Control of topological liquid crystal defects in microstructured cells

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Plan of the talk

- Microstructured surfaces
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- Liquid crystals in planar-hemispherical cells
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- Modelling defects in planar-hemispherical cells
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- The next steps
Polystyrene latex spheres self-assemble on a gold surface to form a closed packed hexagonal structure. The interstitial spaces are filled with gold up to a required height and the spheres are removed by washing the sample in toluene.

Cavities obtained by halting the deposition of gold at increasing heights.
The planar hemispherical cell

We have used these microstructured surfaces to build planar-hemispherical cells and we have studied their reflection properties with or without liquid crystals.
Reflection patterns from empty cells

The cell is illuminated with a uniform beam of linearly polarised white light. The reflected light is analysed through a cross-polariser.
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The reflected light intensity pattern can be interpreted using a ray optics model.
Liquid crystals are highly anisotropic molecules that have orientational, but not positional, order.
Liquid crystals filled cells

The orientation of the liquid crystal molecules is constrained by the geometry of the cell and by the applied electric field.

It is not immediately obvious what the configuration of the molecules in a planar-hemispherical cell might be.
We have measured the intensity of the cross-polarised light reflected back from the cell as a function of the applied voltage. As the voltage is increased the symmetry of the pattern changes from four-fold to two-fold with respect to the rubbing direction, independently of the polarisation of the incident light.
Modelling liquid crystals

We represent the director field using a $3 \times 3$ traceless symmetric tensor $Q$. The degree of order of the liquid crystal is given by $S^2 = \text{Tr}(Q^2)$, while the orientation direction is the principal eigenvector of $Q$. The equilibrium configuration of $Q$ is the minimum of a Landau-de Gennes free energy:

$$F = \frac{1}{2} \xi_0^2 |\nabla Q|^2 - \chi_0 \text{Tr}(Q\mathcal{E}) + \frac{1}{2} \nu \text{Tr}(Q^2) - \sqrt{6} \text{Tr}(Q^3) + \frac{1}{2} \text{Tr}^2(Q^2).$$
Numerical model

We have represented the tensor $Q$ on the five element basis of the $3 \times 3$ traceless, symmetric tensors [Sonnet, PRE 1995].

The standard equation is of the type:

$$\partial_t a_i = \xi_0^2 \nabla^2 a_i - \chi a e_i - \vartheta a_i + \gamma_{ijk} a_j a_k - 2a_i a_j a_j$$

where $a_i$ and $e_i$ are the $i$-th component of $Q$ and $E$ on the tensor basis.

We have integrated these equations using a finite element scheme based on the Crank-Nicholson algorithm.
Numerical Results

Geometry
Numerical Results

Geometry

Electric field

xy

xz

yz
Reflection patterns

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- We have represented the light beam as the 45° ray;
- We have calculated the phase shift of the polarisation due to the orientation of the liquid crystal along its path.
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- We do not have a good model for the electromagnetic field: we need one.

- Once we have this, we shall be able to study cooperative effects between neighbouring cells and extend this work to planar-hemispherical optical cavities.
Thank you