# Physical Properties of Nematic Banana Phases

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As an example we discuss the symmetry properties and the macroscopic behavior of a nematic liquid crystal phase with D2d symmetry. Such a phase is a prime candidate for nematic phases made from banana-shaped molecules where the usual quadrupolar (nematic) order simultaneously exists with the octupolar (tetrahedratic) one. In particular, the nematic preferred direction is along one of the (improper) 4-fold rotational axes of the tetrahedratic order, thus resulting in a nematic-type phase that is a (tetragonal) biaxial one without inversion symmetry. However, only the orientation and rotation of the director is observable optically, visually rendering the phase uniaxial. As a consequence, many static as well as reversible and irreversible contributions unknown in conventional nematics arise. In particular, there is a linear gradient term in the free energy that can lead to a helical ambidextrous ground state, although the molecules are achiral. In addition, there are static and irreversible coupling terms of a type only met otherwise in macroscopically chiral liquid crystal systems, e.g. the ambidextrous analogues of Lehmann-type effects known from cholesteric liquid crystals. We also discuss the role of hydrodynamic rotations about the nematic director. The behavior in a static electric field gives rise to additional possibilities to distinguish a D2d from ordinary nematics. First, a D2d phase allows second harmonic generation as it breaks parity symmetry. Secondly, it has an unusual reorientation behavior: Below a threshold field, the director is oriented in the usual uniaxial nematic way. Above this threshold value the director turns away continuously from its original orientation to a direction oblique to the field, a phenomenon unknown in an ordinary uniaxial nematic. In addition, we describe the non-hydrodynamic aspects of the dynamics, if the two order structures, the nematic and the tetrahedratic one, rotate relative to each other. Finally, we discuss certain nonlinear aspects of the dynamics related to the non-commutativity of three-dimensional finite rotations as well as other structural nonlinear hydrodynamic effects.