THE ANNUAL NEWSLETTER OF THE BRITISH LIQUID CRYSTAL SOCIETY JUNE 2012

BLCS Newsletter

Deep Impact (in Glasgow)

A perspective from the current BLCS Chair,
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Impact in LC science

A couple of interesting conversations at the recent BLCS conference in Glasgow opened my eyes to some of the incredible impact UK liquid crystal science has made, and is still making today.

Some of you may not know that the materials in a typical modern VAN LCD, found in a shiny new tablet or a big liquid crystal TV, are based on negative dielectric anisotropy liquid crystals originally designed and made at Hull University (Toyne, Hird, Goodby). Likewise, the discotic liquid crystals, that are the key to the optical compensation films which make your screen viewable from all angles, are based on discotic materials developed in Hull and Leeds. As Richard Bushby told us in his invited lecture in Glasgow, the same sorts of materials are found as lubricants in modern high performance hard disk drives.

Multi-billion dollar technologies such as these rely on fundamental research. It may be 10 years or 15 years or 20 years down the line before we really see the true "impact" of today's science. But what an impact this original UK work has made!

I take a number of things from these observations. It is hugely important for the UK liquid crystal community to "blow its own trumpet". We should be proud that UK LC research has been so important in shaping the modern world! Secondly, we can move into the future with confidence. The 2012 conference in Glasgow pointed to the exciting work going on in UK liquid crystal science right now in 2012 (and right across the multidisciplinary areas that make our subject so special). The impact of that research is going to be felt across a wide range of areas of life from handheld devices to medicine. Finally, it's important for liquid crystal scientists to get these messages across to the people who fund us. Both EPSRC and the UK government rightly talk about the importance of "impact". The message from this year's BLCS is that the pathways to future impact are clear to see – and it's down to the liquid crystal community in the UK to make sure we get this message across.

A "Fairly Reasonable Scientist"

One of my great pleasures of the BLCS conference 2012 was to introduce a keynote lecture from Professor John Goodby of York University. John's

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amazing work in liquid crystals has long been recognised internationally and nationally. John was the first winner of the BLCS's GW Gray medal. He has also won the Royal Society of Chemistry's Tilden medal and its Interdisciplinary Science Award. John's election, this past year, to the Fellowship of the Royal Society is recognition of the importance of John's contribution to our field of liquid crystals, and also an acknowledgement of the importance of the field itself. Our congratulations go to John! We thank him for the discoveries, the insights and the enthusiasm he's given to liquid crystals; and we look forward to many new insights and discoveries in the future!

BLCS-WW: "The best value for money three days I've ever spent"

Many of you will have met the BLCS Winter Workshop before, either as a lecturer or as a student. It you haven't met it, then its well worth knowing about! The workshop is held annually in Hull over three days and provides fantastic training in all areas of liquid crystals from synthesis, to material properties, to structure, to simulation, through lectures and hands-on training sessions with experts in the field. The workshop is open to students, PDRAs and industry alike. This year's workshop will run from lunchtime Monday 17th December to lunchtime Wednesday 19th December 2012.

Our winter workshop has been run successfully for many years by Dr. Mike Hird, and in the last few years has been generously supported by the EPSRC. Mike is currently in the process of applying again for EPSRC funding to help reduce the costs of attending the school for EPSRC students.

If you are a student working in liquid crystals (or a related area) do please come. Each year we typically have 30-40 students/industrialists on the course but have the capacity to handle even more!

AWARD NEWS

GRAY MEDAL

Article by INGO DIERKING, University of Manchester

Prof Noel Clark receives the 2012 George Gray medal of the British Liquid Crystal Society

The G.W. Gray Medal of the British Liquid Crystal Society is awarded for outstanding contributions to research in the field of liquid crystal science and technology.

Prof Noel A. Clark is one of the most outstanding liquid crystal scientists worldwide. Through his rigorous scientific efforts, he has profoundly influenced liquid crystal research both fundamentally, as well as via applications, for the past four decades. Not only has he realised the "surface stabilized ferroelectric liquid crystal" (SSFLC) together with Sven Lagerwall, he has also opened the door to many applications which are employed today, such as the microdisplays of DisplayTech, which are nowadays produced by the millions every year.

But Noel's interests were always mainly focused on fundamental science. This is primarily evident from his work on liquid crystals, but he has also published significant and substantial work in related areas, such as colloidal crystals, or Raman and IR spectroscopy. Nevertheless, his main achievements are in the field of liquid crystals. Research on Ferroelectric Liquid Crystals (FLCs) would not be conceivable without the contributions of Noel Clark. The above mentioned SSFLC state provided the basis of all applications of ferroelectric liquid crystals. The characterisation of chevrons and their avoidance via deVries behaviour, was a great step towards

FLC applications. In the last decade or so, Noel has devoted much attention towards bent-core, or so called "banana" molecules, which exhibit chiral effects, without themselves being chiral.

But besides the enormous contributions listed above, not everybody knows that Noel Clark also significantly contributed to many other areas of liquid crystal research, such as lyotropic membranes, LCs in confined geometries and free standing films. Noel Clark continues to work hard at present. In recent years he has actively been involved in the new field of DNA LC phases together with Tommaso Bellini.

HILSUM MEDAL

Article by INGO DIERKING, University of Manchester

Prof Doug Cleaver receives the 2012 Cyril Hilsum medal of the British Liquid Crystal Society

The C. Hilsum Medal of the British Liquid Crystal Society is awarded to members of the Society, normally working in the UK, for contributions to liquid crystal science and technology.

Doug Cleaver has contributed largely to the field of computer simulations of liquid crystals. His contributions are not limited to standard computer simulations of the structure and occurrence of different phases, but also to systems of confined geometries, and thin films. He has proposed and implemented extensions and generalizations of modelling potentials, modelled phase transitions, physical properties of liquid crystals, such as elasticity, but also physical properties in relation to substrates, for example anchoring transitions of liquid crystals on patterned substrates. Doug has further applied modelling techniques to investigate amphiphilic self-organised systems.

In addition, Doug is very engaged in public awareness events to promote science in general and liquid crystals in particular to the general public, and especially to school pupils.

YOUNG SCIENTIST AWARD

Article by INGO DIERKING, University of Manchester

Dr Apala Majumdar from the Oxford Centre for Collaborative Applied Mathematics of the University of Oxford received this years Young Scientist Award of the British Liquid Crystal Society for her rigorous mathematical treatment of the physics of nematic liquid crystals, fundamental aspects of continuum theory and multi-scale modeling approaches, especially also to applied systems.

The BLCS Young Scientist Award is normally presented annually for significant research contributions to the field of liquid crystals. Candidates are normally within 10 years of beginning their PhD and are active members of the Society, working in the UK at the time of their nomination.

(See page 8 for the Young Scientist Award Lecture article)

John Goodby elected Fellow of the Royal Society in 2011

Article by VERENA GÖRTZ and PETER RAYNES, University of York

We were all incredibly delighted when it was announced last year that John Goodby had been elected a Fellow of the Royal Society.

John's research began at the University of Hull under the guidance of George Gray. His thesis, simply entitled "Smectic Liquid Crystals", laid many of the foundations for our present-day understanding of the chemical aspects of structures, classification, and properties of smectic liquid crystals. Charged with investigating the relationship between chemical structure and the formation, stability and properties of smectic C liquid crystals, the initial compounds he synthesised gave rise, unexpectedly, to examples of stacked hexatic (smectic B) phases, which were the first experimental 3-D examples of the Halperin and Nelson theoretical model of melting in two-dimensions. As a consequence of John's work, the expressions *bond orientational order* and *hexatic phases* have entered the vocabulary of those working in the fields of liquid crystals, self-assembled monolayers, and superconductors. Other aspects of his PhD work focused on tilted smectic phases, in particular the smectic C phase, but also on the first tilted hexatic phases, the smectic F and I phases, the structures for which were later investigated in detail by Alan Leadbetter, and the discovery of the soft-crystal J and K phases. In addition to working on the synthesis and the study of the optical and thermal properties of liquid crystals, he resolved the classification of smectic phases, which was in some confusion at the time, to give the system of nomenclature that is still in use today. Much of his research on smectic liquid crystals was captured later in 1984 in a highly cited textbook entitled 'Smectic Liquid Crystals: Textures and Structures', John wrote with George Gray.

