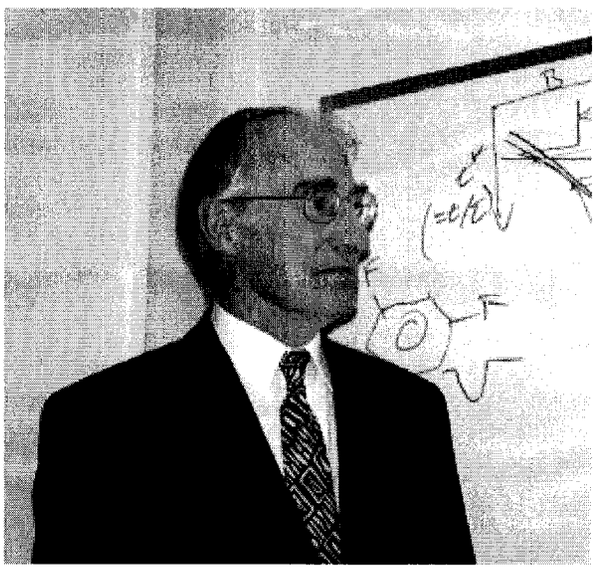
BRITISH LIQUID CRYSTAL SOCIETY

LIQUID CRYSTAL NEWS

October 2002

GW Gray Medal for 2002
Geoffrey Luckhurst



Geoffrey has spent almost 40 years researching into liquid crystalline systems, and to summarise such a long, and very productive career is difficult, but it is not too misleading to say that he has striven to understand the properties of liquid crystals in terms of what the molecules are doing.

He was introduced to liquid crystals when he was an undergraduate at the University of Hull by George Gray, and that of course is true for many chemists, most of whom went on to be involved in the synthesis of new liquid crystals, or moved into the newly developing display field. This was not the path chosen by Geoffrey. He chose to do postgraduate work in Cambridge in the Department of Theoretical Chemistry. This was lead by Christopher Longuet-Higgins and contained not only theorists, but also what are best described as Chemical Physicists. Geoffrey, after his first research supervisor decided to give up chemistry, studied with Alan Carrington, who was pioneering the applications of electron spin resonance (ESR) to problems in Chemistry. Together they published the first paper on the study of a liquid crystalline system using ESR spectroscopy.

On obtaining his Ph.D Geoffrey left Cambridge to spend two years working for Varian in Zurich as an applications scientist, a position which enabled him to interact internationally with many other scientists, and also to develop a taste for good food, and smart suits. In 1967 Alan Carrington moved to Southampton as Professor of Chemical Physics, and he persuaded Geoffrey to take up a lectureship there. Geoffrey established an ESR laboratory and began his seminal studies on liquid crystals using this powerful technique. His early work included showing how both the order parameters $\langle P_2 \rangle$ and $\langle P_4 \rangle$ could be extracted from ESR spectra of free radical probes dissolved in the liquid crystals, and to understand the values obtained he embarked on the development of molecular field theories of orientational order, and also of phase stability. One other notable early development was to show how ESR studies could shed light on the behaviour of the liquid crystal director when a nematic sample is rotated about an axis perpendicular to the magnetic field of the ESR spectrometer. This foreshadowed similar studies by NMR on deuteriated liquid crystals, which have continued to this day, and which have been extended recently to include the alignment behaviour of smectic A phases in magnetic and combined electric and magnetic fields. These studies have revealed a host of new phenomena, and have stimulated the combined use of NMR and X-ray synchrotron experiments to follow director dynamics in smectic A systems.

A defining feature of Geoffrey's work has been the combination of experiment and theory to enhance our understanding of liquid crystalline behaviour. Thus, he has been involved with the development of molecular field theories on biaxial molecules in liquid crystalline phases, and with the measurement of the biaxial order parameters for rigid solutes dissolved in mesophases. Liquid crystalline molecules are almost invariably flexible by virtue of intramolecular motion, and Geoffrey has been at the forefront of the development of molecular field theories to describe the effects of such flexibility on orientational order, and on phase stability, and the confrontation of such theories by deuterium NMR studies. As computers became more powerful it became obvious to Geoffrey that computer simulation would become one of the main ways of understanding liquid crystalline behaviour. He pioneered such studies and in particular he has demonstrated the power of the Gay-Berne model system to understand, in a generic sense, the connection between the strength of the inter-particle forces and phase stability and properties.

The theoretical and experimental work on flexibility and liquid crystal behaviour lead Geoffrey to start a program synthesizing mesogens whose structure would demonstrate the

importance of molecular shape and internal motion. The first idea was to synthesize the series of cyanobiphenyl dimers, in which the aromatic parts are linked by a central, flexible, alkyloxy chain. This lead immediately to some fascinating nematic, liquid crystalline systems, which show a very strong variation in their nematic-to-isotropic transition temperatures as the central chain length is increased. The orientational order of these cyanobiphenyl dimers was also measured by incorporating deuterium in the aromatic cores, and for some cases using a perdeuteriated central chain. Both the order parameters, and the transitional properties, such as the changes in entropy, were shown to be entirely in accord with the predictions of relatively simple, molecular theories. The synthetic program was expanded to include asymmetric dimers, such as those with a cyanobiphenyl group linked to an alkylanilinebenzylidene group. These show nematic and smectic phases. In some cases SmA phases are produced in which the layer spacing is approximately one half of a molecular length. This unusual spacing was interpreted as being the result of an intercalated structure. The synthetic program stimulated both theoretical investigations, and the development of models for computer simulations. A perfect example of the relationship between experiment and theory which characterises Geoffrey's research.

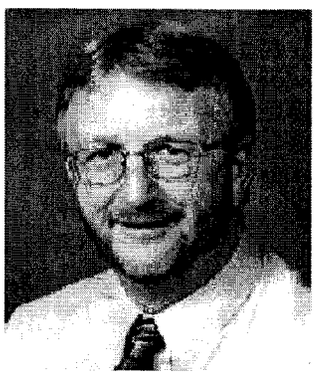
A portrait of Geoffrey would not be complete without a mention of his contributions to the Liquid Crystal literature. He spent a four years as editor of Molecular Physics, and the experience gained by doing this task stood him in good stead when he persuaded the publishers of this well-established, and prestigious Journal, Taylor & Francis, to produce the periodical Liquid Crystals. Geoffrey and Ed Samulski were the first editors, and they established this as the premier Journal serving the liquid crystal community.

Geoffrey was one of the founders of the British Liquid Crystal Group, the immediate forerunner of the BLCS, and he has been a staunch supporter of it's various activities over the years. He served as Chairman of the Society from 1996 to 2000, and it was during this period that he suggested that the George Gray medal should be inaugurated to mark the award to George of the Kyoto Prize. The medal is awarded to recognize distinguished contributions to liquid crystal science.

The award of the medal to him this year is certainly entirely in accord with the distinguished scientists who have received the medal in the 6 years since he was responsible for it's creation.

Professor J.W.Emsley
Department of Chemistry
University of Southampton

Prof. John Goodby awarded Tilden Lectureship



Professor John Goodby of Hull University has been awarded a Tilden Lectureship by the Royal Society of Chemistry for his research into ferroelectric and antiferroelectric liquid crystals for display applications and for his research into the self-organisation of glycolipids.

The Tilden Lectureships were founded in 1939 in memory of Sir William Augustus Tilden, President of the Society from 1903 to 1905. It is awarded annually to three of the younger members of the Society and the lectures should deal with progress in some branch of chemistry. A silver medal and an honorarium of £500 is awarded. The winners for 2002/2003 are Professors A. P. Davis, J. W. Goodby and P. A. Tasker.

The Tilden Symposium centered on John's research will be held at the Department of Chemistry, Oxford University on the 7th of October. Further lectures will be given throughout the year and can be found on the RSC website.

More information can be found at
http://www.RSC.org/lap/awards/endowed.htm

BLCS Young Scientist Lecture 2001

Importance of Quadrupolar Ordering in the Switching Properties of Hysteretic and Thresholdless Antiferroelectric Liquid Crystals

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We present a model of antiferroelectric liquid crystals that explains a number of phenomena observed in their switching properties. These include the pretransitional effect, the thresholded transitions between the antiferroelectric and ferroelectric states, the frequency dependence of the hysteresis loop and the origin of the v-shaped switching observed in some antiferroelectric materials. The role of the quadrupolar interaction between adjacent smectic layers is found to be key in explaining several of these observed characteristics in AFLCs.

INTRODUCTION

Antiferroelectric liquid crystals (AFLCs) [1-5] are smectic liquid crystals in which the director is at a fixed angle, θ to the layer normal. The projection of the director onto the smectic layers is known as the c-director, and is defined by an azimuthal angle, ϕ. The interlayer interaction causes the c-directors of adjacent layers to be almost anti-parallel, the discrepancy being caused by the chirality of the molecules, and giving rise to a macroscopic helical structure. Each layer has C_2 symmetry, and hence a spontaneous polarisation along the C_2 axis (perpendicular to the layer normal and c-director). In the ground state there is no net polarisation due to the anticlinic ordering between adjacent layers. For sufficiently high electric field applied along the smectic layers, all the individual layer polarisations align with each other and the field, forming the ferroelectric state. This field induced phase transition from the antiferroelectric (AF) state to the ferroelectric state (F) is thresholded, indicating a first order phase transition. The range of fields below the threshold is known as the 'pretransitional regime'.

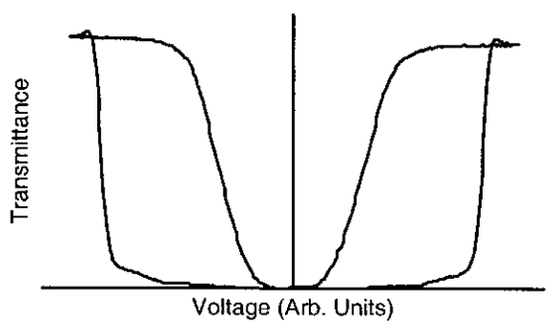

Figure 1. Typical quasistatic hysteresis loop of an AFLC at room temperature

Figure 1 shows the transmittance of a planar aligned antiferroelectric liquid crystal device between crossed polarisers (with one polariser along the smectic layers) as a function of applied voltage. It is clear that there is a small amount of light leakage of the antiferroelectric state in the pretransitional regime. The origin of the pretransitional effect, and of the thresholded nature of the subsequent AF to F transition is discussed in this paper. A model of the influence of defect seeded domain switching on the shape of the hysteresis loop and its frequency dependence is also presented. Finally an explanation for the formation of the twisted ferroelectric state in so-called thresholdless antiferroelectric devices is hypothesised.

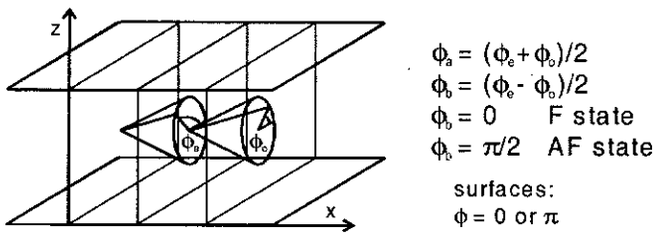

Figure 2. Geometry of the AFLC theoretical model

Theoretical Model

Throughout this work, a one-dimensional theoretical model is used, the geometry of which is illustrated in Figure 2. ϕ_e and ϕ_o are the azimuthal angles of the c-directors in adjacent layers. However, it is more convenient to use instead the angles ϕ_a and ϕ_b, where:

$$\phi_a = \frac{\phi_e + \phi_o}{2} \quad \text{and}$$

$$\phi_b = \frac{\phi_e - \phi_o}{2}.$$

so that ϕ_a represents the local average azimuthal angle, and ϕ_b the type of ordering present ($\phi_b = 0$ for the F state, $\phi_b = \pi/2$ for AF state). A generalised expression for the free energy (of a pair of smectic layers) that has been used for the modelling is as follows:

$$F = -EP_s \cos\phi_a \cos\phi_b + \frac{K_x}{2}\left(\frac{\partial\phi_a}{\partial x} - \frac{2\pi}{p}\right)^2 + \frac{K_z}{2}\left(\frac{\partial\phi_a}{\partial z}\right)^2 + \frac{K_z}{2}\left(\frac{\partial\phi_b}{\partial z}\right)^2$$
$$+\Gamma\cos^2\phi_b - \Delta\cos^2 2\phi_b.$$

E is the electric field applied across the smectic layers, P_s is the spontaneous polarisation of each layer, K_x and K_z are the interlayer and intralayer elastic constants, and Γ and Δ are the coefficients of the dipolar and quadrupolar components of the interlayer interaction energy, respectively. The first term of the expression represents the interaction of the electric field with the spontaneous polarisations in the two layers, and the final term is the interlayer interaction between the directors in adjacent layers. In order for anticlinic ordering to be preferred over synclinic ordering, Γ must be positive. The other terms represent the elastic energy stored in distortions along the helical axis and across the device thickness. In order to reduce the problem from two dimensions to one, the limiting cases of very thin and very thick devices are considered. This means that elastic terms acting in one direction only need be considered at any one time. For very thick devices, where the helical structure is present and the influence of the surfaces is very weak, the third and fourth terms are ignored, and only variations along the helical axis, x, are considered. Alternatively, for very thin devices where the helical structure is suppressed and the influence of the surface boundary conditions is very important, the second term is ignored, and only variations in ϕ_a and ϕ_b along the z axis are considered.

