Lensing and deflection of light with soft topological solitons

Guilhem POY*[1], Andrew J. HESS[2], Jung-Shen B. TAI[2], Slobodan ŽUMER[3,1], Ivan I. SMALYUKH[2,4,5]

[1]Faculty of Mathematics and Physics, University of Ljubljana, Jadranska 19, 1000 Ljubljana, Slovenia
[2]Department of Physics, 390 UCB, University of Colorado Boulder, Boulder, Colorado 80309, USA
[3]Jožef Stefan Institute, Jamova cesta 39, 1000 Ljubljana, Slovenia
[4]Materials Science and Engineering Program and Department of Electric, Computer and Energy Engineering, University of Colorado Boulder, Boulder, Colorado 80303, USA
[5]Renewable and Sustainable Energy Institute, National Renewable Energy Laboratory and University of Colorado, Boulder, Colorado 80309, USA

Keywords: topological soft matter, optics.

Topological solitons correspond to localized excitations of a background field which cannot be continuously deformed in the uniform state—a property called *topological protection* which makes these solitons very robust to external perturbation. Among various fields supporting the existence of such solitons (cosmology, condensed matter, optics...), frustrated chiral liquid crystal can embed a wide variety of topologically protected excitations such as cholesteric fingers, twist-walls, torons, baby skyrmions, hopfions, etc. Here, we show how two very specific classes of such solitons, which take the form of translationally or rotationally invariant patterns of optical axis inside the intrinsically birefringent liquid crystal phase, can be used to control the flow of light at the microscopic level.

More specifically, this talk will focus on the theoretical [1] and numerical [2] tools that we recently introduced to describe the light-matter interaction between topological solitons and beams confined between two glass plates in the linear optical regime (beam power too weak to induce a modification of the orientational order of the liquid crystal).

First, I will present how the interaction of light with translationally invariant topological solitons can be described with a generalization of Snell's law, thus showing that despite our system's complex nature, our findings can be paralleled with the familiar phenomena of total reflection and refraction at interfaces of optically distinct media, albeit these behaviors arise here in a medium with homogeneous density and chemical composition but with spatial variations of molecular and optical-axis orientations. I will show some example of applications of this law with beam propagation simulations and direct comparisons with experiments done in the group of Prof. Smalyukh in Boulder.

Second, I will focus on a powerful ray-tracing model which can describe the interaction of light rotationally invariant topological solitons. This ray-tracing model allows to get a surprisingly accurate reproduction of the behavior observed in experiments, including lensing and deflection effects. I will present the scope and limitations of this method based on beam propagation simulations and experiments, and will present an outlook on possible applications for tunable photonics devices

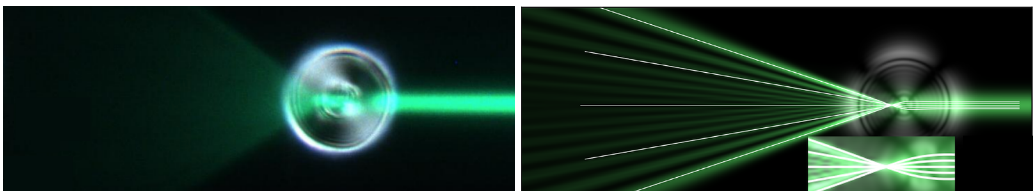

Fig. 1: Experimental (left) and simulated (right) lensing of light with torons.

[1]. Hess, A. J.; Poy, G.; Tai, J.-S. B.; Žumer, S.; Smalyukh, I. I.; Control of Light by Topological Solitons in Soft Chiral Birefringent Media, Phys. Rev. X 2020, 10, 031042.
[2]. Poy, G.; Žumer, S.; Physics-based multistep beam propagation in inhomogeneous birefringent media, Optics Express 2020, 28, 24327.