After two years post-doctoral research, John moved to the USA in 1979 to undertake research in liquid crystals at AT&T Bell Laboratories. Here, many of his seminal contributions to the field were generated through his collaborative work with physicists such as Ron Pindak, Pat Cladis, Alan Kmetz, Alistair Glass and Jay Patel. John initiated a new programme directed at the design and synthesis of materials that were expected to exhibit chiral smectic C* phases and set about the task of developing design parameters for new ferroelectric liquid crystals for display devices. John was also involved with physico-chemical methods of aligning liquid crystals on polymer substrates and, with Patel, Kmetz and Geary, he developed a method of using buffed thermoplastic polymers to align smectic LCs through epitaxial growth from the liquid state. This seminal work led to a fundamental understanding of the mechanism of alignment of liquid crystal systems by shearing thermoplastic polymers.

John's work at Bell Laboratories also saw his first venture into the investigations of molecular chirality in liquid crystals. This work led directly to his seminal discovery of the twist grain boundary (TGB) smectic A* phase. The possibility of incorporating edge and screw dislocations into smectic phases was described theoretically first by de Gennes and later added to by Renn and Lubensky. John was unaware of this theoretical work and had independently recognized the presence of a new phase – indeed a new state of matter, and understood its structure and properties.

In 1988 John returned to the University of Hull, taking over as Head of the Liquid Crystal Group when George Gray retired in 1990. Much of his work on ferro-, ferri-, and anti-ferroelectric liquid crystals and the synthesis of the first achiral anticlinic systems was carried out at Hull. He became involved in the development of materials for large area displays, liquid crystal on silicon (LCOS) devices for light projection and for applications in head-up displays for pilots (with MoD/DERA). His research on the NLO properties of liquid crystals was extended to the examination of high birefringence nematic materials for laser deflectors, telecommunications switches and phase modulators. Although much of John's work focused on calamitic liquid crystals, he had a continuing interest in discotic liquid crystals that could exhibit nematic or columnar ordering. During his research at Hull he became interested in designing materials with disc-like structures that would form nematic phases and created derivatives of triphenylene. His materials are widely used by industry in optical compensation films to provide wide viewing angles for LCDs for monitors, laptop computers, TVs, etc.

John moved to York in 2005 to take up the Chair of Materials Chemistry. At York he has focused on chiral effects in racemates and non-chiral materials, and with his group he has shown that so-called 'racemic smectic C phases' can be reoriented in applied electric fields, and that the nematic phase in bent-shaped, non-chiral materials can exhibit chiral domains through the process of enantio-segregation of conformers—a Pasteur-like effect in a liquid. Over the last ten years John has turned his interests towards super- and supra-molecular LCs which combine aspects of mono-disperse dendrimers with those of giant molecular materials of discrete primary structure. For example, his collaborations with Georg Mehl and Isabel Saez, have produced chiral and non-chiral mesogenic dendritic materials based on silsesquioxane, fullerene, and pentaerythritol scaffolds that have yielded low temperature nematic and ferroelectric phases and fascinating novel tubular nematic columnar phases.

John has been extensively involved in commercialisation of his research. Several of these spin-out activities have not even involved liquid crystals. This includes research with Alan Hall on novel UV curing systems based on the cyclopolymerization of substituted dienes, in particular diallylamines, yielding polymer networks for stealth coatings and adhesives; the development of gel dosimeters for use as patient phantoms in intensity modulated radiotherapy (IMRT) and brachiotherapy treatments of cancer; and biomedical polymer materials in collaboration with Smith and Nephew. However, John's most enduring spin-out activity has been with Kingston Chemicals Ltd, which he set up when at Hull University with Mike Hird.

Finally it is important to note John's service to the science community through his Chairmanship of the British Liquid Crystal Society and Presidency of International Liquid Crystal Society. He has contributed much to the world through his seminars, training courses, books and reviews, and through public awareness of science programmes to both children and adults. In addition, he has also brought his science into the world of art through his exhibitions of liquid crystal textures and collages. He was a founding member of the Editorial Board of the Journal of Materials Chemistry, which has become, after Chemical Communications, the journal with the highest impact factor of the Royal Society of Chemistry. Thus with over 30 years in research which has been realised in over 400 published papers, two books, several edited texts, over 50 patents, and graduating over 30 PhD students, John Goodby has contributed immensely to the fabric of British Science, Industry and Society.

John commented on his election with typical modesty: "All manner of emotions and thoughts went through my mind when I heard this news—family and friends foremost, but also the support and deep friendships with my 'Liquid Crystal' colleagues in the UK and around the rest of the world. You can't reach for the sky without brilliant and innovative research students and post-doctoral research fellows, and inspirational academic, industrial and management friends. I am indebted to them and hope that they too will share in the pleasure of this award."

We both are fortunate enough to have first-hand experience of exploring the scientific world with John and believe the following extract from the citation of his Honorary Doctorate from Trinity College Dublin to be most appropriate: "In this complex scientific field Dr Goodby, an investigator of great application and insight, has made major advances and discoveries. He is a master in this border territory between physics, chemistry, and biology, and offers the possibility of progress to all three."

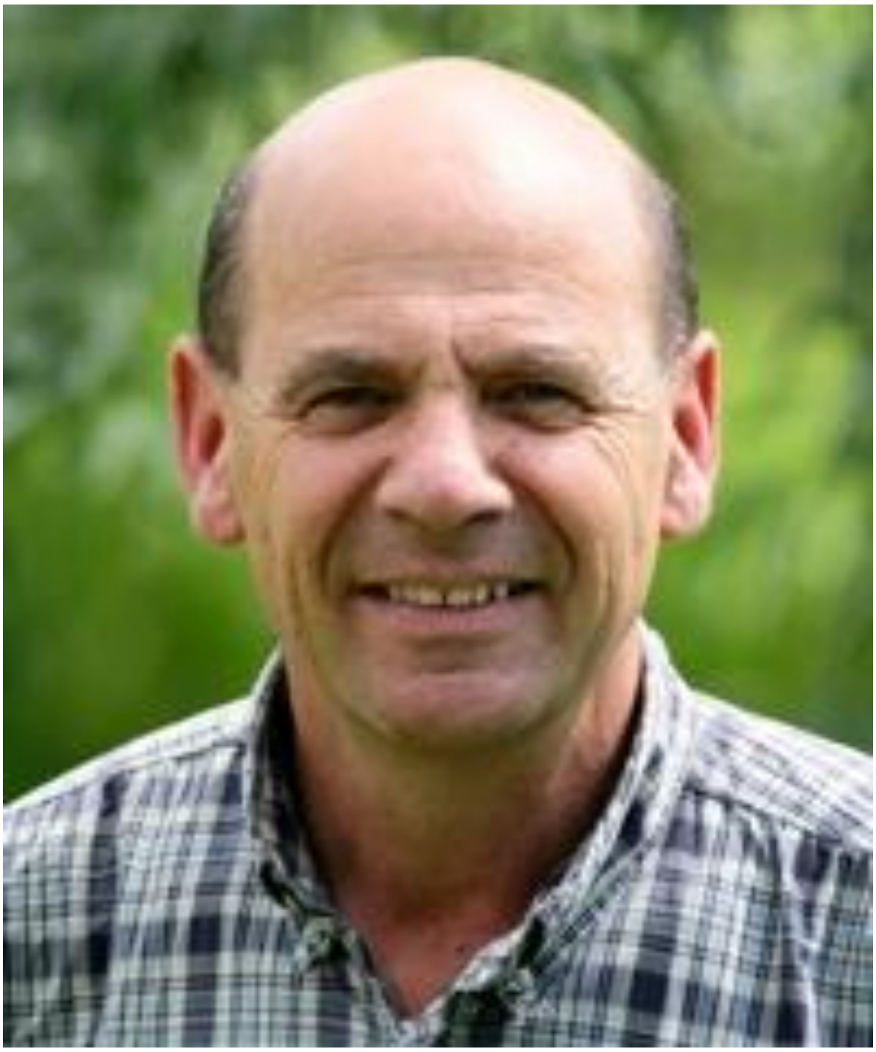
Congratulations John!

