Bistable nematic liquid crystal display device design

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With the increasing use of liquid crystal-based displays in everyday life, led both by the development of new portable electronic devices and the desire to minimize the use of printed paper, Nematic Liquid Crystals [4] (NLCs) are now hugely important industrial materials; and research into ways to engineer more efficient display technologies is crucial. Modern electronic display technology mostly relies on the ability of NLC materials to rotate the plane of polarized light (birefringence). The degree to which they can do this depends on the orientation of the molecules within the liquid crystal, and this in turn is affected by factors such as an applied electric field (the molecules, which are typically long and thin, line up in an applied field), or by boundary effects (a phenomenon known as surface anchoring). Most devices currently available use the former effect: an electric field is applied to control the molecular orientation of a thin film of nematic liquid crystal between crossed polarizers (which are also the electrodes), and this in turn controls the optical effect when light passes through the layer (figure 1).

The main disadvantage of this set-up is that the electric field must be applied constantly in order for the display to maintain its configuration – if the field is removed, the molecules of the NLC relax into the unique, stable, field-free state (giving no contrast between pixels, and a monochrome display). This is expensive in terms of power consumption, leading to generally short battery lifetimes. On the other hand, if one could somehow exploit the fact that the bounding surfaces of a cell affect the molecular configuration – the anchoring effect, which can, to a large extent, be controlled by mechanical or chemical treatments [1]– then one might be able to engineer a bistable system, with two (or more) stable field-free states, giving two optically-distinct stable steady states of the device, without any electric field required to sustain them. Power is required only to change the state of the cell from one steady state to the other (and this issue of “switchability”, which can be hard to achieve, is really the challenging part of the design). Such technology is particularly appropriate for LCDs that change only infrequently, e.g. “electronic paper” applications such as e-books, e-newspapers, and so on.

Certain technologies for bistable devices already exist; and most use the surface anchoring effect, combined with a clever choice of bounding surface geometry. The goal of this project will be to investigate simpler designs for liquid crystal devices that exhibit bistability. With planar surface topography, but different anchoring conditions at the two bounding surfaces, bistability is possible [2,3]; and a device of this kind should be easier to manufacture. Two different modeling approaches can be taken depending on what design aspect is to be optimized. A simple approach is to study only steady states of the system. Such states will be governed by (nonlinear) ODEs, and stability can be investigated as the electric field strength is varied. In a system with several steady states, loss of stability of one state at a critical field would mean a bifurcation of the solution, and a switch to a different state. Such an analysis could give information about how to achieve switching at low critical fields, for example; or at physically-realistic material parameter values; but would say nothing about how fast the switching might be. Speed of switching would need to be investigated by studying a simple PDE model for the system. We can explore both approaches here, and attempt to come up with some kind of “optimal” design – whatever that means!

References


Figure 1: Schematic of a single cell, or pixel, in a liquid crystal display device