Modulated liquid-crystal phases induced by polarity: Twist-bend, splay-bend, and blue phases

S. M. Shamid,1,2 S. Dhakal,1,2 D. W. Allender,1,2 and J. V. Selinger1,*

1 Liquid Crystal Institute, Kent State University, Kent, Ohio 44242, USA
2 Department of Physics, Kent State University, Kent, Ohio 44242, USA

Bent-core liquid crystals exhibit a rich variety of phases with different possible types of orientational order, including isotropic, uniaxial nematic, biaxial nematic, and polar. A classic argument of Meyer [1] shows that polar order of the transverse direction couples to bend in the main director. Recent research has found two remarkable physical phenomena arising from this coupling:

a. Flexoelectricity: Experiments by Harden et al. [2] found that bent-core liquid crystals have a surprisingly large bend flexoelectric coefficient, three orders of magnitude larger than typical values in rod-like liquid crystals. Although these results are controversial [3], we would like to understand what behavior is theoretically possible.

b. Modulated phases: Theoretical work by Meyer [4] and further studies by Dozov [5] have shown that the uniform nematic phase can become unstable to the formation of a modulated polar phase. One type of modulated polar phase, the twist-bend phase, has been seen experimentally [6-9]. An important theoretical question is then: What other modulated phases can form—the splay bend phase predicted by Meyer and Dozov, or other more complex phases?

Here we present a theory of polar order and director bend, which explains both flexoelectricity and modulated phases. For this work, we use both Landau theory and lattice simulations. In the uniform nematic phase, we find the optimal polarization for fixed bend, or conversely the optimal bend for fixed polarization (or applied electric field). This calculation gives the bend flexoelectric coefficient $e_3$, and it shows the difference between the bare elastic constant $K_3$ and the effective (or renormalized) constant $K_3^{\text{eff}}$. As the temperature decreases toward a critical temperature, $e_3$ increases and $K_3^{\text{eff}}$ goes to zero. Below that critical temperature, the uniform nematic phase becomes unstable to the formation of a new phase which has both polar order and spontaneous bend, and hence has a modulated structure.

Our theory predicts the twist-bend and splay-bend phases as well as polar blue phases, with 2D or 3D modulations of the director field and the polar order. The figure below shows one example of a polar blue phase (with green arrows representing polar order and red rods representing the director field). We compare these polar blue phases with chiral blue phases, and discuss opportunities for observing them experimentally.

References:

* presenting author; E-mail: jselinge@kent.edu