Helen Gleeson awarded Holwick Medal and Prize

Professor Helen Gleeson has been awarded the 2012 Holweck Medal and Prize, a bilateral prize of the Institute of Physics and the French Physical Society. The award was instituted in 1945, jointly by the French and British Physical Societies as a memorial to Fernand Holweck, Director of the Curie Laboratory of the Radium Institute in Paris, who was tortured and killed by the Gestapo during the occupation of France 1940-44. The award is made in alternate years by the Councils of one of the two societies to a physicist selected from a list of nominees submitted by the other.

Mark Warner elected Fellow of the Royal Society in 2012

Article by EUGENE TERENTJEV
University of Cambridge



Liquid crystal elastomers, which can be regarded as networks of polymers with directional ordering or as liquid crystals with cross linking, have many new properties hitherto unknown to classical elasticity, liquid crystals and rubber. For instance, large thermo and photo-mechanical response is at the core of a new class of reversible actuators, liquid-like shape changes with no or little elastic energy response of a solid rubber to deformation leads to unique concepts of engines, polarised acoustics and vibration damping, mechano-chiral response and soft ferroelectric solids could change the way photonic and low-current power-generating devices work. Mark Warner is one of the founders of the field of Liquid Crystal Elastomers. This massive achievement in discovering and analysing these properties has been a natural synthesis of his earlier interests in liquid crystals, polymers and networks, where he has pioneered much of the statistical mechanical understanding of polymer liquid crystals. His work has defined a whole new field of condensed matter physics and applied mathematics with great potential for device engineering exploiting novel mechanics. It has inspired experiment and theory in a large number of groups internationally in chemistry, physics, mathematics and engineering, as well as in industry.

In conventional elasticity, stress and hence energy is required to change volume (in liquids and solids) or shape (in solids only). Rotations are elastically irrelevant, spontaneous shape changes due to thermal expansion are small and other factors, such as chirality, have quite negligible mechanical or electrical influence. Mark has conclusively demonstrated that liquid crystal elastomers form a new class of solids disobeying all these rules and requiring sophisticated and subtle extensions of elasticity theory. For the type of deformation proceeding in these elastomers without energy cost via locally rotated states with complex shears and rotation patterns, he has introduced with Terentjev the term “soft elasticity” that is now in wide and frequent use. Having with Finkelmann discovered the large reversible shape changes that can be induced optically in liquid crystalline elastomers doped with dye molecules, Warner has analysed this remarkable phenomenon in great detail, modelling the complex nonlinear aspects arising from surface bleaching at high light intensities. With the exquisite optical control over mechanical response, the subject of photo-actuators is now actively pursued at both the macro and nano-scale level in many laboratories worldwide. His definitive book on “Liquid Crystal Elastomers” written with Terentjev is a brilliant introduction to this exciting new area, in line with Warner’s passion for effectively communicating his ideas and enthusiasm to a wider audience.

We are all very pleased by the election of Mark Warner into the ranks of Fellows of Royal Society, which is a most positive reflection on his work, as well as on the broader field of soft matter and liquid crystals.

REPORT: British Liquid Crystal Society Annual Meeting 2012

Article by FLYNN CASTLES (University of Cambridge, email: fc252:cam.ac.uk)

This year's Annual Meeting of the British Liquid Crystal Society was held from 2nd–4th April at the University of Strathclyde. The event continues to provide a focus for liquid crystal science in the UK, an opportunity to disseminate the latest research, and the chance to make new acquaintances and catch up with old colleagues.

Attendees of the BLCS Annual Meeting enjoy the conference dinner at Barony Hall

The programme listed 81 participants from both academia and industry, whose background reflected the interdisciplinary nature of the field (Chemistry, Engineering, Mathematics, Materials Science, and Physics departments were represented). Over the three days, a total of 25 talks and 27 posters by researchers at British institutions attested to the continuing strength of the field in the UK. The programme was enhanced by two internationally renowned researchers: Alejandro Rey (McGill University), who gave the Ben Sturgeon Lecture, entitled "Capillary Models for Liquid Crystal Fibres, Membranes, Films, and Drops", and Noel Clark (University of Colorado), who was honoured by the Society with the G. W. Gray medal (see page 2).

Invited talks were given by Carl Brown (Nottingham Trent University), Tanniemola Liverpool (University of Bristol), John Goodby (University of York), Richard Bushby (University of Leeds), and Tim Wilkinson (University of Cambridge). The Young Scientist Award Lecture was given by Apala Majumdar (University of Oxford), who gave an overview of her work on the mathematics of liquid crystals that led to her award (see pages 3 and 8-12). Bai Jia Tang (University of Hull) won the best oral presentation award for his talk "Synthesis and characterization of the self-assembly of mesogen coated gold nanoparticles). The poster session provoked lively discussion. Phil Hands (University of Cambridge) was awarded the best poster prize for his work "Compact, inexpensive and widely-tuneable liquid crystal lasers", together with his live liquid crystal laser demonstration. An entertaining Closing Plenary was provided by John Lydon (University of Leeds), complete with poem (see page 18).

The AGM, charied by Mark Wilson (Durham University) saw a no-nonsense presentation of the accounts, and the election of new committee members (see p17 for a list of the new committee). Ingo Dierking (University of Manchester) was elected to the position of Vice-Chariman. The conference dinner was held in the grand surroundings of Barony Hall (pictured). I believe all in attendance will join me in thanking the organisers and catering staff for a fine meal. After dinner speeches were given by the Chariman, Mark Wilson, the Gray Medal winner, Noel Clark, and the Hilsum Medal Winner, Doug Cleaver (Sheffield Hallam University). Later, drinks were had at the hotel bar. (Including a wee dram or two of Scotch for some. When in Strathclyde….)

A huge thank you must go to the meeting organisers, in particular Nigel Mottram and Mary McAuley, for all their time and effort devoted to making the meeting such a success.

The mathematics of liquid crystals: analysis, computation and applications

The British Liquid Crystal Society Young Scientist Award Lecture article

APALA MAJUMDAR (University of Oxford, email: majumdar@maths.ox.ac.uk)

Section I: Introduction

Liquid crystal science has grown tremendously in recent years for fundamental scientific reasons and widespread liquid crystal applications in industry and technology, e.g., display devices, optical devices and biological sensors. The mathematical theory of nematic liquid crystals is very rich, spanning diverse fields such as the theory of partial differential equations, theory of multiscale systems, algebraic topology, combinatorics and scientific computing [1,2,6]. These mathematical tools can be used to address cutting-edge questions in liquid crystal science and industry, such as the structure and evolution of topological defects, microscopic to macroscopic derivation of liquid crystal theories, modelling of liquid crystal devices and theory of biological liquid crystalline systems. It is, thus, timely to develop and promote a two-way feedback system between rigorous mathematical theory and novel liquid crystal applications, since mathematics can not only explain observed physical phenomena but also give new physical insights originating from rigorous theory.

