Modelling light propagation through radial-director liquid crystal waveguides

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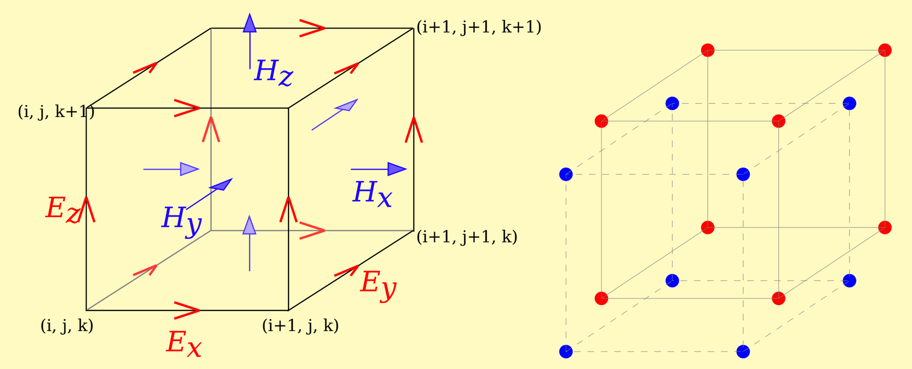
Motivation

- Light guiding is central in complex optics and photonics, for example for efficient data transfer
- Combined birefringence and response to external stimuli in liquid crystal structures could be used for directed guiding of light – such as waveguides.
- Smectic A fibres with radial director profile can be created using 8CB and a surfactant[**?**]
- Point defect in a nematic droplet turns a Gaussian beam into Laguerre-Gaussian – is there a similar effect caused by the line defect in a fibre?

Methods

- FDTD method – direct time evolution of electromagnetic fields in 3D with fully anisotropic ε
- Assumed zero conductivity and vacuum permeability in bulk.
- Simulate long cylindrical waveguide with periodic boundary conditions in z direction
- Staggered grid, adapted for dielectric anisotropy

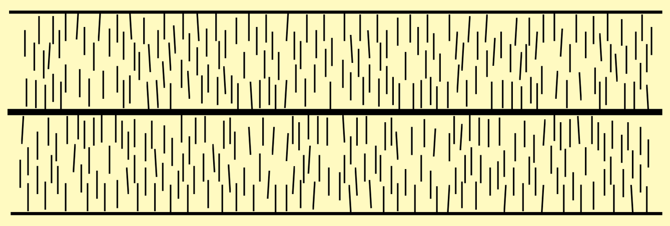


Left: Yee lattice, optimized for diagonal dielectric tensor.
Right: The lattice we used, suitable for full anisotropic ε.
In both cases $\vec{E}$ and $\vec{H}$ are known at different times

- Tested with uniform director, refraction on interfaces, and periodic modulation of refraction index

Parameters

- Observe propagation of Gaussian laser pulse
- Cylindrical waveguide with a radial director profile and a singular disclination line along its axis [TODO: Prerez]



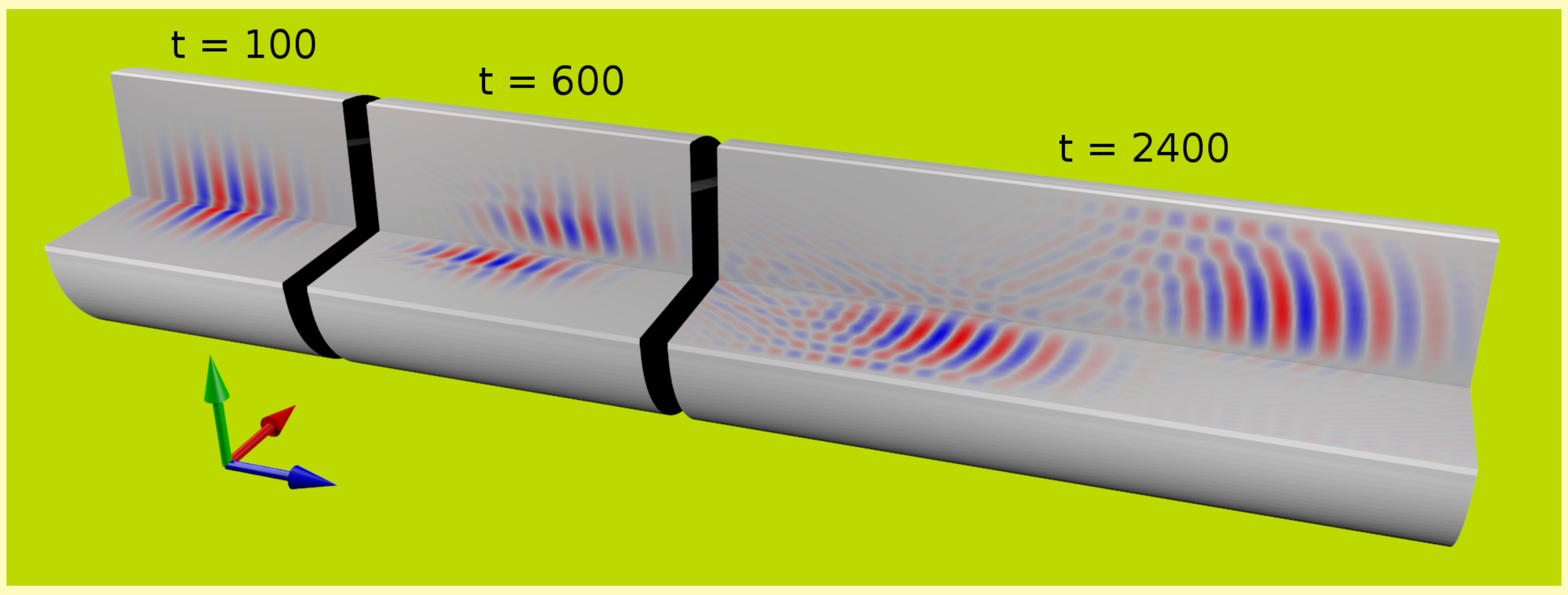
The core radius of the central $+1$ disclination line is much smaller than the wavelength and can therefore be neglected.