Supporting Experiments

The results of the theoretical modelling are supported by experimental results on planar aligned devices filled with the commercial AFLC mixture CS4001. The mixture has a pitch of 2.8 microns and forms surface stabilised and helical structures in the 1μm and 10μm devices used, respectively.

PRETRANSITIONAL EFFECT IN HELICAL DEVICES

The pretransitional regime in 10μm (helical) CS4001 devices has been investigated and the details are reported elsewhere [6]. The helical structure was observed to switch by finger-like domain growth along the smectic layers to a non-helical state of greater birefringence and dielectric permittivity within the pretransitional regime, before undergoing switching to the ferroelectric state. The unwound state is deduced to be an antiferroelectric state in which the directors are approximately in the plane of the applied field [7]. By using the theoretical model, the reason for the destruction of the helix is revealed. The applied field causes a small change in the local antiferroelectric ordering (i.e. ϕ_b) within the helical structure, which results in a net polarisation along the local c-directors. This polarisation then interacts with the applied field, the torque rotating the directors towards lying in the plane of the applied field, thus distorting the helix. Above a critical field:

$$E_{critical} = \frac{\sqrt{182.4K_x(\Gamma + 4\Delta)}}{P_s p}, \qquad [1]$$

the energy of the completely unwound AF state (the vertical AF or VAF state) is lower than that of the distorted helical structure, and switching from one to the other occurs via defect seeded domain growth, as observed experimentally.

AF TO F TRANSITION

If the theoretical model outlined above is applied at higher electric fields beyond the pretransitional regime, the VAF state undergoes switching to the ferroelectric state. The nature of the transition (that is, whether it is thresholdless or hysteretic) is found, by using the model, to depend on the ratio of the quadrupolar to dipolar ordering coefficients, Δ/Γ, as illustrated by Figure 3.

When the ratio of the quadrupolar and dipolar coefficients is very low, ($\Delta/\Gamma < 1/20$), the system is monostable for all applied fields (Figure 3(a)), and therefore the switching from the AF to the F state occurs continuously and thresholdlessly (Figure 3(b)). However, when $\Delta/\Gamma > 1/20$, there is a region of bistablity (Figure 3(c)), and therefore the system exhibits thresholded hysteresis (Figure 3(d)). The parameters Δ and Γ have been measured in the AFLC mixture CS4001 [8], and the ratio determined to be 0.67, i.e. in the regime of bistability. In fact, the theory predicts that for values of $\Delta/\Gamma > 0.5$, the ferroelectric state is a local energy minimum state for all applied fields, although it is not the global energy minimum below the holding voltage. This would mean that in an ideal system, once primed into the ferroelectric state, the device should in theory remain ferroelectric, and simply undergo direct F^+ to F^- switching around the smectic cone as the electric field changes sign. This is inconsistent with experimental observations of the switching behaviour of antiferroelectric liquid crystals, which exhibit thresholded hysteresis, as in Figure 1. This is due to the presence of defects and thermal fluctuations in the cell, which can seed domain switching to the lowest energy state. Therefore, in order to have a complete description of switching in antiferroelectric liquid crystals, it is necessary to incorporate the possibility of defect seeded domain switching into the theoretical model.

DOMAIN SWITCHING

In order to model the domain switching between the antiferroelectric and ferroelectric states, some very simple assumptions about the nucleation and growth of domains are made. A triangular waveform is considered, so that the slew rate of the electric field is always of the same magnitude. As the field increases above zero, the cell remains in the antiferroelectric state until the holding field, $E_{holding}$, at which the AF and F states are equal in energy, is reached. Beyond that, defect seeded domain switching to

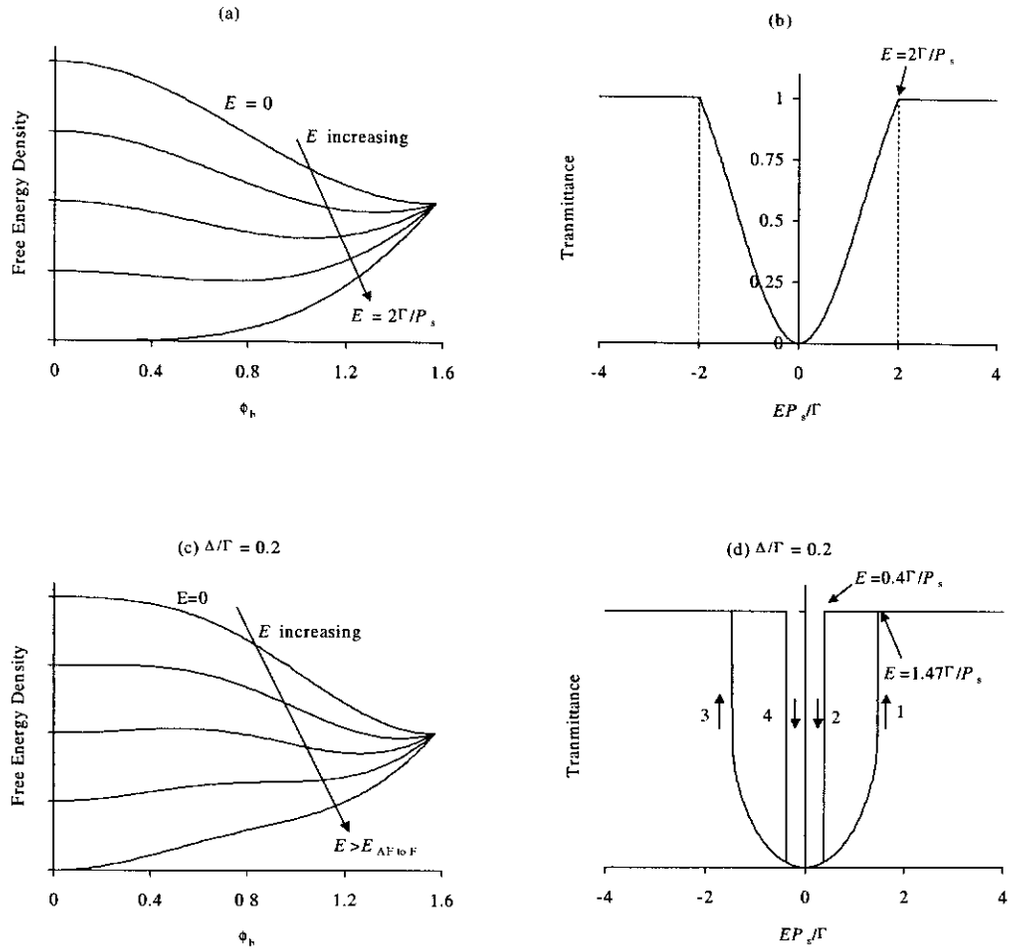

Figure 3. A theory that includes both dipolar and quadrupolar coupling terms can produce both thresholdless and hysteretic switching. (a) When $\Delta/\Gamma < 1/20$, the system is monostable for all applied fields, and therefore (b) the transition from AF to F is continuous and thresholdless. (c) However, when $\Delta/\Gamma > 1/20$, the system is bistable for a range of applied fields, therefore (b) the transition from the AF to the F state is thresholded and hysteretic.

the lower energy ferroelectric state begins. The number of domains nucleated from defects is assumed to be proportional to the difference in the electric field from $E_{holding}$, as is the speed of movement of the domain walls along the smectic layers [9]:

$$\text{number of domains of F state per unit area} = \alpha(E - E_{holding}),$$

$$\text{speed of domain growth along smectic layers} = \nu(E - E_{holding}).$$

With similar assumptions for F to AF switching, and for low slew rates, the hysteresis loop predicted is shown in Figure 4(a). The results are clearly very similar to the experimental ones shown in Figure 4(d) for a frequency of 1Hz. As the slew rate of the electric field in the theoretical model is increased, some interesting features arise in the hysteresis loop, as shown in Figures 4(b) and (c). It is clear that, again, these are qualitatively similar to the experimental results for frequencies of 10 and 25Hz, as shown in Figures 4(e) and (f). The changes in the hysteresis loop with frequency can be understood as follows. At higher slew rates, the domain switching from F^+ to AF (as the electric field decreases) is incomplete by the time that the field changes sign, so that a fraction of the cell is left in the F^+ state. As the domain switching continues, these parts undergo direct F^+ to F^- switching, that is, they switch around the smectic cone, without going via the AF state. In so doing, the transmittance of that part of the cell goes through a minimum and back up to its original value. The overall effect is a combination of a slow process in which the transmittance decreases slowly, and a faster process where the transmittance rapidly decreases and then increases again. This is clearly the case in Figures 4(b) and (e). At higher slew rates still, the switching is dominated by the F^+ to F^- switching and there is very little switching to the AF state, see for example Figures 4(c) and 4(f). This provides confirmation of the assertion above that the material CS4001 is fundamentally ferroelectric. The presence of defects and thermal fluctuations in the cell change the shape of the hysteresis curves observed, in particular dominating at low frequencies.

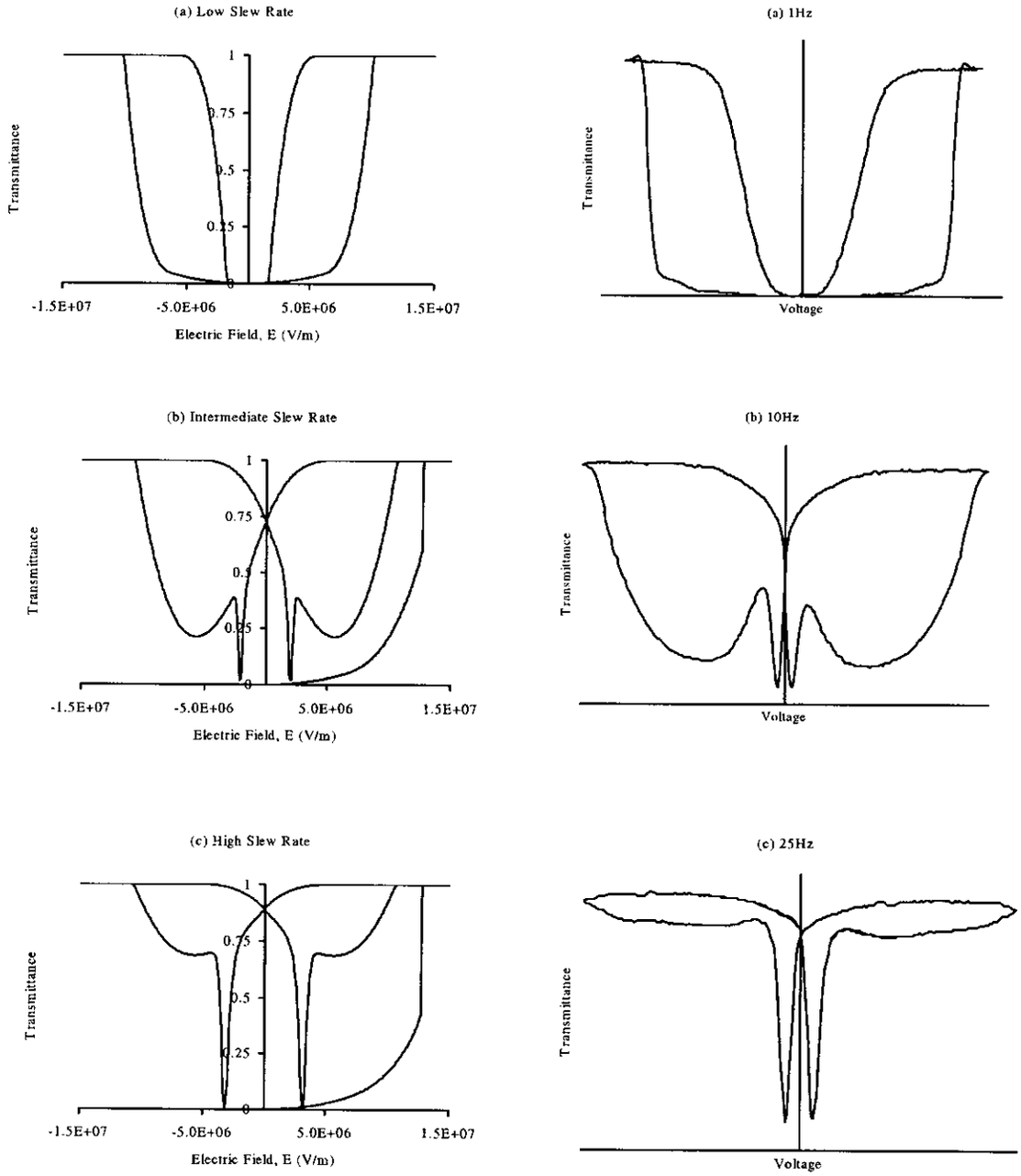

Figure 4. Comparison of the predicted (a)-(c) and measured (d)-(f) hysteresis loops for a range of frequencies of the applied electric field. As the frequency of the applied field increases, the shape of the hysteresis curves change so that the switching becomes more dominated by direct F^+ to F^- switching.

