Optical solitons and chirality-enhanced nonlinear optical response in frustrated liquid crystals

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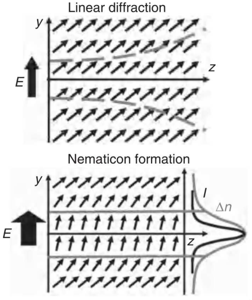
JAVNA AGENCIJA ZA RAZISKOVALNO DEJAVNOST
REPUBLIKE SLOVENIJE

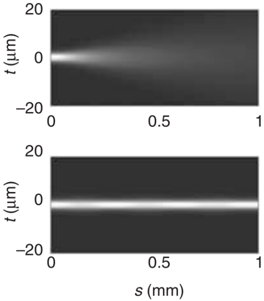
MARIE CURIE ACTIONS

Outline

Motivations

Spatial light solitons in liquid crystals: nematicons



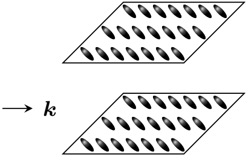


↓ Increasing beam power

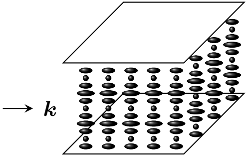
G. Assanto. *Nematicons.* John Wiley & Sons, 2013

Motivations

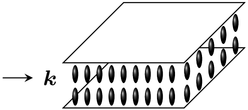
Studied systems in the past 20 years:



thick samples
with planar $\boldsymbol{n}$



thick samples with
cholesteric helix



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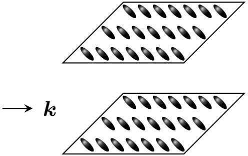

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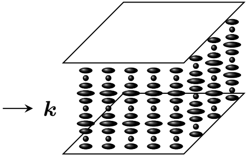

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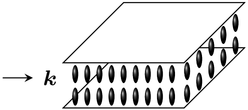

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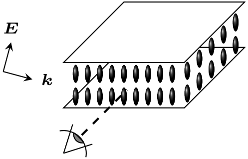
What about confined chiral systems? Can we amplify the optical response with chirality?

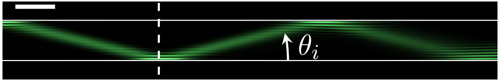
Outline

1. Introduction
2. Previous study with homeotropic cells
3. Simulations of chiral optical solitons in planar cells
4. Theoretical results for planar cells
5. Conclusion

Our first approach: unwound cholesteric with homeotropic anchoring



Side slice of beam intensity (simulation):



Side slice of 3PF signal (experiment):

G. Poy *et al.*, *Physical Review Letters* **125** (2020)

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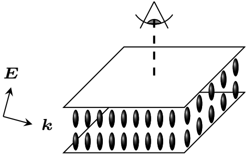


Top view of the thickness-averaged laser intensity (simulation):


Linear optical regime

Non-linear optical regime

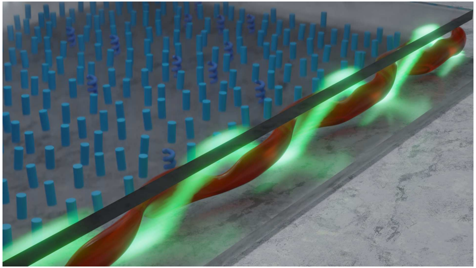
Top view of the scattered laser light (experiments):


Linear optical regime

Non-linear optical regime

G. Poy *et al.*, *Physical Review Letters* **125** (2020)

Summary of first approach



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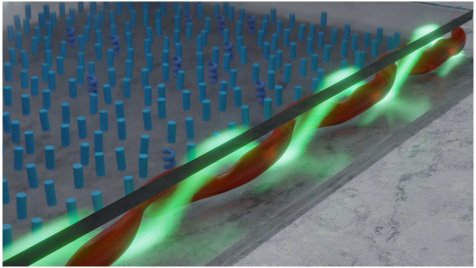

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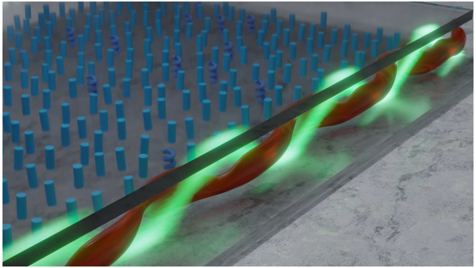

