Liquid Crystal Modelling Group

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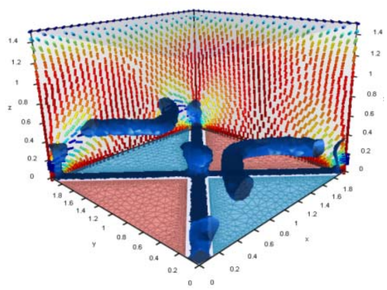
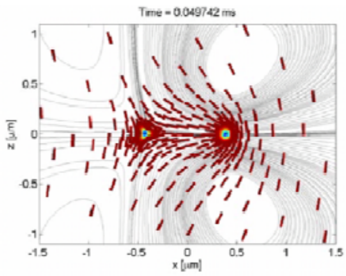
The group has developed advanced and comprehensive 3D modelling of liquid crystal structures for displays and for photonic and microwave applications. The work includes modelling the switching behaviour of liquid crystals in complex geometries, the hydrodynamics of liquid crystals, the optical modelling of liquid crystal cells and the modelling of electromagnetic wave propagation through waveguiding structures containing LC materials. Current computer models and programs developed by the group are based on the Landau-de Gennes continuum model with a Q-tensor representation of the liquid crystal orientation, and include order variation and biaxiality, weak surface anchoring, flexoelectric effects and material flow. Adaptive mesh refinement is implemented to allow accurate modelling of defects and the study of the behaviour of realistic 3D structures. Applications have included the analysis and design of LC on Silicon (LCoS) cells, for displays and communications, optical filters, large area displays, the dynamic study of bistable displays, and other devices where the dynamic behaviour of defects play an important role. One of the current interests is using a hybrid approach to extend these modelling capabilities further to dimensions where the current continuum theory alone is not adequate. This will enable us to study structures with features in the range of 10s of nm, as in LCoS cells for LC displays and diffractive devices for communications (reconfigurable SLMs and holograms), reconfigurable photonic band gap structures, the design of nanostructured dielectric films and the inclusion of nanostructures in liquid crystal cells, as surface features or as suspended, moving particles.

Research Topics

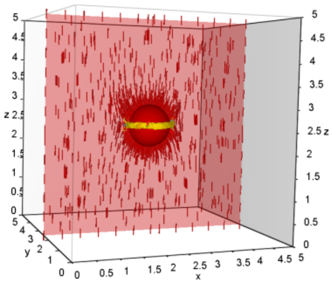
Dynamic 3D modelling of LC structures including defects

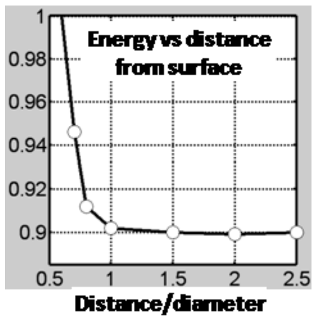




We are interested in the development of accurate and comprehensive modelling of LC structures containing small features, surface relief and defects and in the study of devices where their operation relies on the creation and controlled evolution of defects.

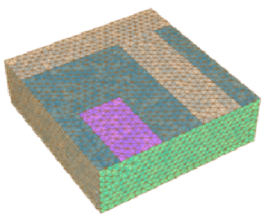
Particles in liquid crystals

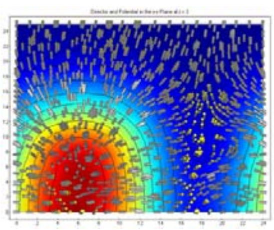


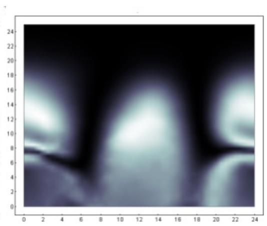


Inclusion of particles in the form of colloids or fixed to a surface in a liquid crystal cell is becoming an interesting research topic due to the very strong effects these particles can have in the effective material parameters and the behaviour of the cell. We are interested in using and extending our modelling methods to the modelling of the local effects of the presence of these particles in LC mixtures and in the study of the dynamics of particles immersed in liquid crystals.