THRESHOLDLESS SWITCHING

So far, only the switching properties of hysteretic AFLCs have been considered in this paper. In 1995, it was discovered that some AFLC materials instead exhibit thresholdless analogue switching [10]. It may seem from the discussion above that this could be explained if the material had a very low quadrupolar to dipolar coefficient ratio. However, the 'thresholdless AFLC' mode is now widely accepted to be simply that of a twisted ferroelectric state [11], i.e. the bulk AFLC material when confined to a cell geometry forms a twisted ferroelectric structure with v-shaped switching properties. However, although the formation of the twisted ferroelectric structure has in the past been attributed to the polar influence of the cell surfaces, we have found that this is a necessary but not sufficient condition. Figure 5 shows the possible ground states that can be formed in a cell with infinite polar anchoring conditions, that is, either a twisted ferroelectric or a twisted antiferroelectric structure or both (bistability). The results are generated using the theoretical model in zero field in the thin cell limit (no helix). The phase diagram shows that in order for the twisted ferroelectric state to be formed in preference to the twisted antiferroelectric state, either the cell must be very thin, or there must be a very high ratio of the quadrupolar to dipolar coefficients. Since the thresholdless mode has been reported in standard

thickness cells, we conclude that the latter is the case in Refs 10 and 11.

Frequency Effects and Priming

It is also interesting to note that for standard cell thicknesses (~3μm), the twisted ferroelectric state will never be the only stable state: the twisted antiferroelectric state will also be a local energy minimum, although either state can be the lowest in energy overall. In these cases, either state could be lower in energy. If the F state is lowest energy, then the cell will remain ferroelectric and undergo analogue switching. If, however, the AF state is lowest in energy, then some interesting effects can occur. When a field is applied to the twisted AF state, thresholded switching to the F state will occur. When the field is removed, the device will return to the AF state, just as in a non twisted device. The switching will be hysteretic, unless the frequency of the applied field is so high that there is insufficient time for the material to return to the AF state, in which case the material will remain in the twisted F state. This is in complete analogy to the frequency dependent behaviour observed in non-twisted devices, as discussed above. It also agrees with some of the experimental observations of thresholdless AFLC behaviour. For example, it has been reported that in some materials thresholdless behaviour occurs only at high frequencies [12]. Also, a priming effect has been observed [11], in which the device switches hysteretically the first time, and from then on thresholdlessly, unless the device is left unswitched for a period of the order of minutes. In this latter case, the energies of the twisted F and AF states must be very similar, so that the return from the F to the slightly lower energy AF state is very slow.

Temperature Effects

It has also been observed that the thresholdless effect can sometimes appear at elevated temperatures, when it is hysteretic at low temperatures [12], which can be understood as follows. As the temperature increases towards the phase transition with the SmC* phase, the dipolar ordering coefficient Γ will decrease, since it must change sign at the phase transition. The quadrupolar coefficient Δ will not change sign, therefore the ratio Δ/Γ will increase (becoming infinite at the phase transition). Therefore, provided that there is polar anchoring at the surfaces, a device that is hysteretic at room temperature should become thresholdless close to the phase transition.

Thresholdless Effects in CS4001

Our knowledge of the material parameters of CS4001, together with Figure 5, suggest that in a device with polar anchoring conditions, both twisted F and AF states should be stable, with the AF state lower in energy. In fact, we have recently observed priming and thresholdless switching in localised areas of a 1μm surface stabilised device of CS4001 at room temperature, as illustrated in Figure 6. Other areas of the device exhibit hysteretic switching of the type illustrates in Figure 1. The results suggest that isolated parts of the cell create a polar anchoring condition (whilst others don't) which has caused a twisted antiferroelectric state to form in those parts (whilst non-twisted in others). The action of the electric field is to prime the device into the ferroelectric state, from which point thresholdless switching around the smectic cone occurs.

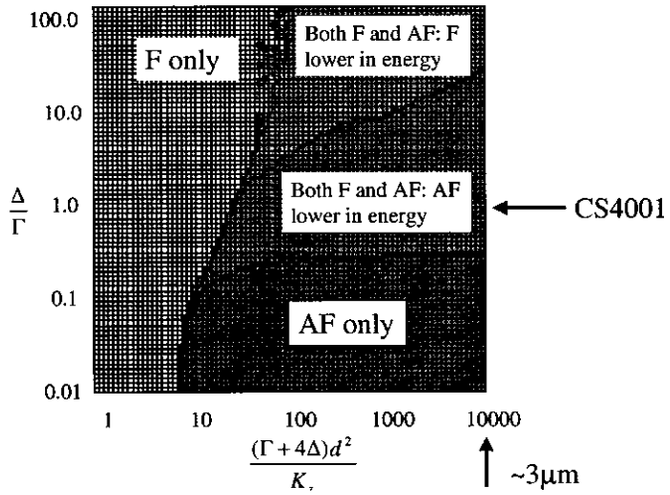

Figure 5. Phase diagram showing the stability of the twisted ferroelectric and twisted antiferroelectric states as a function of the cell thickness and of the ratio of the quadrupolar to dipolar ordering coefficients. The results show that in order for the twisted ferroelectric state to be energetically preferred over the twisted antiferroelectric state, either the device must be very thin, or there must be a very high quadrupolar to dipolar ordering ratio. The results also show regions of bistability, in which both twisted AF and F states are stable.

SUMMARY AND DISCUSSION

We have presented a unified description of switching in antiferroelectric liquid crystals. The helical structure unwinds within the pretransitional regime, to form a vertical antiferroelectric state with the plane of the directors parallel to the applied field. The mechanism for the helix unwinding is the interaction of the applied field with a polarisation that is induced due to a small change in the antiferroelectric ordering. This process also causes a small change in the optical tilt angle, therefore introducing a small amount of light leakage within the pretransitional regime.

The thresholded and hysteretic switching between the antiferroelectric and ferroelectric states can be explained in terms of a quadrupolar ordering term in the bulk free energy expression. The ratio of the dipolar and quadrupolar coefficients is such that the ferroelectric state is an energy minimum, for all applied fields. The shape of

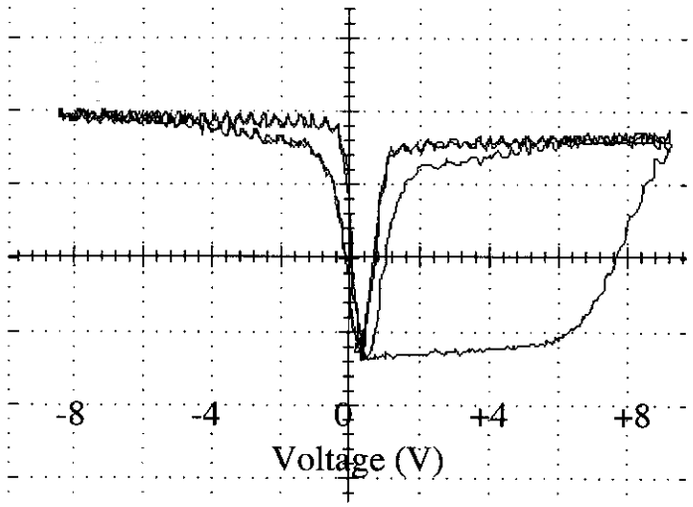

Figure 6. Transmittance of some parts of a 1μm device of CS4001 between crossed polarisers in response to an applied field. The electric field primes the device from the twisted AF state to the F state, and from then on the device undergoes thresholdless switching.

the true hysteresis curve at low frequencies, however, is dominated by the nucleation and growth of domains, which allow switching to the state of lowest energy, i.e. the antiferroelectric state below the holding voltage. At high slew rates, however, the domain growth is too slow to respond to the rapid changes in the electric field, and hence the fundamental switching behaviour is observed, i.e. the device demonstrates direct F^+ to F^- switching.

The formation of a twisted ferroelectric state in a polar anchored device (and therefore v-shaped switching behaviour) is explained in terms of a high ratio of the quadrupolar to dipolar ordering coefficients. This may be observed close to the phase transition with the SmC* phase if not at room temperature. The theory also shows regions of bistability where both twisted AF and twisted F states are stable. Where the AF state is lower in energy, frequency dependent and priming effects are predicted, in agreement with both the experimental results of others and also with our own measurements on CS4001 devices. The frequency dependence of the results is entirely analogous to that observed in non-twisted devices, i.e. the AF state (whether twisted or otherwise) is the lowest energy state below the holding voltage, therefore the material will return from the F to the AF state by domain growth when the frequency of the applied voltage wave is low enough to allow this to happen. In this case, hysteretic switching will be observed. At higher frequencies where the domain growth is too slow to respond to the changes in applied field, once primed into the ferroelectric state, the device will remain there, and undergo direct switching around the smectic cone from F^+ to F^-. The difference between the twisted and non-twisted cases lies in the resulting transmission curves. For the twisted case, the electro-optic response is v-shaped. For the non-twisted case, however, a w-shaped response is obtained (Figures 4(c) and (f)), as the electric field must change sign before any change in the director structure occurs.

ACKNOWLEDGEMENTS

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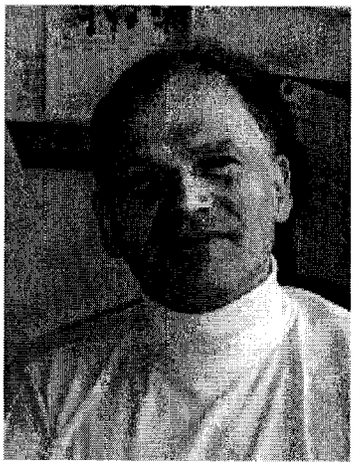
Professor Roy Sambles gets an FRS.



Professor Roy Sambles has been elected a Fellow of The Royal Society for his contributions to the optical studies of surfaces and layered systems. Roy has a rather broad research record which covers a wide area of condensed matter and optical physics. This ranges from the fundamental physics of melting and many-body effects in pure metals through to innovative studies of optical surfaces and highly technologically relevant work underpinning our understanding of modern liquid crystal displays.

Roy spent his early years in St Dominick, in Cornwall. After successfully completing science A levels at Callington Grammar in Cornwall, he went on to Imperial College London. There he obtained a first class degree in Physics in 1967, completing his PhD there in 1970.

His early research work, first at Imperial College and later at Exeter, concerned primarily the physics of metals, switching only in the 80's to optical studies of surfaces and thin films in particular metal surfaces supporting surface plasmons and liquid crystals.

As a postgraduate working with Maurice Blackman FRS at Imperial Roy used electron microscopy to study the fundamental processes of melting and evaporation of small metal particles. This work confirmed unequivocally the validity of Lord Kelvin's theory of enhanced vapour pressure over curved surfaces and also established in 1969 that small particles melted at substantially reduced temperatures. Possibly more importantly he drew attention to the idea that melting is a process which normally commences at a free surface of a solid with the formation of a thin skin. His work on the melting of lead and the remarkable superheating of bismuth preceded the present interest in surface melting by over twenty years.

On moving to Exeter in 1972 he began new research in the resistivity of thin metal samples, producing a series of definitive articles, perhaps the most significant of which being a critique of this whole area of research. This drew attention to the rather uncritical manner in which experimentalists in this area had been comparing their data with theory, highlighting many of the pitfalls. Subsequently much better quality work has been produced, across the World, as workers started to take seriously the points he made. He recognised that surface scattering in metals should be described by an angular dependant specularity parameter and established that this is indeed the case through a series of detailed experiments. Concurrent with this resistivity work he also explored the area of electron resonances in metals working as visiting Professor at Leuven (Belgium) in 1978 and Detroit in 1982. These studies provided the fundamental characterisation of Fermi-liquid many body parameters for a range of pure metals.

Returning to Exeter after a sabbatical period in the USA in 1982 he moved his research into the area of optical studies of surface waves and guided modes. Since then he has been instrumental in establishing new optical procedures for characterising thin liquid crystals cells as well as developing a series of novel experiments with optical excitation of surface waves. In all this work he has always provided a fundamental theoretical background with which high quality experimental data is compared.

One of his earliest papers in this area, with Kevin Welford and Mike Clark (then at RSRE Malvern) showed the potential for using guided waves in order to explore the details of the director profile in liquid crystal cells. Prior to this study the primary tools for optical characterisation of such cells, which now form the basis of the majority of flat panel displays, were optical microscopy and polarisation sensitive transmissivity measurements. Both of these techniques provide an integral of the optical response through the cell yielding very limited information on the all-important director profile through the cell. Now, at last, someone had developed a probe, which provided the essential information required to underpin this ubiquitous technology giving, amongst other information. Working first with Kevin Welford, then later with several others, including Steve Elston, Guy Bryan-Brown, Emma Wood and Fuzi Yang the Exeter group produced a definitive series of optical studies of liquid crystal cells.

