1. PRF# 56046-ND7
2. Simultaneous 3D Director Imaging and Biaxial Rheology of Lyotropic Chromonic Liquid Crystals
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Most significant results:

1. The phase diagram of Tartrazine and Allura red. For concentration 44 wt % in water, tartrazine shows a columnar phase below 26 C; coexisting columnar and nematic phase at the temperatures between 40 C and 26 C, a coexisting range of nematic and isotropic at temperatures between 52 C and 40 C. In contrast, Allura red in water solutions with 34 weight % concentration showed only the nematic phase, at the temperatures below 70 C; a coexisting region of the nematic and isotropic between 71 C and 88 C, and isotropic phase above 88 C.
2. A new technique of patterned alignment of lyotropic chromonic liquid crystals (LCLCs) has been developed. The alignment direction of LCLCs is photo-patterned into complex spatially varying structures with a micron-scale precision by using plasmonic metamasks. Conventional approaches to photo-patterning typically use multiple exposures of photosensitive aligning layers to differently polarized light beams. Moreover, in the case of LCLCs, photo-alignment also requires an addition of surfactants which are toxic and thus preclude interfacing with many biosystems. In the proposed approach, the multiple exposures are eliminated by using a plasmonic metamask with a pattern of nano-slits that control the polarization of a transmitted light. A single exposure of a photosensitive layer of azo-dye to the light with local polarization determined by the mask is sufficient to create the pattern of spatially-varying orientation of the dye molecules. When this photo-patterned azo-dye is used directly to align the LCLC, it produces only a transient effect, as the dye dissolves in water. To prevent the mixing, we use an additional layer of photo-polymerizable liquid crystal monomer that physically separates the azo-dye from the LCLC while transferring the alignment pattern from the azo-dye layer to the bulk of the LCLC. The approach is demonstrated to produce complex patterns of spatially-varying orientation of LCLCs, including those with topological defects; it requires no surfactants, and thus makes it possible to interface the patterned LCLCs with bio-matter. The demonstrated single-exposure and surfactant-free photo-patterning of LCLCs opens new opportunities in the development of advanced materials and systems based on aqueous soft matter. The patterned images made with LCLCs are shown in Fig.1.

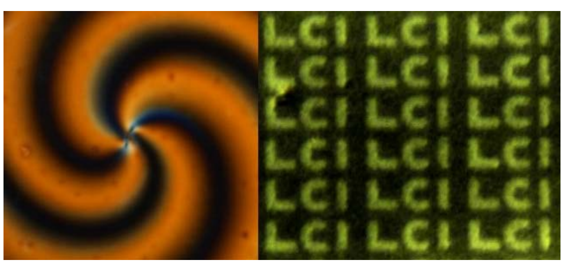

Figure 1. Polarizing optical microscopy textures of patterned alignment of LCLCs.

The surface alignment of LCLC was also used to enhance interactions among swimming bacteria By using the developed approach for the so-called homeotropic alignment of LCLCs, we demonstrated that bacteria *B. Subtilis* can swim not only parallel but also perpendicularly to the director, Fig.2. The experiments demonstrate that the dynamic activity of bacteria can be effectively controlled by the surrounding anisotropic environment, thus opening opportunities for designing spatiotemporal behavior and development of materials and systems with an efficient transformation of chemical energy into sustained mechanical motion and useful work. This research, published in New Journal of Physics, has been included in the exclusive “Highlights of 2017” selection for its “novelty, scientific impact and broadness of appeal”

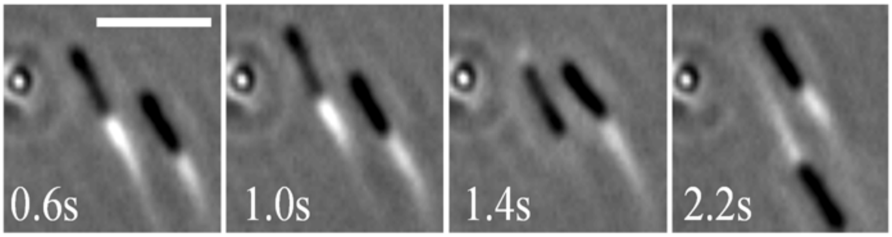

Figure 2. Swimming and backtracking of *B. Subtilis* perpendicularly to the director in a liquid crystal. Scale bar: 10 micrometers.

3. We significantly improved the analysis of microscopy images by extracting all the useful information theoretically contained in a complex microscope image. Using a generic, methodological approach, we extract the information by fitting experimental images with a detailed optical model of the microscope, a method we call parameter extraction from reconstructing images (PERI). As a proof of principle, we demonstrated this approach with a confocal image of colloidal spheres, improving measurements of particle positions and radii by 10–100 times over current methods and attaining the maximum possible accuracy. With this unprecedented accuracy, we measured nanometer-scale colloidal interactions in dense suspensions solely with light microscopy, a previously impossible feat. Our approach is generic and applicable to imaging methods from brightfield to electron microscopy, where we expect accuracies of 1 nm and 0.1 pm, respectively. This work was recently published in PRX.

4. The impact of this research on the career of O.D. Lavrentovich is enormous. By using patterned LCLCs, the Lavrentovich’s group demonstrated an unprecedented command of dynamic behavior of swimming bacteria, by controlling geometry and polarity of their trajectories and spatially varying concentration. Taras Turiv, one of the graduate students involved in the project, after obtaining experience with alignment of LCLCs, used these materials as media for swimming bacteria. Greta Babakhanova, who also worked on the alignment of LCLCs, also benefitted tremendously, since she applied the patterning technique to liquid crystal elastomers and demonstrated how one can produce deterministic changes in the surface profiles of polymer coatings activated by temperature. Both students are working on their PhD theses. Taras Turiv success in research was reqarded by the University Fellowship for Spring 2019 semester. Greta Babakhanova received the Best Poster award at the recent International Liquid Crystal Conference in Kyoto, Japan.

5. The impact of this research on Cohen has been equally impactful. Through development of PERI Cohen’s group is poised to make measurements that have thus far been impossible to make placing this group in a unique position to make a large impact in the field. The graduate student funded by this award, Dr. Brian Leahy, is now a postdoc in the Manoharan group at Harvard. An additional graduate student funded by this award, Meera Ramaswami is making excellent progress towards her PhD.