- Waveguide radius 10μm, inside 8CB with $n_o = 1.52037$ and $n_e = 1.66810$, surrounded by water with $n = 1.33$
- Mesh size $256 \times 256 \times 128$.

References

Electric field

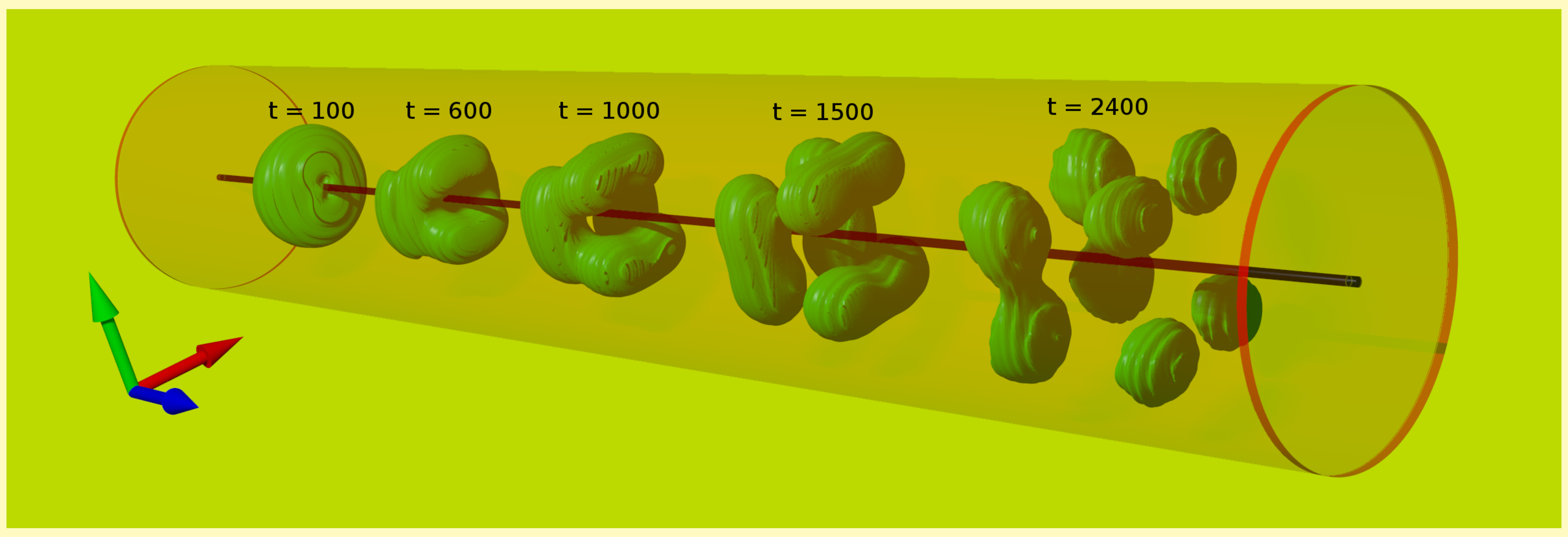
- We showed that a Gaussian beam entering a fibre quickly turns into a Laguerre-Gaussian beam, and then [into something else].



Snapshots of electric field $\vec{E}$ at three different times. Incident light is polarized along the x axis. Left: The Gaussian pulse just after entering the waveguide. Center: After a short time, a dark spot forms near the axis. Light near the xz and yz plane differs both in phase and propagation velocity. Right: After a longer time, the difference in velocity greatly distorts the pulse. Reflection from waveguide walls causes noticeable interferrence and waveforms lose clarity, although the pattern remains visible.

Field intensity and phase

- Using data for electric and magnetic fields we calculated the local energy density. This enabled us to determine the shape of the pulse in time.



Shape of the originally Gaussian pulse at different times after entering the waveguide. Plotted are the isosurfaces where local field amplitude is greater than 5% of the maximum. At first, the pulse is roughly spherical. Soon a minimum forms at the axis, and the upper and lower parts start overtaking the left and right ones, due to the difference in refraction indexes. The pulse gradually splits into 8 parts, which appears to be a stable configuration.

- The pulse splits into multiple intensity regions. Note that the regions are positioned diagonally to the incident light polarization.
- We were also interested in planes of constant phase. By calculating the wave phase at every grid point, we determined that the initially Gaussian pulse quickly transforms into [še vedno ne vem kaj].

Conclusions

- A method was developed to model the propagation of light through structures with non-uniform anisotropic dielectric tensor
- The method was tested to produce correct results for reflaction and reflection of light, as well as for the photonic band-gap in periodic structures
- When applied to a radial-profile liquid crystal waveguide, the method predicts the splitting of a single pulse into eight intensity regions, aligned diagonally around the axis in two ranks