The original waveguiding technique and variants developed provide the key optical probe of liquid crystal cells giving scientists and technologists, in unprecedented detail, information on the director structure and the switching processes in these devices. This work gives a fundamental scientific underpinning for new liquid crystal displays and it was the scientific basis upon which one of his ex research students, Dr Steve Elston, was awarded the prestigious Marconi prize in 1996 and Professor Sambles was awarded the George Gray medal in 1998. Also during

this very productive period Roy, in 1991, was promoted to the first personal Chair in Physics at Exeter.

In the last few years his original optical waveguiding work has moved on two further, and very exciting steps. Firstly, with Fuzi Yang, he introduced a procedure for determining the full director profile in fully leaky cells based upon low index glass plates. This means that optical guide wave techniques can be used to explore commercial 'off the shelf' cells and not just special prototypes designed for research purposes. Secondly, with Nathan Smith, he introduced a convergent beam procedure which allows the examination of individual pixels as well as cell dynamics. Combining these two latest developments allows for the complete exploration of static and dynamic liquid crystal cell theories.

In the early 90's Roy also began to explore a new area of optics that of combining diffractive elements with voltage tuneable liquid crystals. It is now clear that this combination may lead to much device potential as illustrated by the bistable nematic display (ZBD) based on blazed gratings developed at DERA.

In parallel with his work on liquid crystals Roy's research group undertook a series of studies of surface plasmons using both attenuated total reflection and grating coupling. This work runs from fundamental measurements of thin metal films at low temperatures in Ultra-High vacuum through to developing biosensors.

One of his contributions in this area was to note (with Guy Bryan Brown) that, by rotating the grating vector of a diffraction grating away from the plane of incidence, while optically exciting a surface plasmon there is strong conversion of incident p-polarised radiation into s-polarised output. This led to several publications and a patent for optical biosensing. In 1997 he extended this idea discovering that even in the absence of a surface plasmon deep metal gratings will give 100% polarisation conversion. Further studies on zero order (non-diffractive) metal gratings has led in 1998 to the discovery of a whole new family of localised surface plasmon modes. Subsequently, with Alastair Hibbins he has shown how thick metal plates may act, with very thin slits in them, as 'filled Fabry-Perot's at microwave frequencies, thereby introducing a whole new microwave technology.

In 1990, with Fuzi Yang, he also discovered that any thin absorbing film, appropriately surrounded by dielectrics, will support a new type of coupled optical surface wave, the surface exciton polariton.

In 1996, with Steve Kitson and Bill Barnes he reported the first observation of a full photonic band gap for surface plasmons, finding, with an appropriately manufactured silver bigrating, a gap from 1.9eV to 2.0eV for which there are no propagating surface plasmons on this structure. This may pave the way for thresholdless laser manufacture.

In addition, with Peter Vukusic, in the past few years he has discovered how sculpted multilayered structures in butterflies wing scales lead to vivid iridescence and remarkable colour mixing effects. The results of this work has lead him on to novel studies of structured surfaces both in the visible and the microwave region of the spectrum. Most recently he has turned his attention to the exciting prospect of controlling microwaves with liquid crystals.

Throughout his research career Roy says that he has been brilliantly supported by Sandra, his wife of 36 years, his parents and his family, and sees his election to the Fellowship of the Royal Society as a personal award to him which is actually a recognition of many peoples efforts.

Jay Patel

Jay Patel has been a good friend to the British Liquid Crystal Society for a number of years, and has given invited lectures at our conferences, so it is with great sadness that we inform our membership that Jay's wife, Susan, died in tragic circumstances last May. The Chairman of BLCS has conveyed deepest sympathies to Jay on behalf our membership. Susan gave Jay immense support in his endeavours to initiate and build liquid crystal device companies in the USA, and she will be greatly missed by all who knew her.

John Goodby

Hot LCD News

LG.Philips LCD Breaks Production and Sales Records for LCD Monitors

SEOUL, South Korea, Sept. 18 - Setting a new industry record, LG.Philips LCD Company today announced that it has reached a major milestone with an accumulated production of 10 million TFT-LCDs for the desktop monitor market. In addition, the company also announced it would set an accumulated sales record of 10 million TFT-LCDs for monitors next month. When that happens, LG.Philips LCD will become the first TFT-LCD company ever to produce and sell more than 10 million monitor units. Details at www.lgphilips-lcd.com.

A New Device Fabrication Technique

Within the ever changing world of liquid crystal device technology, the one constant has always been cell construction. Since the development of the first room temperature devices, liquid crystal has always been sandwiched between two pieces of glass, and an electric field applied by substrate electrodes. However, workers from Phillips have recently reported in Nature (Roel Penterman et al. Nature 417, 55–58 (2 May 2002)) that they have developed a new type of construction technique where the liquid crystal is 'painted' onto a single substrate. Through a clever mixture of liquid crystal, a polymer-forming monomer, an ultraviolet-absorbing dye and a photo-initiator, they are able to create a device that is essentially an open sandwich. The mixture is painted onto a single substrate using a common technique such as die coating or doctor blading and then a two exposures of ultra-violet light are used construct the device. First an exposure of 400nm light is made through a mask to construct a series of polymer boxes containing the liquid crystal. A second exposure is then used to cause phase separation and polymerization, this time forming a thin layer that caps the liquid-crystal-containing cells.

The letter to Nature though, also maps out the work that needs to be done before such a device type could be mass produced into large displays. While the electrode pattern needed to drive the device is readily achievable, the geometry of the device does not allow for the typical twisted or super-twisted nematic type switching. Also, glass has always been the common choice for substrate materials due to it's impermeability to contaminants from the air. A polymer coating or plastic substrate is generally not as impervious as glass, and at the moment these devices may not have the lifetime of those in production today. However, every technology has it's challenges in the initial stages, and perhaps the ability of this unique technology to create a display anywhere will be the driving force behind any problems being quickly solved.

Final Judgement on Kent vs ADS Case

Dallas and Wylie, Texas, July - On July 22, 2002 the Clerk of the United States District Court for the Northern District of Texas, Dallas Division, United States Magistrate Judge Jeff Kaplan presiding, filed the Final Judgment in the 6 year patent case affirming the validity of the West patent owned by Kent State University and exclusively licensed to Kent Displays Systems. The judgment, which was formally entered the following day, states that, "...the devices made used, sold and offered for sale by ADS...and the methods used by such devices, literally infringe..." the West patent. "ADS" refers to Advanced Display Systems, Inc. of Wylie, Texas.

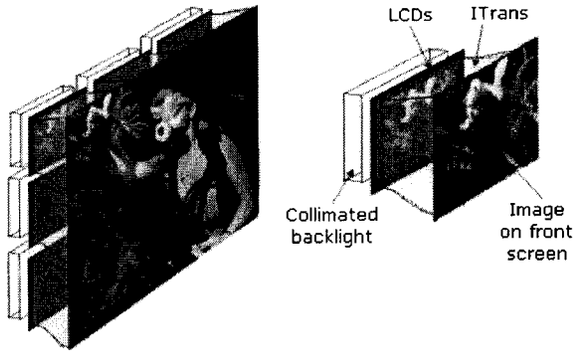
In the judgment, ADS and Bao Gang Wu, ADS's founder and one-time President, have been found liable for willfully infringing and inducing infringement of the West patent. Based on these findings, they both have been placed under a court-ordered injunction. Additionally the Judge has ordered that all those companies and individuals in active concert or participation with them are now subject to the injunction.

Uk Resurgence in Tiled Displays

Cambridge and Oxford, UK, 29 July - Once all but abandoned as too difficult, seamless tiling - the making of a large display by "tiling" smaller ones in such a way that the seams between the display tiles are virtually invisible - experienced a dramatic resurgence of interest when Rainbow Displays, Inc. (Endicott, New York) showed a 37.5-inch tiled LCD display in Seoul, Korea at IDMC in early September of 2000. This display went on to win the SID/Information Display 2001 Display of the Year Gold Award. Now, two small British companies are reinforcing the recent interest in tiled displays.

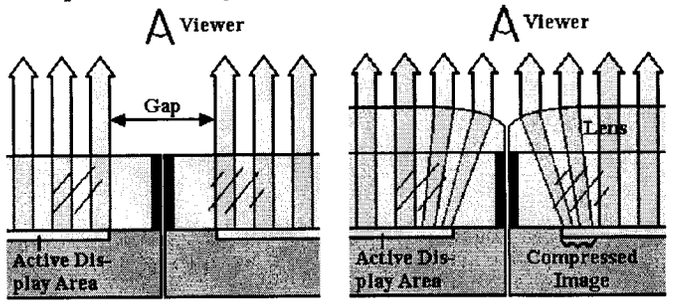
Today, Screen Technology Limited (Cambridge, UK), announced that a 6-percent equity in the company had been

taken by QinetiQ, which was formerly the larger part of the UK's Defence Evaluation and Research Agency (DERA). Screen Technology's has ITrans™ technology will enable high-brightness, seamless displays of essentially unlimited



size to be built at low cost, the company says. ITrans currently uses standard production LCD panels, but the technology can also work with OLEDs and other emerging technologies. An ITrans display consists of a white backlight, a standard display panels, and ITrans modules that use proprietary optical elements to expand the displayed image on the tiled display and present it in on the front screen of the modules, which tile seamlessly, the company said. Details at www.screentechnology.com.

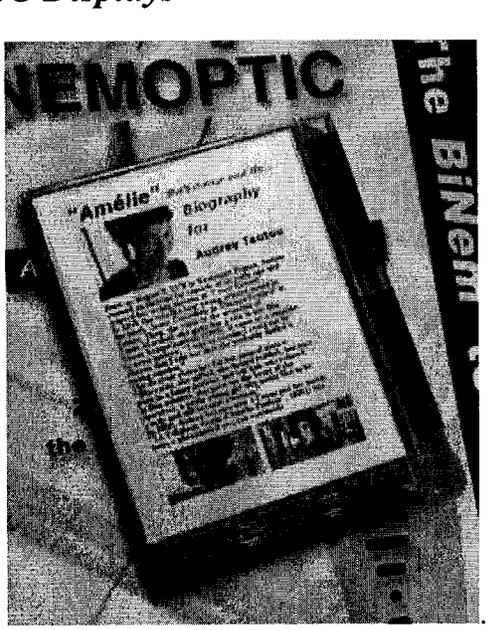
Start-up company Seamless Display Ltd. (Oxford, UK), takes a somewhat different approach. COO Justin Fry says the technology produces a nearly seamless image, with the seams being replaced by a faint shadow. Interestingly, this approach can be applied as an aftermarket solution, or new video panels can use the technology by incorporating a Seamless Display lens into existing production techniques. Converting to Seamless Display technology involves modifying the video drivers to compress the image in immediate proximity to the edge.



A thin lens is laminated over the display or incorporated into the edges of the front panel to optically stretch the compressed image over the join. This results in a continuous apparent image. So, instead of attempting to make seamless tiles, Seamless Display optically erases the borders that normally surround adjacent video screens, leaving only a shadow of a line. Seamless Display Technology can be applied to any display screen with relatively thin inactive edges. "This is an exciting new idea for removing the gaps in tiled displays. It is a simple "add on" to existing panels which is applicable to LCDs and many other flat panel display technologies," said Peter Raynes, Professor of Optoelectronic Engineering at Oxford University. Details at www.seamlessdisplay.com

Picvue to Produce BiNem® Displays

Magny Les Hameaux, France, April 5 - Picvue, the Taiwanese LCD manufacturer, and Nemoptic, the French R&D company, signed a Cooperation Agreement for Nemoptic's BiNem® (Bistable Nematic) LCD technology.



The objective of this agreement is to transfer the BiNem® technology to Picvue production lines in Taiwan and mainland China. The BiNem® technology combines outstanding optical performances and power savings while being very competitive with other passive LCD technologies. "The BiNem® technology will strengthen our position in the PDA and mobile-device markets and provides excellent solutions for e-books," said Jacob Lin, President of Picvue. "The partnership with the very dynamic company Picvue is a key milestone for the BiNem® technology", said Alain Boissier, the President of Nemoptic. Details can be found at www.picvue.com.tw, www.nemoptic.com

These highlights were taken from the SID website www.sid.org

IX OLC and BALC 2001, Naples

The OLC Conferences, with participation from leading scientists from all over the world, have become the most important forum today for the presentation and discussion of new research results in the field of Optics of Liquid Crystals. Noted for its high scientific level together with an informal atmosphere, the focus of this biannual meeting is primarily on fundamental scientific aspects with a now strongly emerging interest in applications of liquid crystals in new upcoming technologies. It is remarkable that many inventions, now in commercial use, have been presented for the first time at OLC Conferences. This year, coming back to its origin in the Naples area, a new idea arose to face the challenges and odds for the liquid crystal technology in an unabated growing and fascinating subject that can be named by one phrase: All-Optical-Networking. Never has been a market so much more driven by anticipation and expectations than by real innovative devices.