Liquid crystals, like most physical systems, are inherently multiscale and can be modelled on at least four different scales: (i) atomistic, (ii) molecular, (iii) mean-field and (iv) macroscopic/continuum length scales [4,6]. Continuum theories are the least detailed and yet the most popular in the modelling and mathematical communities. This is primarily because continuum approaches are the most amenable to mathematical analysis and computationally inexpensive compared to microscopic approaches. In particular, continuum approaches are widely used for the modelling of liquid crystal displays (LCD) [3,9,11].The working principle of any LCD is simple to understand: the cell geometry must be able to support a bright/transparent and a dark/opaque state [5,11]. Conventional LCDs are monostable in the sense that only one of the optically contrasting states is stable in the absence of an electric field and a constant source of power is needed to maintain the bright and dark states simultaneously. Recently, there has been a lot of industrial momentum in the development of bistable display technology [5,11]. Bistable LCDs typically use a combination of complex surface morphologies and surface treatments to stabilize multiple optically contrasting states in the absence of an electric field. As a consequence, power is only needed to facilitate the switching mechanisms in a bistable LCD but not to maintain static images. Examples of bistable LCDs include the Zenithally Bistable Nematic Device (ZBND) and the Post Aligned Bistable Nematic Device (PABN) [9].

The working mechanisms of bistable LCDs are poorly understood, especially in the context of cell geometry and boundary treatments, i.e., what makes a given cell geometry bistable? Industrial researchers are interested in understanding the effects of geometry and material properties on (a) the structure and optical properties of the low-energy stable states and (b) switching characteristics of the bistable device. Mathematically, these modelling questions are related to generic issues about the topological classification, existence of multiple equilibria, their energetics and stability in three-dimensional polyhedral geometries [8,9]. This paper is organized as follows. In Section 2, we review coarse-grained mathematical theories for nematic liquid crystals: their strengths and limitations. In Sections 3 and 4, we discuss applications of continuum theories to novel bistable LCDs such as the PABN device [9] and planar liquid crystal wells reported in [11], followed by some brief conclusions in Section 5. These results have been published in a batch of joint papers and we review the main mathematical ingredients in this review paper; all relevant work is cited throughout the text.

Section 2: Review of Liquid Crystal Theories

In this section, we review coarse-grained mesoscopic and macroscopic liquid crystal theories: (i) mean-field Maier-Saupe theory and (ii) continuum Oseen-Frank and Landau-de Gennes theories for liquid crystals [4,6]. These theories are coarse-grained, in the sense, that they are relatively computationally inexpensive and contain no information on the atomistic or individual molecular scale. Further, these theories are examples of variational theories with associated energy functionals. The physically observable states or static equilibria correspond to either local or global energy minimizers subject to the imposed boundary conditions.

The Maier-Saupe theory describes the state of alignment of a nematic liquid crystal by a probability distribution function, ρ, for the molecular orientations [4]. The macroscopic variables are defined in terms of the moments of ρ and the mean-field **Q**-tensor order parameter is defined to be the normalized second moment of ρ [1,6]. The second moment definition naturally constrains the eigenvalues of **Q**, denoted by λ(**Q**), to be bounded within the range

$$\frac{-1}{3} \leq \lambda(Q) \leq \frac{2}{3}$$

Continuum theories, such as the Oseen-Frank and the Landau-de Gennes, contain no information about either the probability distribution function ρ or the molecular properties. The macroscopic order parameters are defined in terms of anisotropic macroscopic average quantities such as the dielectric anisotropy and magnetic susceptibility [4]. In contrast to the mean-field case, there are no natural bounds on the macroscopic order parameters. The Oseen-Frank theory is the simplest continuum theory for nematic liquid crystals restricted to purely uniaxial materials with a constant degree of orientational ordering [4,8]. In the Oseen-Frank framework, the state of alignment of the molecules is described by a unit-vector field **n**, where **n** is an average measure of the preferred direction of molecular alignment in space. The Oseen-Frank free energy is given by

$$E[n] = \int K_1(\nabla \cdot \mathrm{n})^2 + K_2(\mathrm{n} \cdot \nabla \times \mathrm{n})^2 + K_3(\mathrm{n} \times \nabla \times \mathrm{n})^2 + (K_2 + K_4)\left(tr(\nabla \mathrm{n})^2 - (\nabla \cdot \mathrm{n})^2\right) dV$$

where the K_i's are material-dependent elastic constants. The static equilibria are local or global minimizers of the Oseen-Frank energy, subject to the imposed boundary conditions.

The Landau-de Gennes theory is one of the most general continuum theories for nematic liquid crystals, since it can account for both uniaxiality and biaxiality along with all physically observable singularities [2,4]. The macroscopic Landau-de Gennes **Q**-tensor order parameter contains information about both the degree and directions of orientational ordering. The Landau-de Gennes theory is also a variational theory and the associated energy density is a nonlinear function of the **Q**-tensor order parameter and its spatial derivatives.

$$I[Q] = \int f_B(Q) + w(Q, \nabla Q)\, dV$$

It remains an open problem to rigorously mathematically describe or quantify the non-equilibrium dynamics and intricate defect patterns within the Landau-de Gennes framework.

On the one hand, the Maier-Saupe theory is restricted to purely uniaxial phases and cannot account for either non-equilibrium phenomena or spatial inhomogeneities. On the other hand, the Landau-de Gennes theory makes physically unrealistic predictions for temperatures below the nematic-isotropic transition temperature [10]. For example, for the commonly used liquid crystal material MBBA, the Landau-de Gennes theory predicts large values for the equilibrium scalar order parameter (larger than unity) when we move to temperatures just 2°C below the nematic-isotropic transition temperature [10]. In [1], we propose a new theory that interpolates between the Maier-Saupe theory and the Landau-de Gennes theory and hence, retains mean-field level of detail in a macroscopic framework. Of key importance is the definition of a new bulk potential

$$\Psi_B(Q) = \left(\min_{\rho \in A} \int_{S^2} \rho(s) \ln \rho(s)\, ds \right) - \kappa |Q|^2$$

$$A = \left\{ \rho \in L^1(S^2);\ \int_{S^2} \left(p_i p_j - \frac{1}{3}\delta_{ij} \right) \rho(s)\, ds = Q \right\}$$

which determines the optimal microscopic state corresponding to a given macroscopic state and demonstrates a logarithmic divergence whenever one or more of the eigenvalues approach the limiting values, -1/3 or 2/3. Consequently, the stationary points or the static equilibria respect the mean-field constraints, -1/3≤ λ(**Q**) ≤ 2/3, in all temperature regimes, yielding physically realistic predictions for all temperatures. More details can be found in [1].

Section 3: The Post Aligned Bistable Nematic Device

The Post Aligned Bistable Nematic (PABN) device is a three-dimensional (3D) bistable cell manufactured by Hewlett Packard Laboratories [5,9]. The PABN cell consists of a liquid crystal layer sandwiched between two solid substrates and the bottom substrate is featured by a periodic array of 3D microscopic posts. The top surface is treated to have homeotropic/normal boundary conditions whereas the bottom surface and the post surfaces are treated so as to induce planar degenerate or tangent boundary conditions. Experimental observations and optical modelling suggest the existence of at least two stable optically contrasting states: an opaque **high-tilt** state and a transparent low-tilt **planar** state.

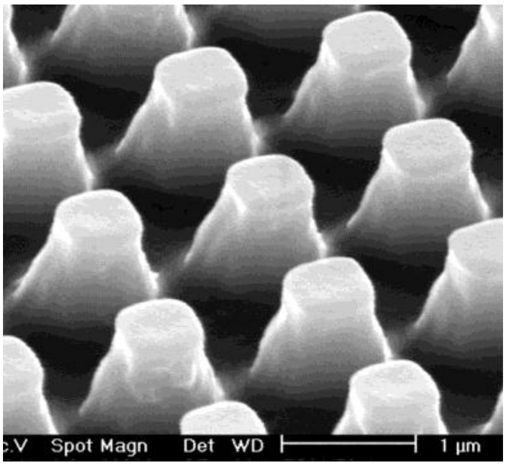


Figure 1: The PABN device [5].

