L. Wood, G.P. Bryan-Brown, P. Brett, A. Graham, J.C. Jones and J.R. Hughes (2000) “A zenithal bistable device suitable for portable applications”, *Proceedings of SID 2000.* **31**, 11.2, p124 – 127.

Correspondence: Email: jcjones@dera.gov.uk; Telephone: +44 1684 895353; Fax +44 1684 896530