Complex nematic fluids show a variety of interesting mechanisms—including self-assembly, activity, memory, and material flow—that can be used to create complex optical and photonic structures. Here, we present our modeling work, in full collaboration with partner experiments, along two recent research directions: (i) controlling the microscopic flow of active and passive nematic fluids in microfluidic environment, and (ii) assembly and topology in nematic fluid as achieved by manipulating colloidal particles. Our work is based on the phenomenological Beris-Edwards model, which is solved via a hybrid lattice Boltzmann method in full three spatial dimensions. For the passive nematic fluids, we demonstrate the emergence of three characteristic flow regimes dependent on the driving pressure, where material flow fronts are shaped by tuning the nematic orientational profiles. This approach is shown further to be able of flow-steering and multi-stream flows, and moreover to be compatible with micro-controlling the flow with external electric and light. Alternatively, for active LCs in channels, we show active flow states, which are found to importantly depend on the confinement and anchoring conditions by the surfaces. In a cylindrical capillary, we find that active flow emerges not only along the capillary axis but also within the plane of the capillary, where radial vortices are formed. Also, we show that topological defects, imposed by heterogeneous boundary conditions, act as sources of activity—effective local pumps—driving the flow. For the particle assembly, we show that three-dimensional colloidal crystals can be assembled from elastic dipoles and quadrupoles of spherical beads in nematic liquid crystals, interestingly showing responses to external electric field like giant electrostriction and electro-rotation. Finally, by generalizing the particle shape, we demonstrate mutually linked particle- and field-knots, which reveal novel inter-linked topology of physical and field structures.

Selected recent references:

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