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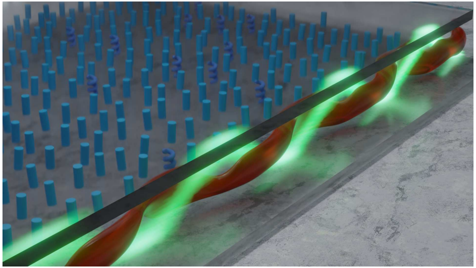

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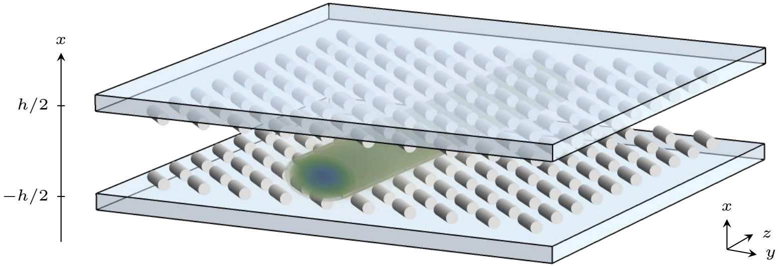
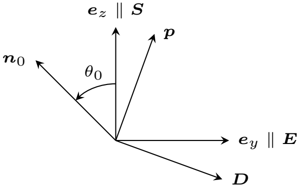
New approach: unwound cholesteric with planar anchoring





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- When $q < q_c \approx \pi/h$, the unwound cholesteric is stable.

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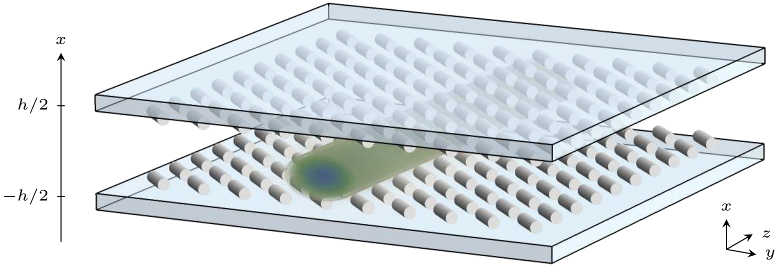

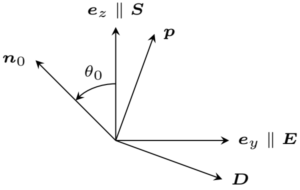

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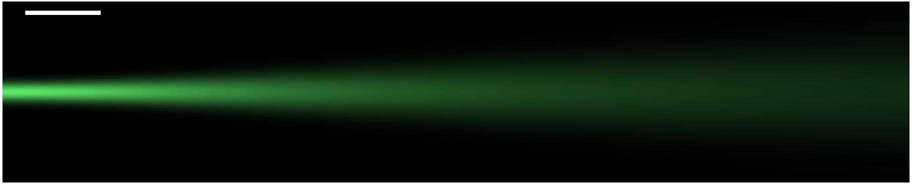
Can we get additional insight in this simpler sample geometry?

Outline

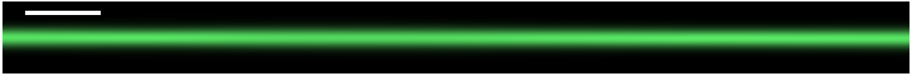
Simulated self-focused intensity profiles

Vanishingly small power

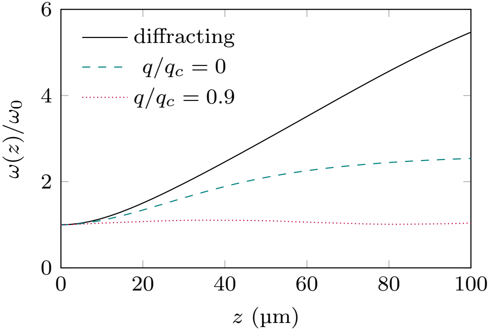


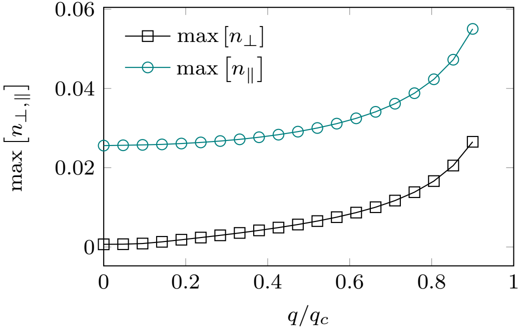
$P = 3.76\ mW$, achiral sample ($q/q_c = 0$)