Although new developments in LC-materials, preparations techniques, and new transparent active devices make LC-components most promising, this is still probably a new and partly unidentified terrain for LC-scientists, especially for younger people in our community. Therefore, the BALC 2001 'Basics and Perspective Applications of LC in Optical Communication Technologies' Tutorial, co-located with the OLC 2001 meeting, provided a forum to learn more about the opportunities involving Liquid Crystals in optical communications and related areas.

Being the first of its kind (and most probably not the last) in conjunction with OLC-meetings, the BALC tutorial focused on the fundamental aspects of liquid crystal technologies that will be relevant to telecomms. The students, who almost unanimously said that the Tutorial met their expectations, rated the educational level of the lectures very high. To help reach the proposed goal, an electronic booklet (CD-Rom) containing all the lectures' slides was distributed during the Tutorial.

OLC 2001 followed the traditional format, which has proved to be very fruitful in past meetings. First of all, the use of LC based materials for the realization of photonic devices, thus confirming the choice of the Tutorial subject. LC on silicon (LCOS) devices were presented by Prof. W. Crossland from Cambridge University; integration of LC materials in guiding devices have been reported by several authors, G. Assanto (Italy), J. F. Henninot (France), T. Wolinski (Poland), D. Hermann (Sweden); holographic PDLC and polymeric LC systems by Cipparrone (Italy), Sukhov (Russia), Ramanujam (Denmark); a quite new use of LC as self-organizing molecular semiconductors for opto-electronic applications has been presented by Dr. J. Hanna from Tokio Institute of Technology; a look into the future can be defined the report by Prof. I. C. Khoo from Penn State University.

A second field of great interest was dealing with optics used as a tool either for investigation of LC surface properties or for changing LC surface properties and configuration. Very interesting results obtained with the Second Harmonic and Sum Frequency Generation techniques were presented in the plenary lecture given by Prof. Y. R. Shen from Berkeley University and by S. Soria (Germany); new and interesting results were presented by Yamamoto (Japan), Copic (Slovenia), and Olenik (Slovenia) using dynamic light scattering, by E. Lacaze (France) and by L. Cristofolini (Italy) using different optical techniques. A deeper understanding of the physical mechanisms of photo-induced changes of surface properties and configuration is being achieved: reports by Y. Reznikov (Ukraine), F. Simoni (Italy), T. Kosa (USA), L. Komitov (Sweden), J. Stumpe (Germany) and the plenary lecture given by Prof. T. Ikeda (Tokio University) are quite important steps in this direction.

A third field that clearly emerged from the conference presentations was related to photosensitive materials, either LC themselves or mixed into LC hosts. Several very important studies on nonlinear optical properties of such materials have been presented in Sorrento and also potential applications have been envisaged, for instance related to the possibility of optically addressing a number of devices (like SLMs) that are electrically addressed at present. Reports by M. Kreuzer Germany), T. Galstian (Canada), A. Zolotko (Russia) and E. Benkler (Germany) are worth being mentioned here.

Quite interesting reports were presented on chiral LC systems by A. Jakli (USA), S. Lagerwall (Sweden) and J. M. Otón (Spain): these reports are also particularly important in view of their applications that is in the field of displays and micro-displays. Beautiful 3-D images of the LC director bulk configuration in distorted cells, acquired by means of fluorescent confocal microscopy, were exhibited by O. Lavrentovich. Finally, I wish to mention two reports: one by Prof. E. Santamato (Italy), who initiated the OLC series 15 years ago, about manipulation of LC molecules via the exchange of orbital angular momentum between light and matter. The second is by D. Wiersma (Italy) who reported about the realization of a tunable random laser, using as tuning material a nematic LC infiltrated in a porous glass: a fine temperature tuning allows the laser emission spectrum to be controlled by broadband to narrow banded.

Three lively and crowded poster sessions were also held during the meeting, in which a variety of results were presented ranging on all the above-mentioned subjects and on several more. They also formed the backbone of the Proceedings volume: this will be a special issue of selected and peer-reviewed papers that will appear on a forthcoming number of the Journal Molecular Crystals and Liquid Crystals, thanks to the sponsorship of the publishers, Taylor & Francis.

Giancarlo Abbate
OLC2001 Conference chairman

The effect of elastic anisotropy on nematic disclination lines

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Introduction

Under a polarising microscope, liquid crystals exhibit beautiful optical patterns such as the Schlieren texture of a nematic, the fingerprint texture of a cholesteric and the focal conic structure of smectics. These textures are due to an assembly of topological defects and are determined by the molecular ordering of the particular mesophase [1]. Such defect textures are useful in identifying liquid crystal phases but are generally an unwanted effect causing a reduction in contrast of a liquid crystal display. Whether needed for identification or unwanted in displays, a clear understanding of defects will be extremely useful. Figure 1 shows a typical Schlieren texture, in the xy coordinate plane, of a nematic sample when it is placed between crossed polarisers (two polarisers with polarising directions perpendicular to each other) and light is shone through the cell in the z direction.

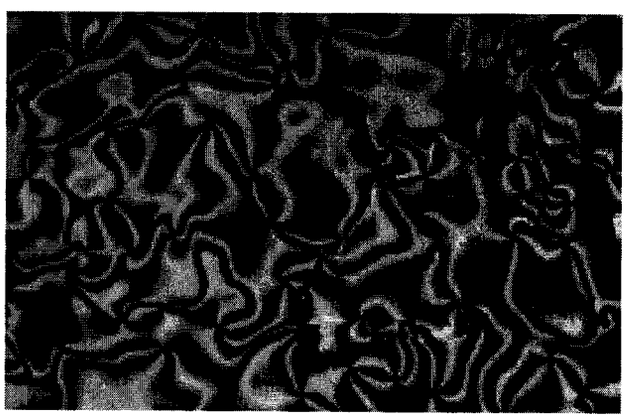

Figure 1:Schlieren texture of a nematic liquid crystal (from Date et al.[2])

The presence of crossed polarisers means that, at any point in the sample where the average molecular direction (the director) is aligned with either one of the polarisers, the transmission of light through the cell is blocked resulting in a dark area. When the director is not aligned with a polariser a lighter region is visible. The lightest regions in Figure 1 occur when the director is at 45 degrees to both polarisers. We can see from Figure 1 that there are points in the cell where the director orientation changes as we trace a path around that point. In fact each such point is a line perpendicular to the xy – plane called a disclination or defect line. For example, if we pick any point in Figure 1 where four dark regions merge then trace a path around that point, in going from one dark region to another the director has changed alignment from one polariser direction to the other polariser direction, in other words by 90 degrees. In a full circuit the director must have rotated by 360 degrees. A full rotation by 360 degrees indicates a disclination line of strength $S = +1$ or $S = -1$ (depending on whether the director rotated clockwise or anti-clockwise as we went round the disclination). When two dark regions merge at a point (usually a little harder to see) a defect of strength $S = +½$ or $S = -½$ occurs. In this paper we will consider the director structure around disclination lines of strength $S = +½$ and $S = -½$. Analysis has shown that only defects of half-integral strength are singular because defects with integral strength can escape into the third dimension, the z direction in our case [3]. Figures 2(c) and 3(c) show director configurations for $S = +½, -½$ .The director distortion that occurs around these defects can be characterised by bend and splay distortion. When $S = +½$, bend is dominant when $x < 0$,and splay is dominant when $x > 0$.When $S = -½$ there are three regions where bend is dominant, and three regions where splay dominates. The lower plots in Figures 2 and 3 show the calculated transmission through the cell if the director structure is placed between crossed polarisers which are aligned with the x and y axes. For a director at an angle ϕ to the x-axis the transmission will be proportional to $\sin^2(2\phi)$.

The properties of defects in liquid crystals have been discussed by many authors (see the reviews by Chandrasekhar and Ranganath [1]and Klèman [3])and have been described in terms of continuum mechanics and in terms of topology. In this paper, we solve the Euler-Lagrange equations, derived from a continuum description of the nematic material in terms of the director $\mathbf{n}$ (whose solution will be a minimum energy configuration) using analytic and numerical methods.

Theory

The bulk free-energy density of a deformed liquid crystal relative to an undeformed one was given by Frank [4]as

$$F = \frac{1}{2}[k_{11}(\nabla \cdot \mathbf{n})^2 + k_{22}(\mathbf{n} \cdot \nabla \times \mathbf{n})^2 + k_{33}(\mathbf{n} \times \nabla \times \mathbf{n})^2],$$

where k_{11} ,k_{22} and k_{33} are the elastic constants which refer to splay ,twist and bend distortions, respectively and $\mathbf{n}$ is the director. The director is chosen to be of unit length $|\mathbf{n}|=1$and to have the symmetry $\mathbf{n} = -\mathbf{n}$ The ∇ symbol denotes the usual gradient operator, $(\partial/\partial x, \partial/\partial y, \partial/\partial z)$ in Cartesian coordinates, and $\cdot$ and $\times$ denote the scalar and vector products. The total free energy of the system is then $E = \int_V F dv$, where the integration is over the volume of the liquid crystal region. Consider a planar

director structure in which **n** is confined to the *xy*-plane, so that

$$\mathrm{n} = (\sin\phi, \cos\phi, 0) \qquad \phi = \phi(x, y)$$

Using this expression for the director there will be no twist distortion in the region and thus the only elastic constants to enter the free energy are splay, k_{11}, and bend, k_{33}. We will seek director configurations which minimise the free energy of the system. In practice it is easier to work in cylindrical polar coordinates and we seek a solution $\phi(r,\theta)$ which depends on r, the distance from the origin ($x = 0, y = 0$), and θ ,the angle from the x -axis. From now on we will measure the angles ϕ and θ in radians.

In this paper we consider how the minimum energy solution changes as the ratio of the elastic constants k_{11}/k_{33} is altered. We concentrate on the two most common half strength defects, S = +½ and S = −½. As we will see, these defects have different amounts of splay and bend distortion and, although when $k_{11}/k_{33} = 1$ these defects look the same when viewed between crossed polarisers, we find that when $k_{11}/k_{33} = 1$ there is a significant difference. Minimisation of the total free energy yields the differential equation (the Euler-Lagrange equation) for the director angle ϕ.

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial F}{\partial \phi_r}\right) + \frac{\partial}{\partial \theta}\left(\frac{\partial F}{\partial \phi_\theta}\right) - \frac{\partial F}{\partial \phi} = 0,$$

where F is the free energy density in equation (1) and $\phi_r = \partial\phi/\partial r$, $\phi_\theta = \partial\phi/\partial\theta$.

It should be noted at this point that for an in finite region of liquid crystal there is no intrinsic length scale in this problem. No combination of the parameters k_{11}, k_{22} and k_{33} will lead to a number with the dimensions of length. For this reason, the governing equation derived from equation (3) is unchanged under the transformation $r \rightarrow \alpha r$ for any scaling factor α. This indicates that the solution to the equation is independent of r. We will introduce boundaries into our problem in the form of a inner and outer cylindrical surfaces at $r = r_c$ and $r = r_\infty$ respectively, but since they preserve the circular symmetry, the r-independent solution remains the minimum energy configuration. With this assumption the director angle is now only dependent on the polar angle θ and $\phi(\theta)$ satisfies the equation

$$\left[(k_{33} - k_{11})\sin^2(\phi - \theta) + k_{11}\right]\left(\frac{\mathrm{d}^2\phi}{\mathrm{d}\theta^2}\right) + (k_{33} - k_{11})\sin(2(\phi - \theta))\left(\frac{1}{2}\left(\frac{\mathrm{d}\phi}{\mathrm{d}\theta}\right)^2 - \frac{\mathrm{d}\phi}{\mathrm{d}\theta}\right) = 0.$$

Various solutions to this equation are immediately apparent (for example $\phi = \theta$ for any values of k_{11} and k_{33} or $\phi = S\theta + c$ when $k_{11}/k_{33} = 1$ if S and c are constant) but in general this equation cannot be solved analytically because of the non-linearity involved.

We can however observe some inherent symmetries in equation (4). The rotational transformation $\theta \rightarrow \theta + \alpha$ with $\phi \rightarrow \phi + \alpha$ leaves equation (4) unchanged. This allows us to choose the boundary condition $\phi(0) = 0$ without loss of generality. If we were to want the more general condition $\phi(0) = \alpha$ we would solve the system with $\phi(0) = 0$, to obtain $\phi(\theta) = \phi_0(\theta)$ say, and then the solution with $\phi(0) = \alpha$ would be simply $\phi(\theta) = \phi_0(\theta) + \alpha$.