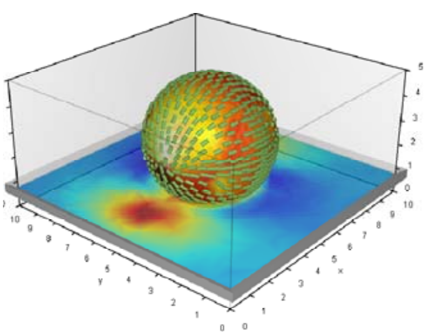
Applications to Display Devices:



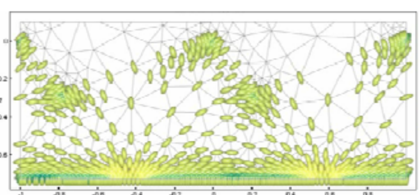




The modelling permits the accurate study of intricate display structures, for example, end effects in In-Plane-Switching cells and the effect of spacers in LC cells.

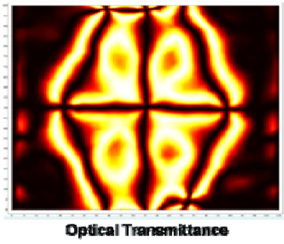


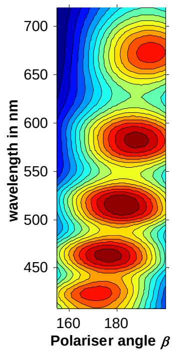
Bistable Display Devices:



The modelling has been applied to study the dynamic switching behaviour of bistable display structures like the Post Aligned Bistable Nematic (PABN) display of Hewlett Packard and the ZBD display and also other bistable structures in which defect creation and evolution are central to their operation.

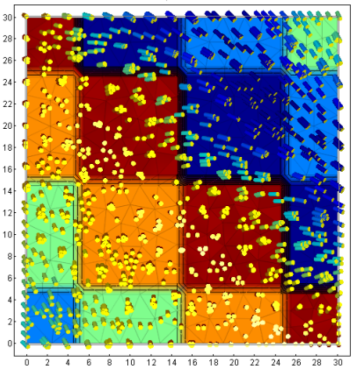
Optical Modelling:



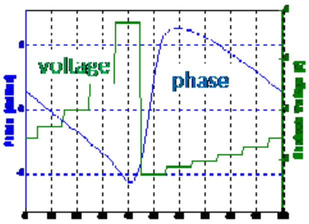


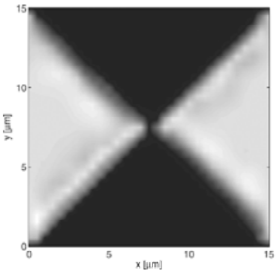
We are also interested in the development of accurate methods to model the optical behaviour of liquid structures, not only for displays but also for devices where diffraction effects are present. This also includes work on liquid crystal Fabry-Perot filters and microlenses.

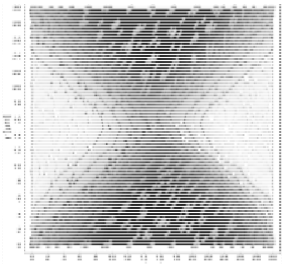
LCoS devices / Diffraction devices:

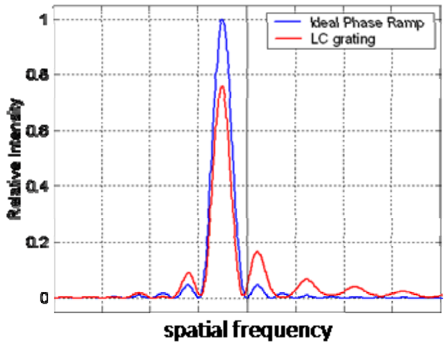


Liquid Crystal on Silicon provide the means to obtain the very high resolution and processing capability needed for reconfigurable or programmable diffraction devices, gratings, spatial light modulators and holographic devices. We are interested in the study and design of these structures and in investigating the ways in which the liquid crystal switching can be made to follow the very high resolution available in the Silicon backplane. Liquid crystal disclinations can be used to force abrupt transitions in the phase response when required by the high resolution devices.



