Modelling light propagation through radial-director liquid crystal waveguides

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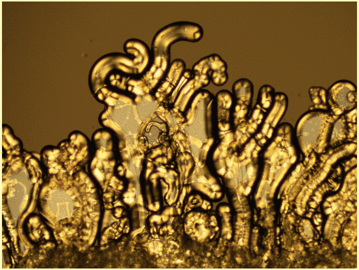
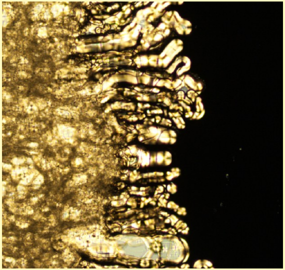
Motivation

- Anisotropic birefringent profiles of liquid crystals for guiding light
- Sm A fibres with radial director profile using 8CB
- Defects in LC $\leftrightarrow$ defects in optical fields





K. Peddireddy et al., Langmuir **28** (2012)

Methods – Maxwell's Equations

$$\nabla \cdot \vec{D} = \rho_f \qquad \nabla \cdot \vec{B} = 0$$

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \qquad \nabla \times \vec{H} = \vec{J}_f + \frac{\partial \vec{D}}{\partial t}$$

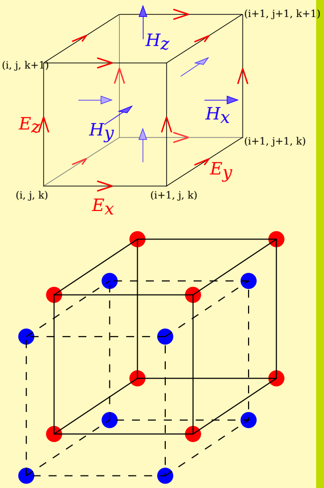
Nice for simulations

- Time-derivative of one field $\propto$ space-derivative of other
- Alternate between calculating E and H
- Suitable for parallel computation

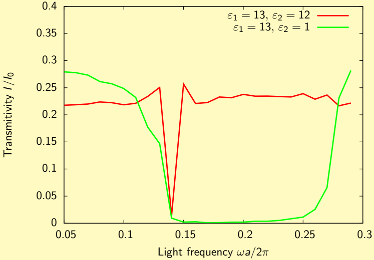
Methods – Finite-difference time-domain

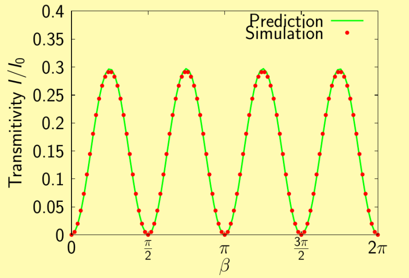
$$\varepsilon \frac{\partial \vec{E}}{\partial t} = \nabla \times \vec{H} \qquad \frac{\partial \vec{H}}{\partial t} = -\nabla \times \vec{E}$$

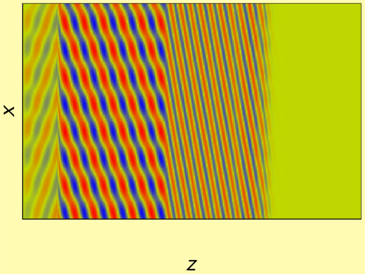
- Direct time evolution of electromagnetic fields
- Anisotropic and non-uniform ε, follows director as $\Delta\varepsilon \propto Q$
- Staggered grid, fields known at different times



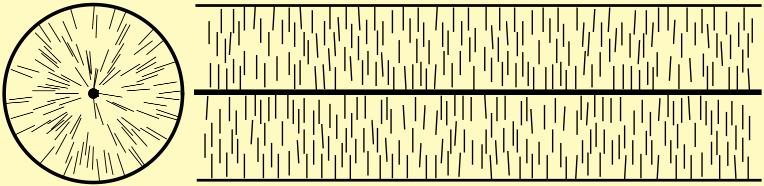
- Uniform director
- Refraction on interface
- Photonic bandgap of periodic structure







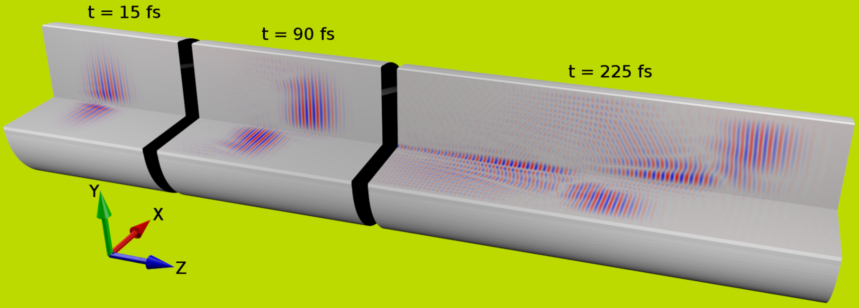
Radial-director waveguide



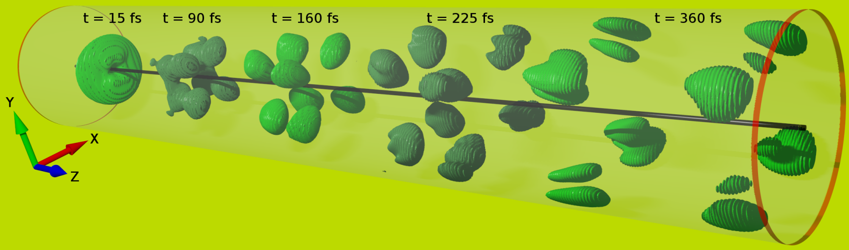
- Fibre radius 10 μm
- Gaussian pulse, wavelength 480 nm
- 8CB with $n_o = 1.51$ and $n_e = 1.68$, surrounded by water
- Long waveguide simulated with periodic boundary conditions

Results – Electric field

- Gaussian beam $\rightarrow$ Laguerre-Gaussian, dark spot at the axis
- The difference in refraction index deforms the beam

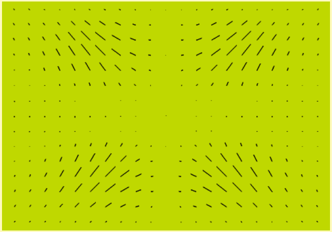


Results – Pulse shape

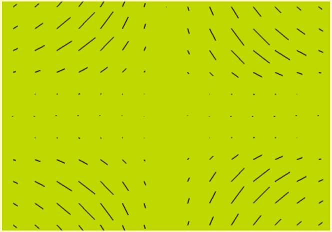


- 8 intensity regions in 2 ranks
- Positioned diagonally to incident polarization
- Two propagation modes with different polarizations

Results – Propagation modes

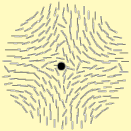


Mode 1



Mode 2

- Polarization forms -1 disclination line
- Disclination lines are rotated by 45° with respect to each other



Conclusions

Method

- Model the propagation of light through media with non-uniform fully-anisotropic dielectric tensor
- Direct solving of discretized Maxwell's equations

Results

- Topological defect in LC $\rightarrow$ topological defect in optical field
- Propagation modes of a radial-director liquid crystal waveguide
- Splitting of a single pulse into eight intensity regions