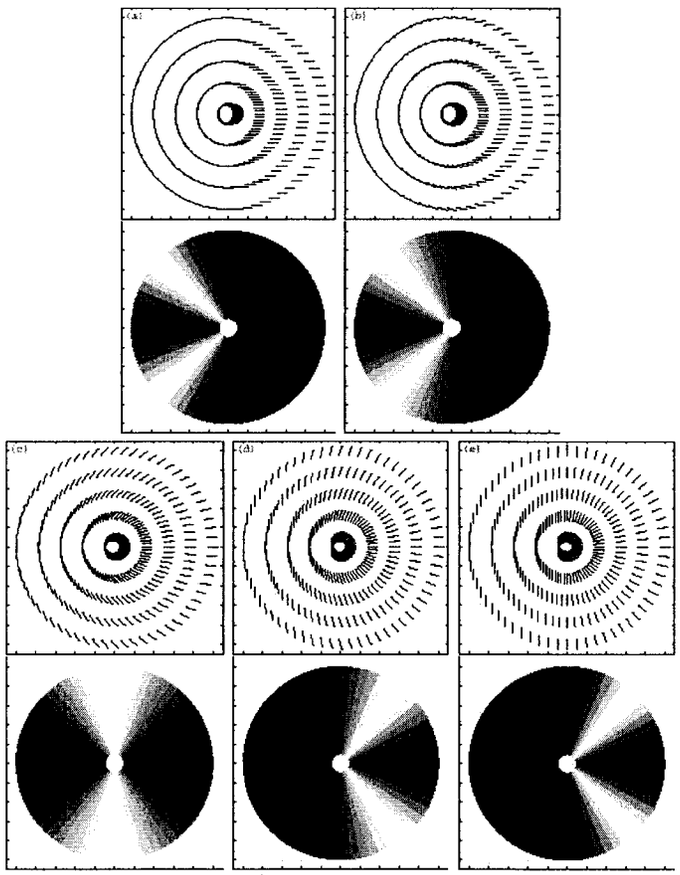

Figure 2: Director configurations for an S = + ½ disclination line with (a) $k_{33}/k_{11} = 0$, (b) $k_{33}/k_{11} = 0.2$, (c) $k_{11}/k_{33} = 1$, (d) $k_{11}/k_{33} = 0.2$, (e) $k_{11}/k_{33} = 0$ (numerical results). The upper-half of each plot shows the director configuration and the lower half represents the transmission of such a structure when placed between crossed polarisers.

A second transformation is $\theta \rightarrow -\theta$ with $\phi \rightarrow -\phi$ which leaves equation (4)unchanged and thus the director angle at the position $(r,-\theta)$ is simply the negative of the director angle at (r,θ). We therefore do not need to solve the equation over the full domain ($-\pi < \theta < \pi$) but over the semi-infinite region $0 < \theta < \pi$. These two symmetries mean that, without loss of generality, we may take the boundary conditions to be $\phi(0) = 0$ and $\phi(\pi) = S\pi$ where S is the power of the defect, ± ½ in our case.

One last remark should be made about the size of the liquid crystal domain. We have assumed that our nematic liquid crystal is contained in the region $r_c < r < r_\infty$. It is not necessary to specify the values of r_c and r_∞ to solve equation (4) since this equation is independent of r. However, if the liquid crystal region was not bounded by the cylinder at $r = r_\infty$, the energy of the system would be

infinite since we would have an infinite region of distorted liquid crystal. In reality, other defects or cell surfaces would influence the director orientation at a certain distance from the centre of the defect resulting in a finite energy. The region $r < r_\infty$ can be thought of as the 'zone of influence' of the defect, outside of which other effects influence the director structure. The inner boundary at $r = r_c$ is also necessary to achieve a finite energy. This is in fact the size of the 'defect core'. In this inner region the distortion is so high that a change in the nematic order occurs. An accurate model of the defect core must include this change in order and it has been shown by Schopohl and Sluckin [5] that there exists an amount of biaxiality in this region. In this paper, however, we are modelling the region outside the defect core assuming that the nematic order parameter/biaxiality remains constant and only the director varies.

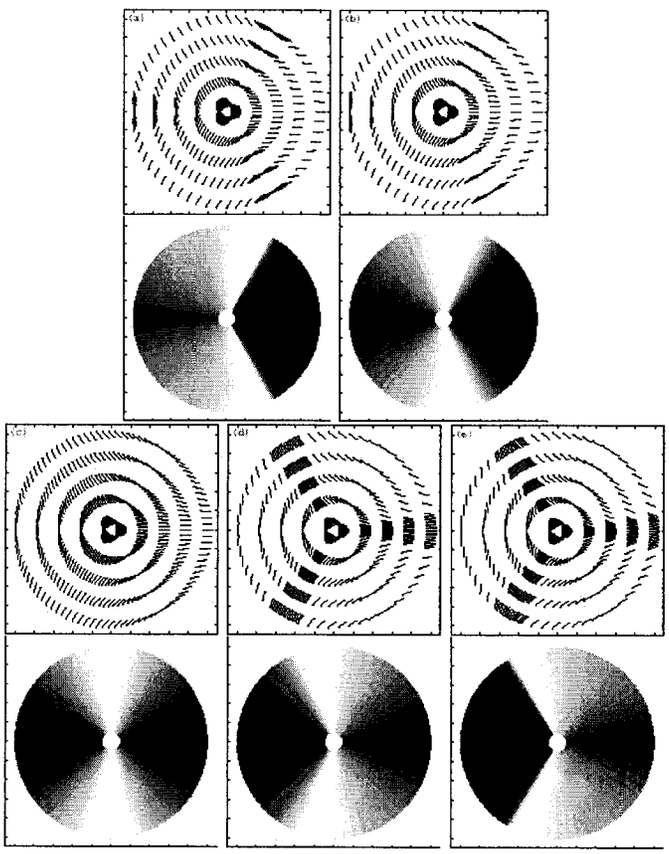

Figure 3: Director configurations for an S = - ½ disclination line with (a) $k_{33}/k_{11} = 0$, (b) $k_{33}/k_{11} = 0.2$, (c) $k_{11}/k_{33} = 1$, (d) $k_{11}/k_{33} = 0.2$, (e) $k_{11}/k_{33} = 0$ (numerical results). The upper half of each plot shows the director configuration and the lower half represents the transmission of such a structure when placed between crossed polarisers.

Analytic solutions

As mentioned above, it is possible to obtain exact or approximate analytic solutions for a variety of k_{11} and k_{33} values. With elastic isotropy, when $k_{11}/k_{33} = 1$, equation (4) simplifies significantly to $\frac{d^2\phi}{d\theta^2} = 0$ which, with the boundary conditions $\phi(0) = 0$ and $\phi(\pi) = S\pi$, has the solution $\phi = S\theta$. This is the solution for any disclination strength S. The director structures for S = +½ and S = -½ are shown in Figures 2(c) and 3(c). Because of the isotropic elastic constants, there is an equal amount of splay and bend distortion in these configurations. When $k_{11}/k_{33} = 1$ this will not be the case and the system will prefer either splay or bend distortion depending on which is smaller, k_{11} or k_{33}.

From the director configurations in Figures 2(c)and 3(c) we can also calculate the effect of rotation of the polarisers relative to the liquid crystal sample. If we rotate the polarisers anti-clockwise by $\pi/8$ radians (22.5 degrees) the direction of the polarisers will be $\pi/8$ and $5\pi/8$. The darkest regions will then occur when the director is oriented such that $\phi = \pi/8$, $\phi = 5\pi/8$, $\phi = 9\pi/8$ or $\phi = 13\pi/8$. For the S = + ½ defect $\phi = \theta/2$ so this occurs at the values $\theta = \pi/4$ or $\theta = 5\pi/4$. The dark regions have rotated anti-clockwise by double the polariser rotation angle. However, for the S = − ½ defect $\phi = -\theta/2$ so the new dark regions occur at the values $\theta = -\pi/4$ or $\theta = -5\pi/4$. The dark regions have rotated clockwise by double the polariser rotation angle. In this way it is possible to distinguish between positive and negative strength disclinations.

For the S =+ ½ defect it is also possible to write down the exact analytic solution for the two extreme cases of $k_{11}/k_{33} = 0$ and $k_{33}/k_{11} = 0$. When $k_{11}/k_{33} = 0$ splay distortion contributes nothing to the total energy and the liquid crystal will attempt to replace any bend distortion with splay distortion in order to reduce the total energy. For the S = +½ disclination it is possible to replace all bend distortion with splay and Figure 2(e) shows such a director configuration. The analytic solution is $\phi = \theta$ when $0 < \theta < \pi/2$, $\phi = \pi/2$ when $\pi/2 < \theta < 3\pi/2$ and $\phi = \theta - \pi$ when $3\pi/2 < \theta < 2\pi$. When $k_{33}/k_{11} = 0$ the opposite effect occurs all of the splay distortion is replaced with bend distortion and Figure 2(a) shows the director configuration. The analytic solution is $\phi = 0$ when $0 < \theta < \pi/2$, $\phi = \theta - \pi/2$ when $\pi/2 < \theta < 3\pi/2$ and $\phi = \pi$ when $3\pi/2 < \theta < 2\pi$.

We can also determine an approximate analytic solution when the elastic constants are nearly equal. If we take $k_{11}/k_{33} = (1 - \varepsilon)$ where ε is a small positive number then, if ε is small enough, it is reasonable to assume that the solution to equation (4) is close to the solution $\phi_0 = S\theta$ (which is the solution when $k_{11}/k_{33} = 1$ or when $\varepsilon = 0$). When we consider $k_{33}/k_{11} < 1$ we will take $k_{33}/k_{11} = (1 - \varepsilon)$, although in this case the equation and solution changes slightly. We use the Taylor series expansion of the solution at $\varepsilon = 0$ in powers of ε

$$\phi = \phi_0 + \sum_{i=1}^{\infty} \varepsilon^i \phi_i$$

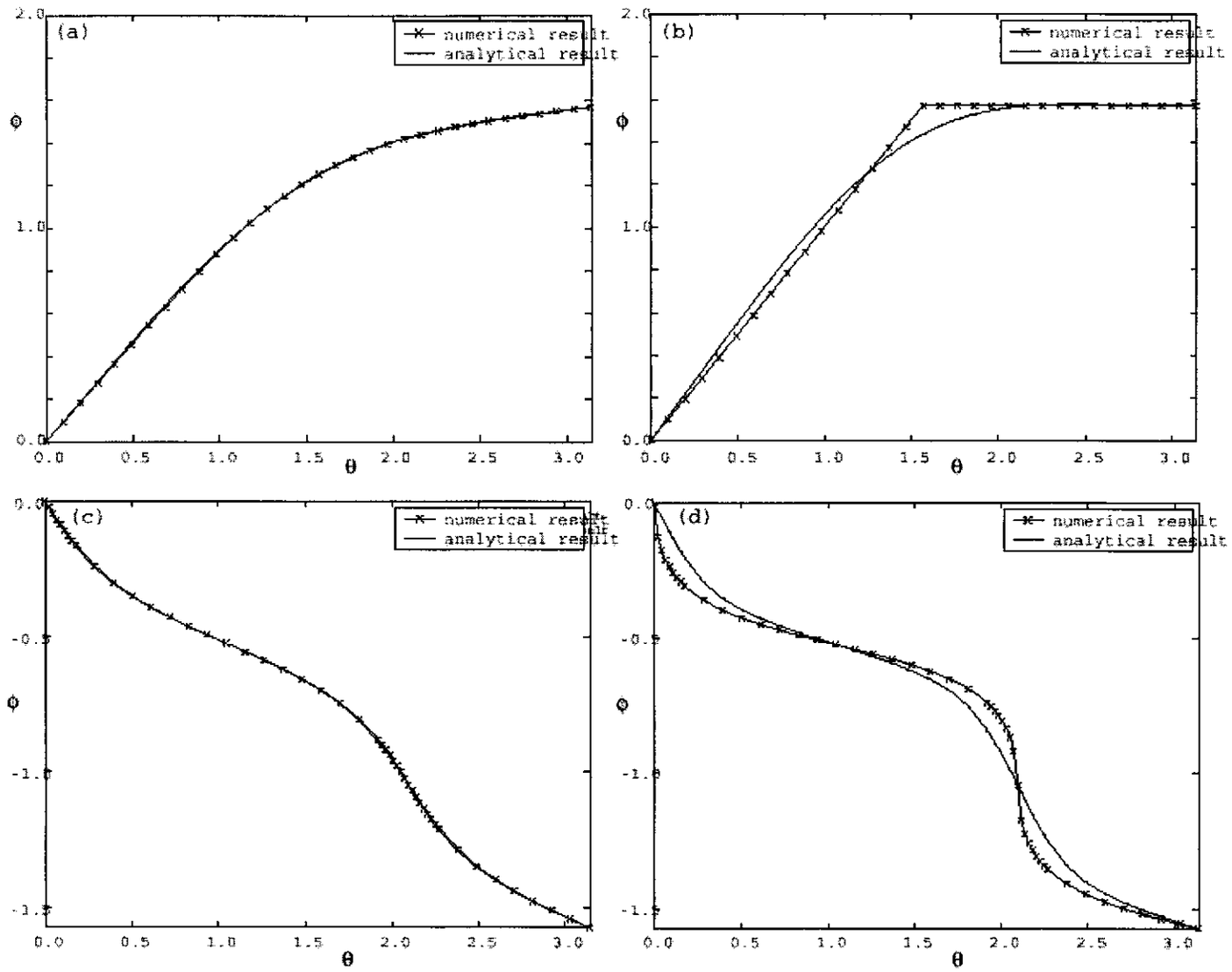

Figure 4:Comparison between the approximate analytic solution equation (5) with six terms and the numerical solution for (a) $S = +\frac{1}{2}$, $k_{11}/k_{33} = 0.2$, (b) $S = +\frac{1}{2}$ $k_{11}/k_{33} = 0.0$ and for (c) $S = -\frac{1}{2}$ $k_{11}/k_{33} = 0.2$, (d) $S = -\frac{1}{2}$ $k_{11}/k_{33} = 0.0$. For $k_{11}/k_{33} = 0.2$ the analytic solution is a good approximation to the exact solution.