We develop a simple mathematical model for the PABN device wherein we treat each microscopic post to be a perfectly rectangular post, neglecting factors such as post tilt and curvature. We work within the simple Oseen-Frank theoretical framework so that the modelling variable is a unit-vector field or director field **n**, as stated in Section 2. For simply-connected geometries (such as the PABN cell), the director field (**n** ↔ - **n**) and the unit-vector field representations are equivalent [2]. The tangent boundary conditions mean that on any post face, **n** is constrained to take its values in the plane of the face so that on the edges, **n** is necessarily either parallel or antiparallel to the edges and hence, discontinuous at the vertices.

The first step is a complete topological classification of the admissible tangent unit-vector fields around the post geometry [8, 9]. The tangent unit-vector fields are partitioned into different equivalence classes and we expect to find a local energy minimizer in each equivalence class. Such topologically distinct local energy minimizers, if they exist and have similar free energies, naturally induce bistability in prototype devices.

We identify four minimal topologies in the PABN cell; these topologies are minimal in the sense that they have minimal distortion consistent with the boundary conditions and are expected to support the minimum energy ground states. The four topologies are distinguished by the orientation of **n** on the four vertical post edges. We label the four topologies by {T, P_1, P_2, P_3}, where T denotes the tilted topological class and P_1, P_2, P_3 are three different candidates for the planar topological class. We take **n** to be oriented upwards on all vertical edges in the 'T' case whereas **n** continuously interpolates between upwards and downwards in the 'P' cases. A continuous interpolation between upwards and downwards necessarily creates an intermediate planar region on the post faces. Thus, we treat the 'edge orientations' on the vertical edges as topological parameters and by appropriate choices of the edge orientations, we can successfully generate 'tilted' and 'planar' topological classes.

Given these four topological classes, the next step is to construct explicit initial conditions and numerically compute local energy minimizers with these topologies. We have constructed explicit representatives for the four cases {T, P_1, P_2, P_3} and used these representatives as initial conditions for a finite-element solver [9]. Our simulations demonstrate the existence of four topologically distinct low-energy states in the PABN geometry (see Figure 2) that mimic the tilted and planar states in terms of their energetics and morphologies. These topologically distinct local energy minimizers are naturally separated by an energy barrier that leads to their long-term stabilities. Moreover, these states have comparable energies over a range of post heights, $h \in [0.5\,L, 0.9\,L]$, where L is the post cross-sectional length. This bistable range is commensurate with experimental observations.

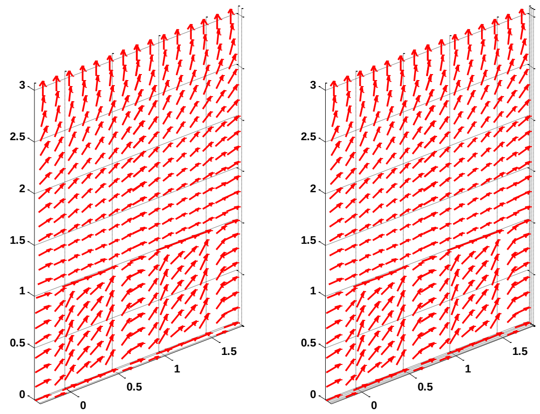


Figure 2a: Numerical simulation of the T solution between pairs of neighbouring posts [9].

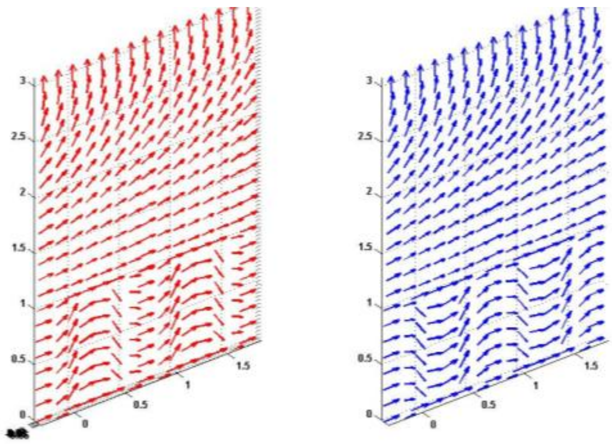


Figure 2b: Numerical simulation of the P_3 solution between pairs of neighbouring posts [9].

In summary, we have proposed a simple mathematical model for the PABN geometry that elucidates a novel topological mechanism for bistability in 3D geometries. These methods can be further developed to study non-equilibrium behaviour in the presence of an external electric field with special reference to optical contrast, switching characteristics and response times.

Section 4: Planar bistable liquid crystal wells

In this section, we describe the modelling aspects of a two-dimensional bistable LCD, comprising of a periodic array of micro-meter sized liquid crystal filled wells [7,11]. The well surfaces are treated to induce tangent boundary conditions so that the molecules, in contact with these surfaces, have to be in the plane of the surfaces. The well height is typically much smaller than the cross-sectional length and hence, one can neglect structural variations across the height of the cell and focus on the alignment profile on the bottom well surface. Experimental observations and numerical modelling indicate the existence of two topologically distinct stable equilibria: (i) **diagonal** state where the nematic molecules roughly align along one of the square diagonals and (ii) **rotated** state where the alignment direction rotates by p between a pair of parallel edges; see Figure 3 below.

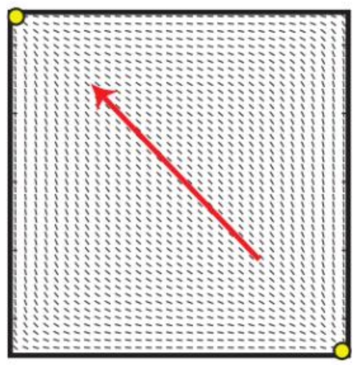


Figure 3a: Diagonal State [11].

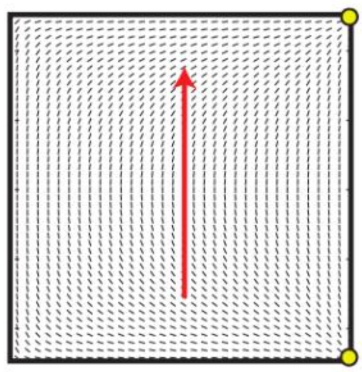


Figure 3b: Rotated State [11].

We model this bistable device within the Landau-de Gennes theory of nematic liquid crystals wherein the alignment profile is mathematically described by the Landau-de Gennes **Q**-tensor order parameter [7]. The Landau-de Gennes energy density consists of three components: bulk energy density which dictates the preferred phase of the liquid crystal material, elastic energy density which penalizes spatial inhomogeneities and surface anchoring energy density parameterized by anchoring coefficient W>0. We compute bifurcation diagrams for the static equilibria as a function of the anchoring coefficient W. There are six distinct static equilibria for $W \geq W_c$, where W_c is a critical anchoring coefficient that can be estimated numerically. Preliminary numerical investigations indicate that W_c scales linearly with the material-dependent parameter $\varepsilon = \sqrt{(K/CL^2)}$, where K is an elastic constant, C is a bulk constant and L is the square dimension. Of the six static equilibria, two are labelled as diagonal and four as rotated based on their alignment profiles. The diagonal states exist for all $W \geq 0$ whereas the rotated states exist for $W \geq W_c$. Moreover, as $W \to 0$, the diagonal states degenerate to the constant solutions, $\theta = \pi/4$ and $\theta = 3\pi/4$, respectively (θ is the director angle with respect to the x-axis, as per convention).

