Improved ray-tracing for slowly varying director field: Simulation of optical micrographs of nematic and cholesteric droplets

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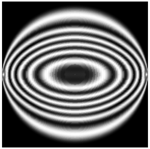
July 27, 2018

Outline

Motivations

Transmission of an arbitrary birefringent sample between polariser and analyzer: Jones method



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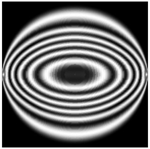

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  $\Rightarrow$ generalized Jones method by Mur et al

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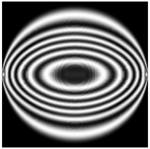

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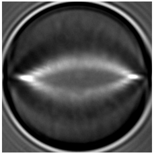
- Second limitation: deflection of the extraordinay rays.
  How to explain the non-zero contrast of natural light micrographs?



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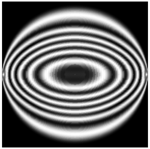

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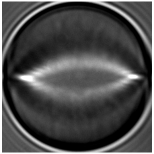
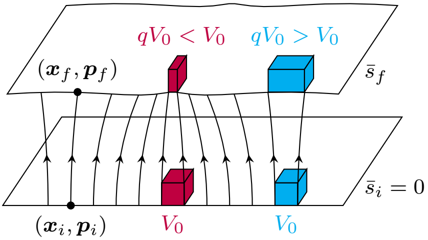


Question

Can we design an efficient method to simulate natural light micrographs of LC samples, including light deviation effects?

The improved ray-tracing method

Working hypotheses: $|\nabla \boldsymbol{n}| \sim \frac{1}{L} \ll \frac{1}{\lambda}$ + Mauguin regime



$$\frac{\mathrm{d}\boldsymbol{\eta}}{\mathrm{d}\bar{s}} = \{\boldsymbol{\eta}, \mathcal{H}\}$$

$$\boldsymbol{\eta} \equiv (\boldsymbol{x}, \boldsymbol{p})$$

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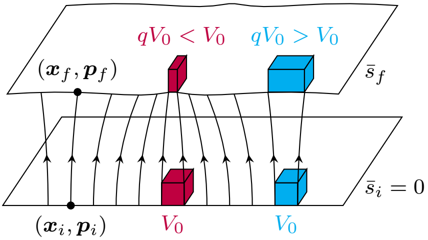

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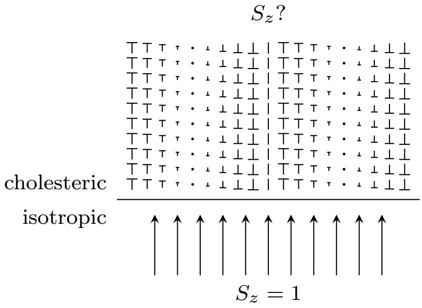
- Evolution of extraordinary and ordinary rays: Hamilton Eqs.
- New result: $n_{\text{eff}} \sqrt{q}\, E$ and $\sqrt{q}\, B$ are conserved along a ray

Outline

Setup

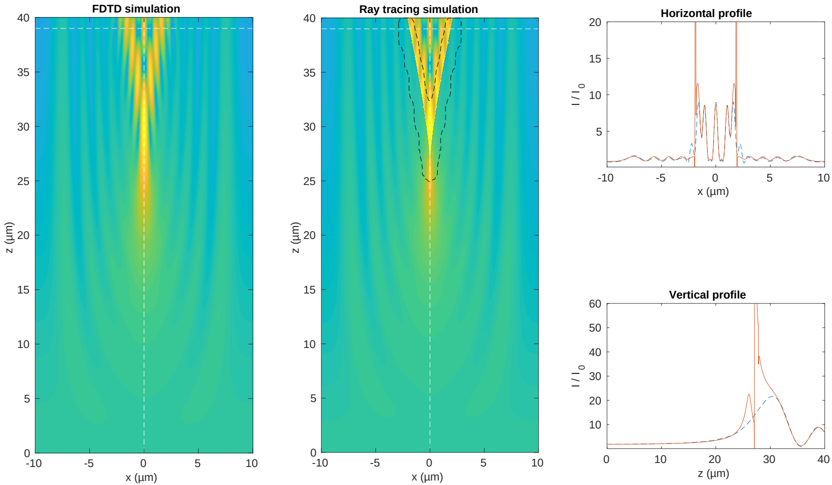
Incident plane wave on a transverse cholesteric helix:
Poynting vector field $\boldsymbol{S}$ inside the cholesteric phase?



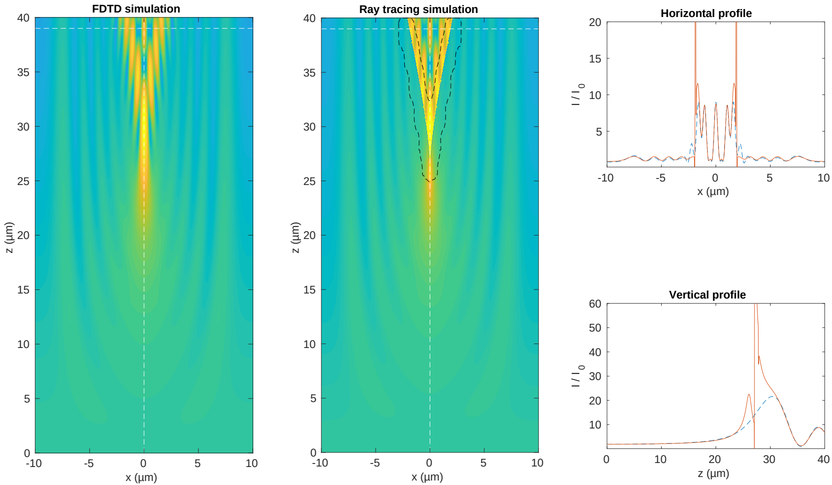
Two methods of resolution:

- Our improved ray-tracing method
- Exact resolution of Maxwell Eqs. (FDTD)

Results


FDTD simulation
40
35
30
25
20
15
10
5
0
z (µm)
-10
-5
0
5
10
x (µm)
Ray tracing simulation
40
35
30
25
20
15
10
5
0
z (µm)
-10
-5
0
5
10
x (µm)
Horizontal profile
20
15
10
5
I / I0
-10
-5
0
5
10
x (µm)
Vertical profile
60
50
40
30
20
10
I / I0
0
10
20
30
40
z (µm)

Results

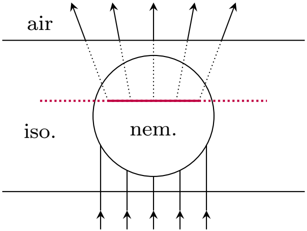


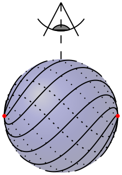
Fast and accurate reconstruction of $\boldsymbol{S}$ far from the caustic boundaries

Outline

1. Ray-tracing method in birefringent media
2. Validation on a simple test-case
3. Application to the visualisation of cholesteric and nematic droplets
4. Conclusion

Setup





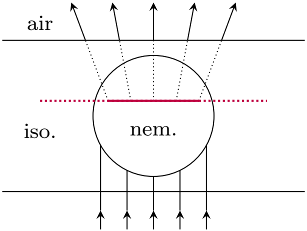
Twisted bipolar droplet:

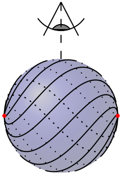
- Planar anchoring: 2 defects
- Double twist

Two studied mixtures, with two different origin for the twist:

- CCN-37 + R811: spontaneous twist q_0 of the cholesteric phase
- SSY + water: giant elastic anisotropy $K_2 \ll K_{1,3}$

Setup





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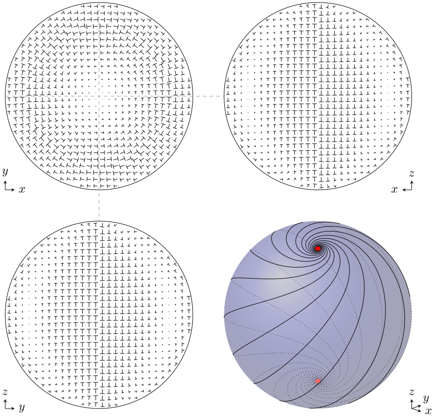
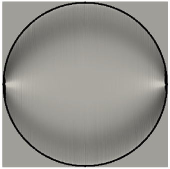
Natural light micrographs: average over all polarisation states.

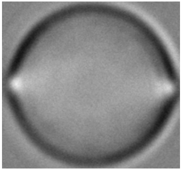
Cholesteric twisted bipolar droplet (CCN-37+R811)

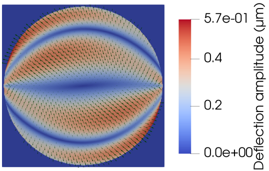


simulation



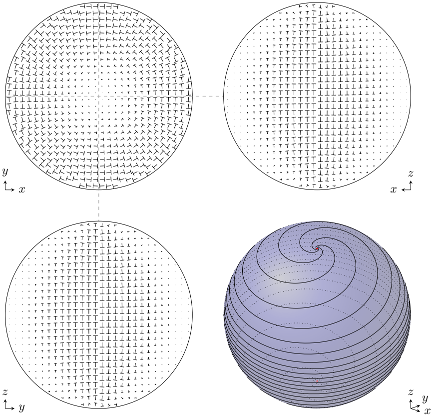
experiment



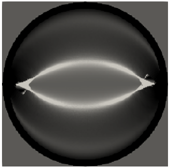


Deflection map (extraordinay rays)

Nematic twisted bipolar droplet (SSY in water)



simulation



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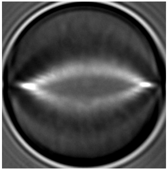

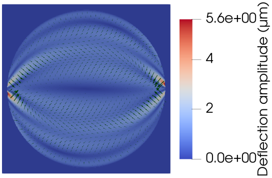

Deflection map (extraordinay rays)

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Conclusion and outlook

- New method with fast and accurate reconstruction of $\boldsymbol{S}$ far from caustics.

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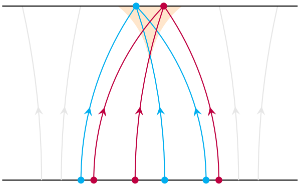
- Good agreement with experimental micrographs of twisted bipolar droplets.
- Perspectives:
  - ⋆ Beyond the Mauguin regime: elliptic polarisations
  - ⋆ Role of numerical aperture?
  - ⋆ Link between chirality and symmetry-breaking in micrographs?
  - ⋆ New systems: skyrmions, cholesteric fingers, banded droplets...

Thank you for your attention!

Two sources of discontinuity



Mapping $\boldsymbol{x}_i \to \boldsymbol{x}_f$:

- No caustics: one-to-one correspondance
- Caustic domains: many-to-one correspondance

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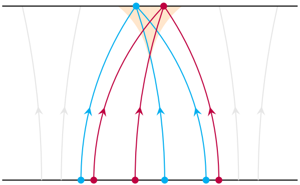

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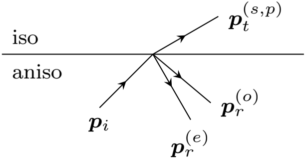

Optical index discontinuity:
generic Fresnel boundary conditions