where $\varepsilon = 1 - k_{11}/k_{33}$. Substituting $k_{11}/k_{33} = 1 - \varepsilon$ into equation (4) gives

$$\left[1 - \epsilon\cos^2(\phi - \theta)\right]\left(\frac{\mathrm{d}^2\phi}{\mathrm{d}\theta^2}\right) - \epsilon\sin(2(\phi - \theta))\left(\frac{1}{2}\left(\frac{\mathrm{d}\phi}{\mathrm{d}\theta}\right)^2 - \frac{\mathrm{d}\phi}{\mathrm{d}\theta}\right) = 0.$$

By substituting equation (5) into equation (6) and equating coefficients of powers of we get a series of equations for the functions ϕ_i. Recall that, if we consider a strength S defect then the boundary conditions require $\phi(0) = 0$ and $\phi(\pi) = S\pi$. We can satisfy these boundary conditions using only the first order term since $\phi_0(0) = 0$ and $\phi_0(\pi) = S\pi$. Therefore, the higher order terms in equation (5) must have zero boundary conditions, $\phi_i(0) = 0$ and $\phi_i(\pi) = 0$. The first four functions in the expansion are

$$\begin{aligned}
\phi_0(\theta) &= S\theta \\
\phi_1(\theta) &= \frac{S(S-2)}{8(S-1)^2}\sin(2(S-1)\theta) \\
\phi_2(\theta) &= \frac{S(S-2)}{16(S-1)^2}\sin(2(S-1)\theta) \\
&\quad \frac{S(S-2)(5S^2-10S+1)}{256(S-1)^4}\sin(4(S-1)\theta) \\
\phi_3(\theta) &= \frac{S(S-2)(71S^4-284S^3+440S^2-312S+80)}{2048(S-1)^6}\sin(2(S-1)\theta), \\
&\quad + \frac{S(S-2)(5S^2-10S+1)}{256(S-1)^4}\sin(4(S-1)\theta) \\
&\quad + \frac{S(S-2)(29S^4-116S^3+160S^2-88S+16)}{6144(S-1)^6}\sin(6(S-1)\theta),
\end{aligned}$$

Here we can see that an extra mode is added in each of the terms. When $\varepsilon << 1$, we expect a truncated expansion

series (we later consider the first six terms) to give a reasonably accurate solution since higher order terms will be negligible. However, when $\varepsilon \approx 1$, the truncated approximation is no longer accurate unless the number of terms used in equation (5) is large.

Numerical Results

We can solve equation (4), for any value of k_{11}/k_{33}, using a standard numerical method. Discretising equation (4) on a non-uniform grid and approximating derivatives with central finite differences, we form a set of nonlinear equations $F(\Phi) = 0$ where Φ is the vector of ϕ values at each grid node. A non-uniform grid is necessary in some cases when the director distortion becomes large and would lead to significant discretisation errors on a uniform grid. The system of equations $F(\Phi) = 0$ is solved using the NAG routine c05nbf [6] by a modification of the Powell hybrid method. In order for the NAG routine to work, we need a good initial guess. Since the analytic solution is known for $\varepsilon = 0$, we use this as an initial guess, and step up the value of ε in discrete steps, using each solution as an initial guess for the next calculation, until we reach the required value of ε. The numerical solutions for various values of ε are shown in Figures 2 and 3. Figure 4(a) and (c) shows a comparison of the approximate analytic solution equation (5) with the numerical solution when $\varepsilon = 0.8$ and S = +½ and S = −½, respectively. Here only six terms of the analytic solution are used, and we can see clearly that this gives very good agreement with the numerical solution. Figure 4(b) and (d) shows the same comparison with $\varepsilon = 1$. We can see that in this case the analytic solution (again with six terms) does not match up well with the numerical solution, and in fact, an infinite number of terms of the analytic solution would be required for good accuracy.

There are two important points to consider regarding the director configurations in Figures 2 and 3. Firstly, it is clear that for a specific nematic material at a constant temperature (so that k_{11}/k_{33} takes a fixed value) the Schlieren pictures for $k_{11}/k_{33} = 1$ will appear different for the two defects $S = +½$ and $S = -½$ (consider for example Figures 2(d) and 3(d)). Secondly, for a single defect (for example $S = +½$ in Figures 2(c) and 2(d)) the Schlieren picture may be significantly different for different values of k_{11}/k_{33}. It is possible to calculate the angle between the regions of maximum transmission in Figures 2 and 3 as a function of k_{11}/k_{33} and also the rate of rotation of the maximum transmission angle as the polarisers are rotated. It is therefore theoretically possible for the ratio k_{11}/k_{33} to be found by examining the Schlieren texture. However, to perform such a calculation accurately the disclination line should have few external influences such as nearby defects and it would be extremely difficult to make a measurement from a sample such as the one shown in Figure 1. Similar calculations can be carried out for integer strength defects although the differences in the Schlieren picture are not as obvious as for S = ±½.

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BRITISH LIQUID CRYSTAL SOCIETY

First Announcement

The BLCS Annual Conference 2003

Fitzwilliam College
Cambridge University
April 7 – 9th 2003

The BLCS annual meeting (AGM) and conference will be held from April 7th to 9th at Fitzwilliam College, Cambridge University. The main emphasis of the conference is for students to present their latest research work along with invited talks and the Sturgeon lecture. Papers are requested on any topic related to liquid crystal materials and their applications. For more information please see the website

http://www-g.eng.cam.ac.uk/photonics/blcs2003

International Liquid Crystal Conference in Edinburgh.

Conference report

The 19th International Liquid Crystal Conference was held in Edinburgh from 30th of June to the 5th of July 2002. It was organised by the joint efforts of the British Liquid Crystal Society in conjunction with the Royal Society of Chemistry. This major conference has been highly successful and it attracted about 900 participants from 43 countries. The organisation of a large conference on such a level is always a very difficult task , and in this case it would just become impossible without enormous personal efforts of several key players and supporting staff. On top of normal duties, these people also had to struggle with various unexpected obstacles created by business oriented enterprises in Edinburgh, which has already become one of the most expensive cities in Europe. In particular, one should mention George Gray (Chairman), John Goodby (Executive Chairman), Duncan Bruce (Executive Secretary), Harry Coles (Honorary Secretary), Iain Stewart (Treasurer) and in particular Geoffrey Luckhurst and Peter Raynes (Co-chairmen of the Scientific Committee).

The conference took place in the excellent Edinburgh International Conference Centre located just a short walk away of the Edinburgh Castle, Haymaket railway station and the Travel Inn hotel. The plenary lectures were given in a large auditorium with all modern facilities in place. This hall was transformed at appropriate times into a number of smaller ones to provide room for several parallel sessions. All posters were displayed in the vast basement hall, where hot lunches together with tea and coffee were also been provided. Additionally, in the same building one could find plenty of smaller rooms, halls and corners with numerous sofas and chairs, where small groups of participants were discussing their business in a secluded atmosphere away from the main crowd. We know that these informal discussions are as important as formal presentations, and it was coveniently fortunate that the complex topology of the Conference Centre proved particularly favourable for stimulating them.

The Conference building was located at the edge of the historical part of the town, and one could easily reach any part of the old town by foot in the evening, taking advantage of the long lasting daylight typical for this northern latitude in Summer. There was a choice between the Medieval Town along the Royal Mile, the classical XVIII century New Town behind the main shopping street and the lavish Victorian West End. Edinburgh is a very special place indeed. The nordic and elegant style of the magnificent old city - just a little bit gloomy, mainly grey and white with pastel green spots - creates a special atmosphere. This atmosphere was quite strong during the stylish wine reception in the main court of Edinburgh Castle at the end of the first day of the conference, and this was a relatively warm and dry day. On average, July is considered to be the best month in Eastern Scotland.

This year has been very different (as nearly everywhere) and for most of the week the colour of the sky was in perfect harmony with that of the castle walls.

Some participants from Mediterranean universities were on the brink of getting a cold after a temperature drop of 20 degrees. The adverse weather, however, has forced more people to stay inside. In fact, I have never seen so many people staying together and talking about science all day long. Surprisingly, the conference centre appeared to be large enough to accommodate all 900 participants without reaching the close packing limit. During some talks, however, the smaller halls were really full and people were sitting on the stairs.

The scientific part of the Conference started with the plenary lecture of P.G. de Gennes who talked about artificial muscles and a possible role of liquid crystal ordering. The lecture was interesting, clear and entertaining, and has provided a good start for the conference. De Gennes discussed a possibility to change shape of some polymer liquid crystalline systems, which have a rubber textile texture, using light, heat or external fields. This may help one to replicate what is happening in the fibres of real muscles which contract in response to electrical signals from the brain. However, de Gennes warned that the research was at an early stage, and we are still a long way from being able to do these things. There were five other plenary lectures delivered in the main hall. Two of them covered various aspects of physics (H.Takezoe, Tokyo Inst. of Technology) and chemistry (C.Tschirschke, Martin Luter Univ., Halle) of unconventional liquid crystal materials, and two other lectures focused upon applications mainly in telecommunications (W.A.Cossland, Univ. of Cambridge), and in displays (D.J.Boer, Philips Research). Finally, the fifth plenary lecture was given by R.W.Pastor (Food and Drug Administration, USA) who talked about molecular simulations in lipid bilayers.

In total there were 100 oral presentations including 20 invited lectures and about 860 posters. Given the amount of presentations, it is practically impossible to describe, even briefly, the proceedings of such a conference. My general impression from the conference is very positive. Nearly all major groups across the world made contributions and all recent discoveries and developments in physics chemistry and applications of liquid crystals were discussed and received significant attention.

The challenging atmosphere at the conference can be illustrated by the following example. Two invited speakers (Joe Maclennan, CU Boulder, and Lev Blinov,

Crystallography Inst., Moscow) have addressed basically the same problem of the origin of thresholdless V-shaped switching proposing completely different explanations, both based on detailed experimental evidence. The problem of V-shaped switching in chiral smectics seems to remain controversial in spite of all efforts.

The total number of submitted abstracts was about 1070. The largest amount came from Japan (151) and USA (129) followed by UK (99), India (88), Russia (81), Korea (64), Germany (53), France (52), Italy (47), Ukraine (43), Poland (34), Taiwan (24) and Slovenia (22). It should be noted that the actual number of participants from India was much smaller then expected due to visa problems related to the conflict in Kashmir. The largest amount of abstracts contributed to the section 'Surfaces and Confined Systems'(16%), although this section was only marginally ahead of the two applications sections taken together (15.1%). The 'Materials and Synthesis' section, which is usually a large one, received 13.3% of all contributions and 'Theory and Simulations' section received 12.4% - mainly due to the growing amount of microscopic simulations. A relatively large fraction of abstracts have been contributed to the 'Chiral Phases' section (9.7%) which shows a renewed interest in chirality. Other traditional topics, i.e. 'Bulk Phases', 'Structural Characterisation' and 'Polymers and Oligomeric Systems' were well represented covering about 8% each. Surprisingly, there were only 4.7 \% of contributions submitted to the 'Amphiphilic, Colloidal and Microphase-separated Systems' section. I do not have detailed statistics about previous conferences, but it seems that at the moment amphiphilic and colloidal systems (including liquid crystalline ones) are widely represented at other conferences on liquids, polymers and membranes. In general, the standing of liquid crystal science remains strong and there are no signs we will be disappointed in the coming future.

We are looking forward to ILCC 2004 which will be organised by the Slovenian group in Ljubljana. This is a large and very active group which attracts many young researchers, and which has a good balance between experiment and theory. The spirit is high and Luibliana is beautiful, and we have every reason to expect that ILCC 2004 will be similarly a resounding success.

Mikhail Osipov
University of Strathclyde

British Liquid Crystal Society Winter Workshop 2001

The British Liquid Crystal Society Winter Workshop was held from lunchtime Monday 17th December to lunchtime Wednesday 19th December 2001.

As I am sure everyone is aware, the Workshop is designed for new entrants to the field of liquid crystals, particularly PhD students, but post-docs, technicians and industrialists also have much to gain from the event. Areas covered by the Workshop include a general introduction to liquid crystals, the synthesis of liquid crystals, identification of liquid crystal phases by optical microscopy, differential scanning calorimetry, and X-ray analysis, liquid crystal polymers, the physics of liquid crystals, liquid crystal devices, and modelling of liquid crystals. Theory and practical work is included, and there is ample opportunity for social activities. All participants are provided with notes from each of the topics covered.