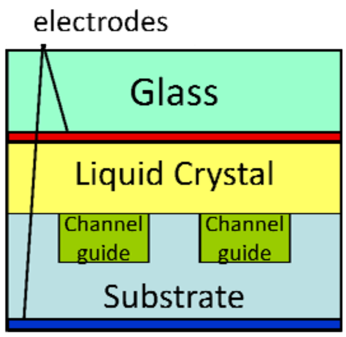


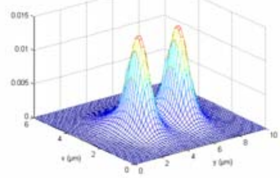


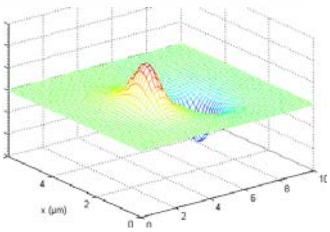


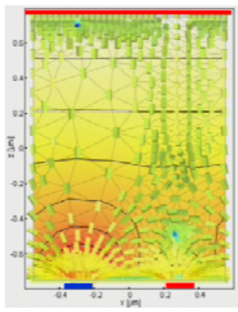
Liquid crystals in waveguiding systems:

We are also interested in the study of waveguides containing liquid crystals, by combining the liquid crystal modelling capabilities with wave propagation methods, modal analysis and beam propagation methods. In particular, we are interested in reconfigurable LC photonic structures using microelectrode arrays to control and use defects. We want to explore the possibilities of inducing bulk switching with very small electrodes and use this to create reconfigurable periodic index structures via the formation of defect walls or defect columns across the liquid crystal layer.



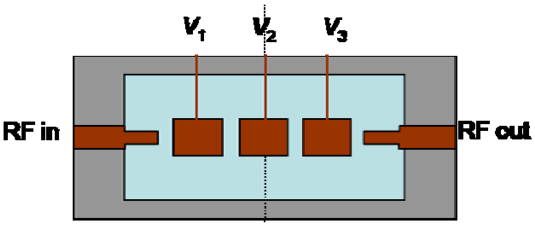


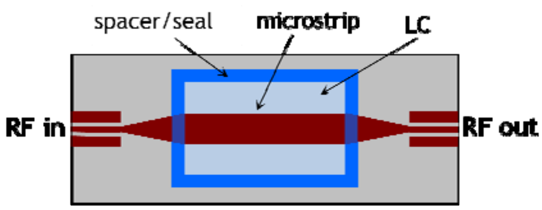


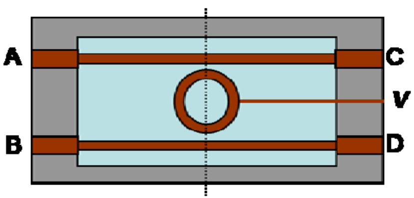


Liquid crystals in microwaves: Investigation of planar transmission lines on LC substrates at mm- wave frequencies.

Few LC materials have been characterized in the microwave range due to the need for complex experimental equipment or for specialized cell geometries. In the calculations involved the interaction between the LC permittivity and the microwave field is usually over-simplified; it is considered as a uniform material, often even as a homogeneous dielectric. We take a comprehensive approach in modelling both the LC orientation and the microwave fields. The spatial distribution of the permittivity is used to calculate the microwave fields. In taking this approach, characterisation of materials is possible using standardized and cost effective test devices. We are currently designing and fabricating planar transmission line structures containing LC for this purpose. This will allow a better characterization of the LC material, which can be used to design more complicated components such as filters and couplers.







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