Lyotropic chromonic liquid crystal droplets: chiral symmetry breaking and surface faceting

Joonwoo Jeong,1,* Zoey. S. Davidson,1 Peter. J. Collings,1,2 Tom. C. Lubensky,1 and A. G. Yodh1

1 Department of Physics & Astronomy, University of Pennsylvania, Philadelphia, PA, USA
2 Department of Physics & Astronomy, Swarthmore College, Swarthmore, PA, USA

Lyotropic chromonic liquid crystals (LCLCs) are composed of organic molecules of plank-like shapes that self-assemble/disassemble in water into columnar aggregates via non-covalent interactions. These aggregates condense into nematic or columnar phases, depending on the concentration and temperature, that show intriguing bulk elasticity and surface anchoring phenomena. While a variety of organic molecules such as drugs, dyes, and biomolecules exhibit LCLC phases, far less is known about the fundamental science and applications potential of LCLCs than thermotropic liquid crystals.

Here, we report on the director configurations of LCLCs confined to spherical droplets. Droplets provide a superb platform to study basic properties of LCLCs because of their highly symmetric finite-volume confining geometry and, usually, their uniform and easily controllable boundary conditions. Specifically, we investigate director configurations of Sunset Yellow FCF (SSY) LCLC droplets, which are dispersed in an oil phase with the help of surfactants, using bright-field and polarized optical microscopy.

A nematic LCLC droplet with a twisted bipolar configuration and two surface point defects (Left) and a columnar LCLC droplet with a concentric configuration, a core line defect, and facets (Right)

The experiments reveal novel droplet types arising from LCLC’s giant elastic anisotropy and from the planar anchoring of their aggregates at an oil-water interface. Because of the unusually small twist elastic modulus of the nematic phase of LCLC, droplets of this phase exhibit a twisted bipolar configuration with unprecedentedly large chiral symmetry breaking. In droplets of the columnar phase, the columnar aggregates wrap in concentric circles around a central disclination line while keeping their 2D hexagonal lattice structure. Moreover, the lattice structure causes surface faceting of the columnar droplets as the LCLC concentration is further increased. Observations of the director configurations are consistent with Jones matrix calculations and are understood theoretically to be a result of the giant elastic anisotropy of LCLCs.

This work provides a new insight about the interplay of elastic anisotropy of confined materials and geometrical frustration imposed by boundary conditions, demonstrating spontaneous formation of chiral structures from achiral building blocks in the nematic phase and of central line defects and surface faceting in the columnar phase. Moreover, since LCLCs are water-loving, these findings and insights take steps towards tapping applications of aqueous liquid crystals for biological media and other materials that “live” in water.

* presenting author; E-mail: jjeong@sas.upenn.edu