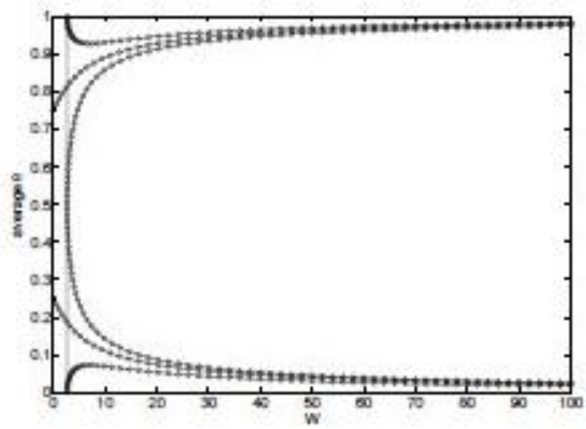


Figure 4: Bifurcation diagram for the static equilibria as a function of the anchoring strength W [7].

We propose a simple model for the switching characteristics of this device based on dielectric effects and the concept of variable anchoring strength [7]. This model does not account for either fluid flow or viscous dissipation. We make the anchoring strength ten times weaker on one of the square edges compared to the remaining edges and the non-uniform anchoring facilitates switching on application of an external electric field. The switching mechanism proceeds by firstly, breaking the anchoring on the weak edge in the presence of an electric field and secondly, re-alignment on withdrawal of the electric field. It is possible that the switching can be much improved, with lower critical voltages and faster response times, by including back-flow effects.

Section 5: Conclusions

In this paper, we give some examples of how simple mathematical models can yield novel insight into operating mechanisms of bistable LCDs, e.g., novel topological mechanisms for bistability, nature of switching mechanisms, critical material parameters, critical voltages and switching times, etc. This mathematical insight can be used for the optimization of modern liquid crystal devices and the design of new devices for specific applications, necessitating continuous cross-disciplinary collaborations between theoreticians, experimentalists and industrial researchers.

Acknowledgments: The author thanks Carl Brown, Nigel Mottram, and Epifanio Virga for very helpful discussions. The results quoted in this review paper have been published in peer-reviewed articles. A. Majumdar is supported by an EPSRC Career Acceleration Fellowship EP/J001686/1, Award No. KUK-C1-013-04 made by King Abdullah University of Science and Technology to the Oxford Centre for Collaborative Applied Mathematics and a Keble Research Fellowship, University of Oxford.

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REPORT: British Liquid Crystal Society Winter Workshop 2011-2012

Article by MIKE HIRD (University of Hull, email: m.hird@hull.ac.uk)

The British Liquid Crystal Society Winter Workshop was held in the Department of Chemistry at the University of Hull from lunchtime Monday 9th January to lunchtime Wednesday 11th January 2012. Until a few years ago, the Workshop was always held in December just before Christmas, however, the University terms dates dictated a move to early New Year. This new time is certainly proving successful and will be continued in future as far as possible. However, the University has changed policy on semester times yet again, and for 2012-2013 the Workshop will be held at the University of Hull, Department of Chemistry from lunchtime Monday 17th December to lunchtime Wednesday 19th December 2012! A return to January in 2014 should be possible since an adjustment of a week in semester times will occur!

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 dendrimers/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 the popularity of the Workshop is being maintained at an excellent level. The total number of delegates of 36 was lower than last year (41), but completely consistent with the long-running numbers of recent previous years (30, 36 and 37). This year four industrial delegates attended (two from Merck and two from Sharp) which is very pleasing and compares well with the five industrial delegates of last year. A total of 32 academic delegates (including 12 non-residential academic delegates from Hull) attended. All delegates seemed to enjoy themselves, and I am sure that they all benefited from the wide and varied academic and social programmes.

Generous EPSRC funding has assisted in the operation of the Workshop for the past six events, which has covered the cost of attendance for all students registered with a UK university. All other academic delegates and industrial delegates made a payment of £130 and £240 respectively.

The EPSRC funding has now ended, and a further application is about to be submitted. Whilst it is intended to operate the Workshop at the University of Hull, Department of Chemistry from lunchtime Monday 17th December to lunchtime Wednesday 19th December 2012, I cannot give any guarantees of the pricing structure. If the EPSRC funding application is successful then the current pricing structure will continue, but if the funding application is not successful, then a complete re-assessment will be required. I will keep you all informed through the BLCS.

REPORT: 2nd International Symposium on Liquid Crystals 2011

Article by BEN OUTRAM (University of Oxford, email: Benjamin.outram@eng.ox.ac.uk)

Ben is a PhD student at the University of Oxford. He was awarded a BLCS bursary to attend the conference.

Set against China's rapid economic and scientific development, the 2nd International Symposium on Liquid Crystals: Science and Technology (LCST 2011) was held between the 17th and 19th of July, bringing together a range of disciplines and academic and industrial research from over 13 countries in the city of Changzhou. I was fortunate enough to be in attendance, and present my research to an engaging audience consisting of some of the most accomplished scientists in the field of liquid crystals. Here I will give my personal take on some of the material that I found most caught my imagination.

Slobodan Zumer from the University of Ljubljana in Slovenia opened the discussion with a talk on colloidal dispersions and confinement in blue-phase systems. Particularly, he focussed on their future application for the self-organisation of microstructures, and how the stability of the phase can be enhanced by the introduction of suitable particles. When the famous liquid crystal scientist Frederick Charles Frank first encountered the blue-phases, he apparently said that they are probably useless except for one intellectual purpose: to bring an example of a topological oddity to science, which has been a topic of study in mathematics for years. With this quote, Zumer used his talk in part as a platform to encourage people to continue in curiosity-driven liquid crystal science, reminding us that discoveries and applications are often unpredictable.

This sentiment was echoed in the next talk given by D. Guillon from France, who described how main-chain liquid crystalline co-elastomer systems bridge the gap between liquid crystal fluidity and elastic and solid materials. With the research and understanding of these materials, who knows what applications will be developed? Indeed, there was in general a very positive and philosophical undertone to the conference with regards to the future that was refreshingly thoughtful, and something not often encountered at these events.

A novel photo-alignment technique was expounded by Mohammed Ibn-Elhaj from Rolic Technologies Ltd., Switzerland, with a focus on use of the technology in large generation displays. Key features of the technology include its uniform alignment potential, alignment patterning with a resolution of 10 nm, precise control of anchoring angle, and even anchoring strength. We will see how the process is used in technology, but its applications in research are certainly also intriguing.

Satyendra Kumar from Kent State University in the USA came under fire in a battle between opposing theories about the behaviour of deVries Smectics, which have the potential for developing defect-free ferroelectric display technologies. DeVries Smectics undergo unusually small layer spacing changes when transissioning from the SmA to the SmC phase. Kumar's research suggests that this is because the deVries SmA phase already has molecules that are tilted in the layer, albeit without directional order, hence giving the phase SmA symmetry. The audience member challenged this theory, instead suggesting that the molecules in the SmA phase are not tilted, but have a degree of interdigitation which accounts for the smaller layer spacing with respect to the SmC phases. A conclusion was not reached and the chair was forced to intervene. Oh the drama of liquid crystal science!

Quan Li also from Kent State University began his lecture with the captivating title "Self-organized Liquid Crystals: From Dynamic Photonics to Renewable Solar Energy", with the subtitle; "The Beauty of the Nanoscale". What was to follow was a fascinating and thought provoking description of liquid crystals and an all-too-brief introduction to the vast amounts of work completed in realising a cool flexible photo-addressed liquid crystal display, among other applications. The technology uses clever chemistry, allowing the twisting power of a chiral dopant to be controlled by flipping the dopant molecule between cis- and trans- variants using UV and visible light. He touched upon other futuristic liquid crystal technologies which go well beyond displays: self-organising semi-conductors and self-healing photovoltaics. Maybe liquid crystals will play an important role in the energy challenges facing the future. Li certainly thinks so.

The poster sessions and other talks revealed a wealth of other fascinating research. Amongst it was research on dipeptide gels which have unusual effects on liquid crystal elastic properties by G. Nair from the Centre for Soft Matter Research in India, luminescent liquid crystals by Y. Huang from Changzhou University who were hosting the conference, and development of a transflective dual-mode liquid crystal display utilising a pi-cell by C. Chen from Shanghai Jiao Tong University.