$P = 3.76\ mW$, chiral sample ($q/q_c = 0.9$)



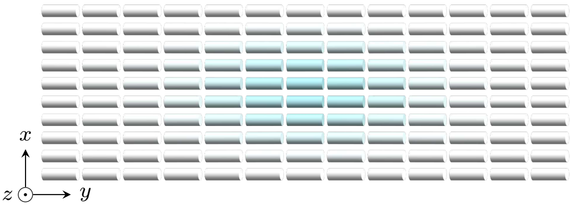
Waist evolution and chirality-enhancement effect



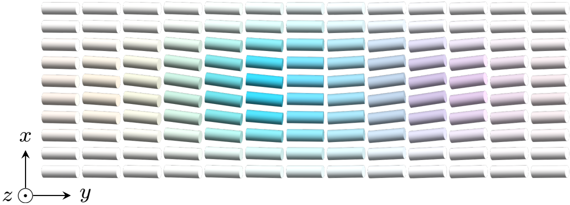


Amplification of nonlinear optical response due to chirality: almost ×3 (higher than in homeotropic cells)

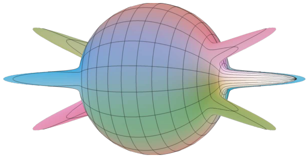
Transverse cross-section of the director field



Achiral sample ($q/q_c = 0$)

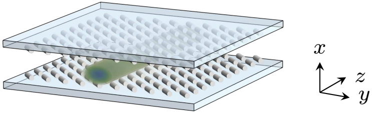


Chiral sample ($q/q_c = 0.9$)



Outline

(1+1)D effective nonlinear beam propagation model



Light fully confined by the plates of the sample:

$$A_y \approx A(y,z)\psi(x,z)\exp\{i\boldsymbol{p}\cdot\boldsymbol{R}\}$$

Waveguide mode along x

Amplitude profile along y

G. Poy *et al.*, *Proc. SPIE 11807, Liquid Crystals XXV* (2021)

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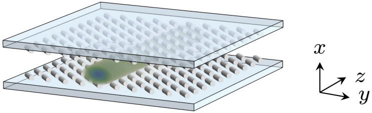

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- Simplified x-averaged wave equation: $$\left[2ip_z\partial_Z + \partial_Y^2 + \frac{2P}{P_0}\Gamma_{\text{eff}}\right]A = 0$$
  - ⋆ ∂_Y^2: diffraction.
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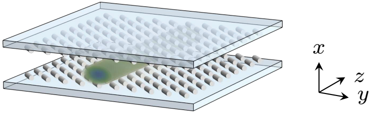

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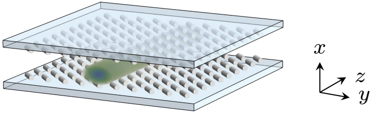

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- Effective Green function of the LC's reponse: $\tilde{G}_{\text{eff}} \sim \frac{|\boldsymbol{k}|^2}{|\boldsymbol{k}|^4-\eta^2q^2k_y^2}$ increases when q increases.

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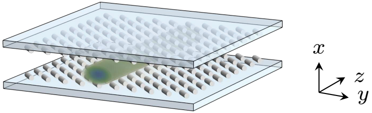

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- Estimation of the power of a fundamental soliton with waist ω_0:

$$P = \frac{P_0}{k_0^2\omega_0^4\left[-\Gamma_{\text{eff}}''(0)\right]}$$

G. Poy *et al.*, *Proc. SPIE 11807, Liquid Crystals XXV* (2021)

Outline

Concluding remarks

Take-home message

Chirality allows to boost the response of frustrated liquid crystals to external fields, and therefore to generate optical solitons at a lower power than in achiral media.

- Experimental implementation: need to avoid π-twisted domains, only keeping the unwound phase inside the LC sample.
- Beyond solitonic science: chirality-enhanced optomechanical manipulation of LC patterns with laser, relevance in spin-orbit interactions, etc.

G. Poy *et al.*, *Proc. SPIE 11807, Liquid Crystals XXV* (2021)

Thank you for your attention!