Lattice Boltzmann simulations of blue phases in cholesteric liquid crystals: equilibrium phase diagram and hydrodynamics

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We use a lattice Boltzmann algorithm to investigate the cubic blue phases in cholesteric liquid crystals. The algorithm solves the Beris-Edwards equations of motion for a cholesteric liquid crystal. These include three equations for the velocity field and five for the order parameter independent components of the tensorial order parameter. The coupling between these equations, also known as back-flow, is naturally incorporated.

Blue phases occur naturally in the neighbourhood of the transition between the isotropic and the helically ordered phases, and display remarkable optical properties. The thermodynamics of blue phases has so far only been considered within drastically approximated frameworks.

We first obtain the equilibrium phase diagram and compare it with previous results published in the literature. We find that the stability region of blue phases (in the chirality-temperature plane) is considerably larger than estimated via previous semi-analytic evaluations.

We then consider Poiseuille flow starting from the simplest cubic blue phase (known as the O_2 phase) and report how the imposed flow affects the disclination line topology typical of that blue phase configuration. We also single out back-flow effects in the steady state flow. The present lattice Boltzmann calculation represents the first numerical treatment of blue phase rheology to our knowledge. We discuss our findings in relation to recent and old experimental results on the flow properties of blue phases and of networks of disclinations in cholesteric liquid crystals.