The conference was, for me, a great opportunity. It was a platform for my brain to tackle hundreds of new ideas in the field of liquid crystal science, to widen and deepen my understanding and give me new avenues for creative exploration in my own research. It was a place for connecting with a world of liquid crystal scientists, to get my face seen and my science heard, and to initiate relationships that will undoubtedly be beneficial to the field and to my own development. It gave me a first true sense of heading to the forefront of the continuing contribution to the sphere of human knowledge. I left the conference with a new motivation, a new excitement, and renewed aspiration. I am extremely grateful for the doors that have opened to me with the help of the BLCS conference travel grant, and encourage other students in the field take advantage of it. Attending the conference was far more valuable than I imagined, and its value will continue to benefit well into the future.

Picture this! A crystal clear future....

NATHAN THOMPSON, LAURA HEWITT, ANNA-JADE ANDREWS, OLIVIA FRARY, LAURA SHUKER, and EMMA PHILLIPS, from Baysgarth Secondar School report on a liquid crystal science project run by STEPHEN COWLING

Pictured Left to right: Nathan Thompson, Laura Hewitt, Dr Stephen Cowling, Emma Phillips, Anna-Jade Andrews, Olivia Frary, and Laura Shuker.

Baysgarth School in North Lincolnshire became one of the handpicked schools to secure a Royal Society Partnership Grant which allowed them to work alongside an academic partner to complete a project with science students to enhance their scientific understanding, practical skills and enthuse them to continue their studies beyond the national curriculum. The projects criteria stated that the projects had to represent an area of science that was not in the national curriculum but was relevant to everyday life. After a discussion between Baysgarth School Science Teacher Emma Phillips and Dr Stephen Cowling from the Liquid Crystals and Advanced Materials Research Group at York University the idea of learning about the importance of liquid crystals to daily lives, synthesising liquid crystals and then mixing them together in different compositions to create a liquid crystal mixtures with low melting points and broad nematic phases for twisted nematic display devices was proposed. Thus the project "Picture This! A crystal clear future...." was born.

Dr Cowling came into the school and gave a series of presentations about what a liquid crystal was and what they were used for including the importance of the UK in developing this technology. He then demonstrated the synthesis of a liquid crystal. The students prepared liquid crystalline esters by synthesis of acid chlorides from carboxylic acids and reaction of these with various phenols. The liquid crystals were characterised by Dr Cowling at York University by 1H nmr and IR. The liquid crystalline properties of the esters were characterised using polarised optical microscopy at Baysgarth School alongside Dr Cowling and then the thermal behaviour was determined by differential scanning calorimetry at York.

The project team experimented with the liquid crystalline esters to prepare mixtures in an attempt to get the desired properties, i.e., low melting point and wide temperature range nematic phase, for a liquid crystal device. Once the project team agreed on a final formulation, this mixture was scaled up and the students prepared their own TN device which was filled by capillary action with their own mixture which was then switched by application of an electric field. The majority of the devices operated successfully! The students disseminated the outline and outcomes of the project to teachers, friends and family through an oral presentation.

Overall the project was a huge success and represented a massive learning curve for some of the students involved. The project provided the students with a wide view of the subject of liquid crystals and its huge impact on their daily lives.

Olivia Frary said: “It gave us confidence to work together but also confidence with our chemistry. My practical skills have improved enormously.”

Anna-Jade Andrews said: “Taking part in this project has given me understanding of how concepts we learn in the national curriculum are applied in real life and the impact science has on everyday life.”

Laura Hewitt stated “I've always loved chemistry and this has given me the boost to carry on with chemistry at degree level next year. I have managed to secure 3 conditional offers from universities to study chemistry and believe this project has helped me to gain these offers.

Everyone from Baysgarth School who took part in the project agreed that it had been a great opportunity and hope that projects such as this can be done in different schools and colleges around the country so that everyone can learn and experience many applications of Science and appreciate the impact it has on our everyday lives.

Treasurer's Annual Report

British Liquid Crystal Society registered charity (328163)

Prepared by AVTAR MATHARU (former Honorary Treasurer)

Balance Sheet at 31 March 2012

Description of Income

	£	£
1. Cash at Bank (opening balance, 18.03.11)		
General Fund	5952.29	
Sturgeon Fund	6131.04	
Total Cash at Bank		12083.33
2. Subscriptions		40.00
3. BLCS 2011 Nottingham Trent		18683.19
4. BLCS 2010 Hull		1521.00
5. Interest accrued (2010-11)		
General Fund	59.96	
Sturgeon Fund	3.21	
Total Interest		63.17
TOTAL INCOME		**32390.69**

Description of Expenditure

1. Pobjoy Mint – Gray and Hilsum medals		767.48
2. BLCS Young Scientist Award		250.00
3. BLCS Bursary (x1)		250.00
4. BLCS 2011 Nottingham Trent		3501.00
5. Cash at Bank (closing balance, 31.03.12)		
General Fund	21237.96	
Sturgeon Fund	6134.25	
Total Cash at Bank	27372.21	
TOTAL EXPENDITURE		**32390.69**

Society's Bankers:

1. National Westminster Bank Plc
   Cottingham, East Yorkshire, HU16 4YW
2. Yorkshire Building Society

BLCS distinguished lecturers

BLCS Chairman MARK WILSON writes

At the last BLCS committee meeting, we decided that society funds were sufficiently buoyant to initiate a *BLCS distinguished lecturer* series. The idea of this is that a group of researchers would be able to invite over to the UK a distinguished liquid crystal academic, who would give a short series of three or four lectures at different UK universities. The universities or local research groups would be expected to cover most/all of the local costs of accommodation and UK rail fare, but the BLCS would aim to cover the costs of flights to bring the visitor over to the UK. Typically, the BLCS would be able to fund two (or possibly three) of these per year depending on demand.

To apply, simply write a short "costed" one page proposal, indicating who would come, why this would be great(!) and the places they would visit (please get agreement first!!); and send to the BLCS chair. The chair will circulate the proposal to the committee, and we should be able to provide an "yay" or nay" answer within a week or so.

We'll review the success or otherwise of the series at next year's AGM. At the minute, its down to BLCS members to come up with good suggestions for *distinguished lecturers.* **We look forward to getting your nominations.**

For those of you busy writing EPSRC impact statements for grants, why not consider writing such visits into your *pathways to impact* statement!

(mark.wilson@durham.ac.uk)

BLCS bursaries

BLCS Chairman MARK WILSON writes (mark.wilson@durham.ac.uk)

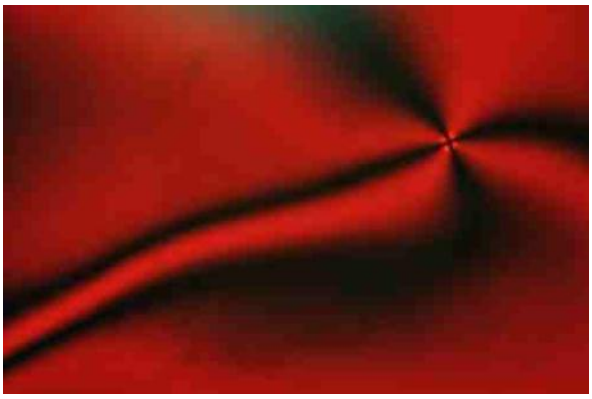
A quick reminder that the BLCS provides 5 bursaries per year for students (of £200 each) to help towards attendance at conferences. Application is quick and easy, the details/rules can be found on our web site at http://www-g.eng.cam.ac.uk/blcs/bursaries.pdf
The committee looks forward to receiving your application!