The three-day format of the Workshop is now well established, and appears to be very popular and successful, despite the greater costs over and above a two-day format. In 1999 the format was changed slightly to include the physics of liquid crystals as a separate session to the devices, with which is was always linked in the past. Additionally, aspects of the physics of liquid crystals were included in the practical sessions. In order to accommodate these important aspects of liquid crystal physics, the NMR of liquid crystals was discontinued from the programme. These changes seem to be working very well in focussing attention to the more important areas.

The support received by the Winter Workshop has been quite variable in recent years, but for the past couple of years numbers have been very good. The 2001 Workshop was extremely well attended with a total of 46 delegates; 10 industrial delegates, 30 academic delegates and 6 non-residential delegates from Hull. The Workshop continues to attract some continental delegates. All of the delegates seemed to enjoy themselves, and I am sure that they all benefited from the academic and social programmes.

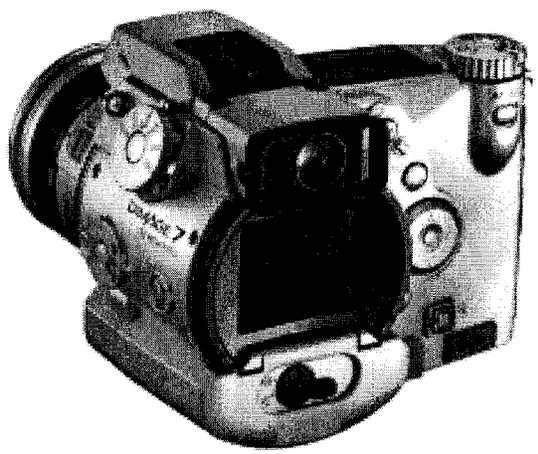
For 2001, the cost of the Workshop was held at £120- (academic) and £240- (industrial), and seems to be quite acceptable. As can be seen from the accounts below, another healthy surplus has been generated, similar to last year due to the identical number of industrial delegates. However, the cost of residence, catering and room hire continues to rise.

M. Hird
University of Hull

*A boondoggle at the Ho-Jo**

(or what I saw at SID 2002)

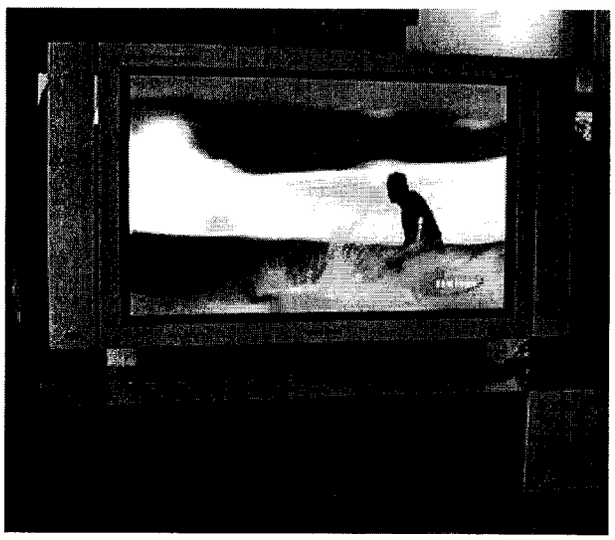
This year's annual SID meeting was held May 19-24th in the Heynes conference centre in Boston, as a combined conference and exhibition. As in most years, it was very well attended, with a good combination of both academic and industrial delegates. Unlike most years, there was no new technology to wow the unexpecting punters, hence most people were looking towards the maturation of display technologies such as OLEDs and light emitting polymers. A key point made throughout the conference was that the AMLCD manufacturers are al last making a profit, which is a transformation from recent years. The consolidation of previously predicted market dominators, microdisplays, was also a strong theme amongst both the exhibits and papers.



The Minolta Dimage 7 (incorporating QVGA LCOS microdisplay from Displaytech)

The technical presentations at the conference were a little disappointing as there was a concentration on the commercial rather than the academic aspects of display technologies. Among the LCD papers, there were V-shaped FLCs from Chalmers, a brace of papers from the ZDB team and a couple of presentations on dye doped LCDs for LCOS devices from CRL-Opto. There were also the usual heavy duty presentations by most of the major AMLCD manufacturers. Other topics presented included the usual bevy of papers on the eternal holy grail of plastic substrates and bendy displays. Best attended paper must go to the latest CDT spin-out, Plastic Logic, who presented their first results from TFT on plastic devices. This was quite interesting to the LC community as they are using LC alignment and LC based polymers to increase the mobility of their TFT devices. They are also using PDLCs as their current electro-optic effect of choice.

The presence of LCD technologies was very strong with all the major players having exhibits with some very impressive newly developed displays. I think one of the overall themes of the conference was the development of many specific displays technologies for predicted markets such as PDAs, projection systems (TV, wall and cinema), hand-held and telephony products. For this reason, most exhibits showed mock-ups of potential future products to highlight their displays and many manufacturers often had several different technologies in the same application. I quickly lost count and consciousness over how many different PDA displays were on show or presented; OLEDs, PLEDs, AMLCDs and colour STNs. In fact I was rather disappointed not to see a plasma PDA display! I can't remember how many different 320x240 pixel colour displays I saw, however the predominant question was always 'what's its power consumption and is it more than 50 cents?'



The Samsung 40" WXGA TFT LCD

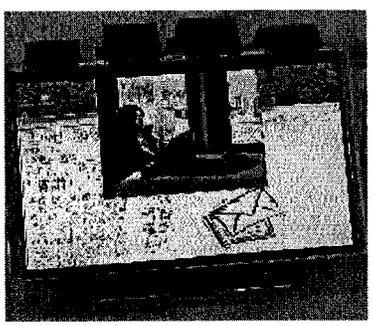
For me, one of the stars of the show was the 40" rear projection display from Samsung based on the (dare I say it) DLP microdisplay engine from Texas Instruments. Rather surprisingly, TI had no presence at the exhibits, but several projection systems were on show. There was even a 3D projection system based on the DLP and a spinning screen from Actuality Systems, which was nice but a little noisy. Even The Wedge demonstrated by Adrian Travis of Cam3D was on show at SID being driven by a DLP based projector. *Adrian how could you!* The rear projection TV from Samsung showed how bright, clear and uniform a DLP based rear projection display can be and also how much further rear projection screens have progressed. I

would have stumped up the cash there and then if they had been selling! There were several LCOS based rear projectors on other stands from Spatial Light, Microvu and Three Five, but they have a little way to go in order to compete with the DLP systems. One of the key aspects being discussed all through the conference amongst the microdisplay projector vendors, was the availability of suitable high-brightness LEDs for use in rear projection displays. Microvue showed a small system based on their SXGA LCOS engines, however brightness limited by the LED sources. One ray of hope for LED sources was LumiLEDs, who were showing a recently developed 4W green single LED, which was very difficult to look at!!

Another interesting series of displays on show were the next generation of AMLCDs, which I always seem to predict in the *'they can't possibly make that'* section of my talks. The 40" TFT single panel on show in the Samsung stand was quite astounding, especially as their stand was next to Rainbow displays who were showing their large area tiled systems of a similar size. I suppose they will take great heart in seeing the Samsung panel as they will say *'if they can make it, we can tile it!'* One thing that Samsung were not revealing was the yield on this huge panel, however I was amazed by the fact they could make such a uniform and bright backlight for it. It was quite remarkable to see the Samsung 50" rear projection display, 60" plasma display and 40" AMLCD panel all together as you could really compare the three technologies. Several of the major Asian manufacturers including Sharp and Toshiba had ultra-high resolution AMLCD panels on show with incredibly small pixels in unfeasibly large numbers. Seeing such a display truly hammers home the resolution argument, however seeing them update every five seconds also suggests that the addressing and data bottleneck problems have yet to be solved.

AMLCDs for notebook computers and monitors are now a mature category. The wide variety of panels from leading manufacturers such as Samsung, LG.Philips LCD, NEC, and Sharp generally looked beautiful. Luminance, viewing angle, number of pixels, and panel diagonal are tailored to different applications in a dizzying number of combinations, with diagonals and number of pixels increasing at the top end, and an increasing number of wide panels in evidence. Larger panels are appearing in notebooks, with 15 inches becoming common, but pixel formats generally top out at XGA or SXGA+ for mainstream computers. A major reason for this was Microsoft as Windows has a lack of convenient scaling of elements such as icons, tool bars, and menus, which scares many users away from UXGA and higher-resolution displays.

This year may not yet be the 'year of the OLED,' but it was clearly the year of OLED (organic light-emitting diode) exhibitors. Dupont, Kodak, Ritek's RiTdisplay Corp., Optrex, Sony, CDT, Covion, Universal Display Corp., Philips Components, eMagin, Opsys, Neoview/Sunic System, and Toshiba-Matsushita Display, among others, were very visible on the show floor. Dow Advanced Electronic Materials was delivering the message that Dow, a CDT licensee, "is poised to become the premier manufacturer of pLED materials." Particularly striking amongst the OLEDs was the refined, very thin version of Sony's 13-inch, 800x600 display. Impressive last year, the display is spectacular this year, with rich, saturated colors. Toshiba-Matsushita Display showed its new 17-inch 1280x768 OLED, decisively taking the "mine is bigger than yours" title from Sony.



The Sharp 8" CGS TFT panel

But OLEDs, DLPs and PDPs aside, my favourite display at the exhibition was a continuous grain silicon (CGS) TFT display on the Sharp stand which incorporated drivers on the CGS backplane. With in excess of 4 million pixels in full colour, the display was a little larger than a postcard showing how soon realistic photograph displays will be with us. The brightness and colour were astounding, however the penalty for the ultra-high resolution was still a slow image update rate.

SID 2003 will be held in Baltimore May 18-23.

**Many thanks to the aerospace man at the bus stop in Boston who educated me on my American English.*

Tim Wilkinson

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Procedures for the Ben Sturgeon Award

Eligibility for the Award

1. Young Scientists or Engineers (under 40).
2. Must have made significant contributions to the displays field over the past 10 years.
3. Ideally the work they are nominated for should be in the liquid crystal display field (this includes all aspects of technology used in LCDs).
4. Under exceptional circumstances nominees from other display areas will be considered. In that case the international value of the work must be clearly demonstrated.

The Nominations

1. Letter of nomination clearly setting out the value of the nominees' work.
2. Additional letters of support are helpful but not essential.
3. CV for the nominee.
4. Publications (papers and patents) list.
5. Copies of key papers.
6. Nominations should be sent to the Chair of SID (UK).

The Role of SID (UK)

1. The SID (UK) Committee will appoint two of its members to the Ben Sturgeon Award sub-committee to review nominations for the Ben Sturgeon Award and make recommendations to the SID Committee.
2. The SID (UK) committee will publicise the award through the SID Newsletter, the SID (UK) Homepage, through EPSRC, DTI and through individual networking.
3. The Ben Sturgeon Award Sub-Committee is responsible for selecting the winner (s). The decision of the Sub-Committee will except in exceptional circumstances (e.g. where the Sub-Committee is unable to come to a majority decision) be approved by the SID (UK) Committee which is responsible for making the award. In any such exceptional case the SID (UK) Committee will make the final selection of the winner based on the information presented by the sub-committee, through a majority vote. In this case the vote will exclude the two SID (UK) nominees to the Ben Sturgeon Award sub-committee.
4. SID (UK) will present the award at their annual autumn conference (usually in association with EID) unless the recipient cannot attend that meeting. In that case SID will make the award at the next SID (UK) Technical meeting.

The Role of BLCS

1. The BLCS committee will appoint two members of the BLCS to the Ben Sturgeon Award sub-committee to review nominations and make recommendations to the SID (UK) Committee. This will allow the BLCS Committee to select the best-qualified people taking into account the candidates nominated. In practice the Sub-Committee members would be appointed from BLCS Committee members provided they have appropriate expertise.
2. BLCS will publicise the award through their Newsletter and the BLCS Homepage, through individual networking and other appropriate routes.

The Role and Constitution of the Ben Sturgeon Award Sub-committee

1. The sub-committee is constituted of two members from the SID (UK) committee and two members from the BLCS committee, selected by the BLCS.
2. One of the two SID (UK) Committee members will be appointed by the SID (UK) Committee as co-ordinator.
3. The SID sub-committee members are responsible for writing the call for nominations in consultation with BLCS.
4. The members of the sub-committee should individually review all nominations and then either meet or through other means come up with recommendations for the award. The recommendations should include a ranking of all the nominations and a justification.
5. In the exceptional case that the sub-committee cannot agree, individual recommendations (with justifications) should be made to the SID (UK) Committee. The Sub-Committee can also recommend two awards being made.

Timetable

Nominate SID Sub-committee members	February
Write call for nominations	March
Issue call for nominations	March/April
Deadline for submission of nominations	June
Appoint BLCS Sub-Committee members	July
Review of nominations	July/August
Sub-committee recommendations	End August
Selection of award winner	Early September
Inform winner	Early/Mid Sept
Publicise Award ceremony (EID)	September
SID order plaque	Mid September
Award ceremony EID	November

Editorial Team

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