(mark.wilson@durham.ac.uk)

BLCS committee

Following the 2012 BLCS Annual Meeting, the new committee for 2012-2013 is

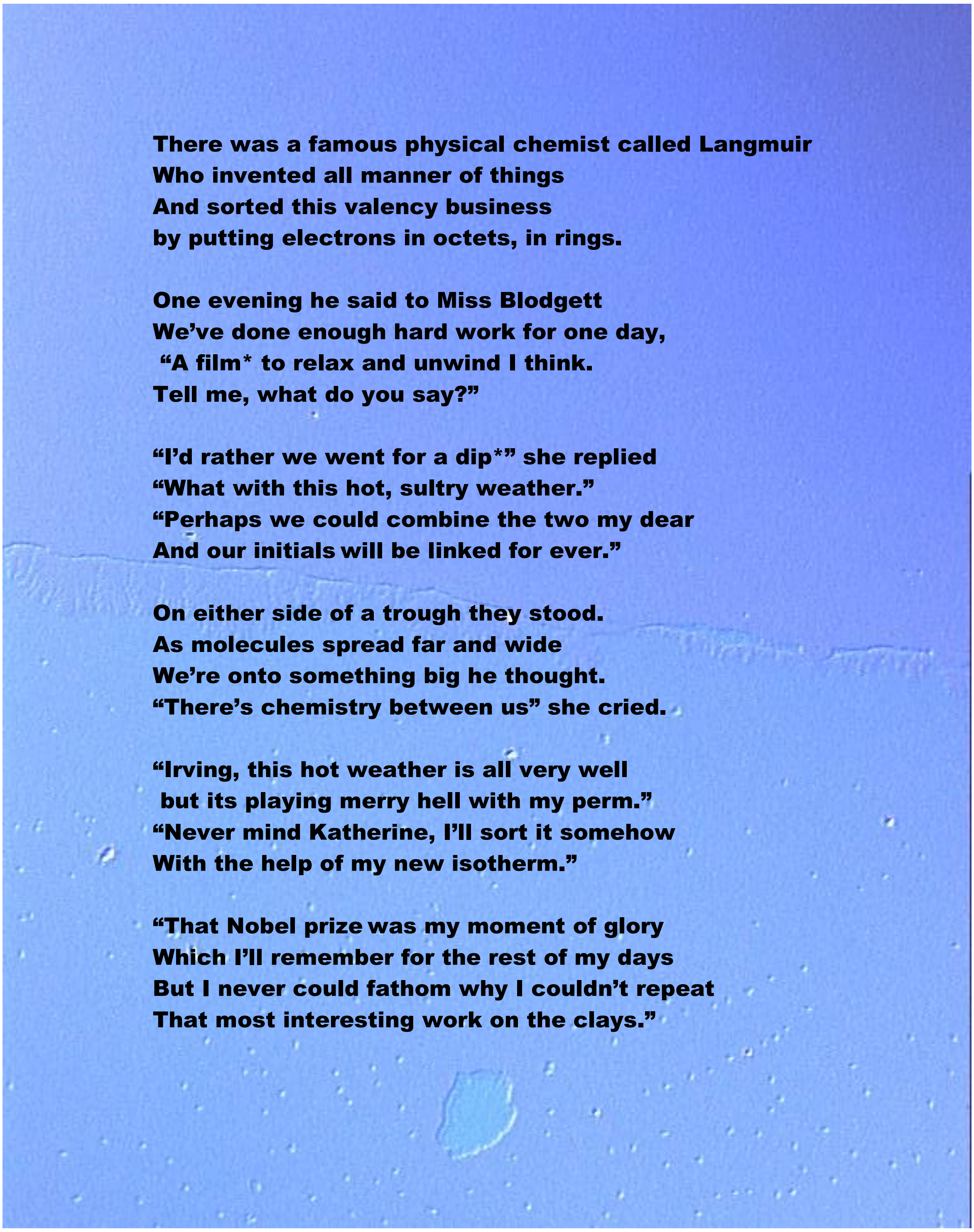
Prof Mark Wilson	(Chairman)
Dr Ingo Dierking	(Vice-chairman)
Dr Stephen Cowling	(Secretary)
Prof Carl Brown	(Treasurer)
Dr Flynn Castles	(Communications)
Dr Verena Görtz	
Ms Kirsty Holdsworth	(Student Member)
Prof Andrew Masters	
Prof Nigel Mottram	
Dr Vasily Oganesyan	
Prof Peter Raynes	
Prof Rob Richardson	
Dr Tim Wilkinson	(Annual Meeting Chair)



(A gratuitous liquid crystal picture. If you have any liquid crystal images that could adorn future issues of the newsletter, please send them to Flynn Castles fc252@cam.ac.uk)

Feat of clay (with apologies to Albert – and of course, the lion)

A poem by JOHN LYDON



There was a famous physical chemist called Langmuir
Who invented all manner of things
And sorted this valency business
by putting electrons in octets, in rings.

One evening he said to Miss Blodgett
We've done enough hard work for one day,
"A film* to relax and unwind I think.
Tell me, what do you say?"

"I'd rather we went for a dip*" she replied
"What with this hot, sultry weather."
"Perhaps we could combine the two my dear
And our initials will be linked for ever."

On either side of a trough they stood.
As molecules spread far and wide
We're onto something big he thought.
"There's chemistry between us" she cried.

"Irving, this hot weather is all very well
but its playing merry hell with my perm."
"Never mind Katherine, I'll sort it somehow
With the help of my new isotherm."

"That Nobel prize was my moment of glory
Which I'll remember for the rest of my days
But I never could fathom why I couldn't repeat
That most interesting work on the clays."

* This piece of nonsense was written simply to incorporate the words *dip* and *film.* The relationship between Irving Langmuir and Katherine Blodgett was impeccably professional.

Dates for the diary:

A list of upcoming British liquid crystal events

New frontiers in anisotropic fluid-particle composites
Kavli Royal Society International Centre
28-29 June 2012.

British Liquid Crystal Society Winter Workshop
University of Hull
17-19 December 2012.

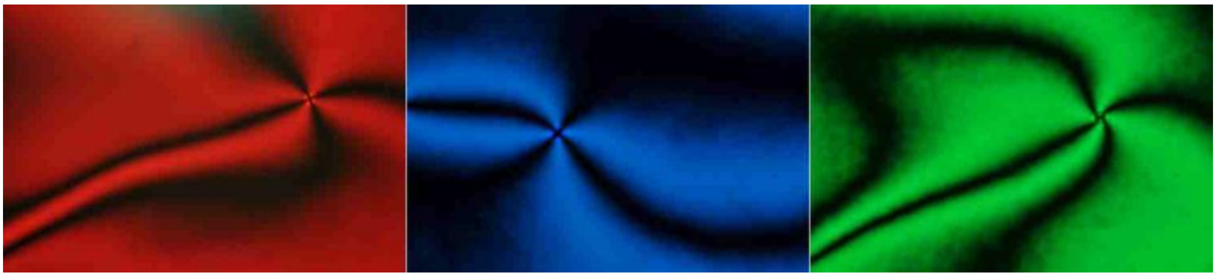
The Mathematics of Liquid Crystals: Symmetry, bifurcation and order parameters
Isaac Newton Institute for Mathematical Sciences, Cambridge
7-11 January 2013.

The Mathematics of Liquid Crystals: Analytical and computational paths from molecular foundations to continuum descriptions
Isaac Newton Institute for Mathematical Sciences, Cambridge
18 -22 March 2013.

The Mathematics of Liquid Crystals: Nonlinear analysis of continuum theories: statics and dynamics
(A Satellite Meeting at the University of Oxford)
8-12 April 2013.

The Mathematics of Liquid Crystals: Liquid crystal defects and blue phase structure; elastomers and related systems
Isaac Newton Institute for Mathematical Sciences, Cambridge
24-28 June 2013.

A calendar of international liquid crystal events can be found on the International Liquid Crystal Society website.



This newsletter was produced by the BLCS Communications Officer, Flynn Castles. If you have any suggestions, comments, or articles to include in future issues, please email fc252@cam.ac.uk