Optical Mode in Tilted Hexatics

In an interesting recent Letter,[1] Dierker and Pindak reported the experimental observation of an optical mode in tilted hexatic liquid crystals associated with the relative motion of the bond angle and the tilt angle. The experimental results presented are undoubtedly of high quality and very convincing. It seems important to point out, however, that the optical mode associated with the relative motion of the bond and tilt angle in tilted hexatics has actually been predicted by the present authors over three years ago[2] theoretically. We found[2,3] that only a combined rotation $2\delta\theta \equiv \delta\Theta + (\hat{\mathbf{p}}\times\hat{\mathbf{c}})\cdot\delta\mathbf{c}$ corresponds to a truly hydrodynamic variable connected with a broken rotational symmetry, whereas the relative rotation described by $2\delta\Phi \equiv \delta\Theta - (\hat{\mathbf{p}}\times\hat{\mathbf{c}})\cdot\delta\mathbf{c}$ is a macroscopic variable. Here we have used the notation introduced in Ref. 2: $\hat{\mathbf{c}}$ denotes the preferred direction inside the plane of the layers, $\hat{\mathbf{p}}$ is the layer normal, $\delta\Theta$ the bond angle, and $\delta\mathbf{c}$ (with $\hat{\mathbf{c}}\cdot\delta\mathbf{c} = \hat{\mathbf{p}}\cdot\delta\mathbf{c} = 0$) describes rotations of the long molecular axis about the centers of mass. That is, there is only one truly hydrodynamic variable associated with the in-phase motion of the tilt- and bond-angle fields,[2] and thus there is only one additional dynamic degree of freedom[2] and therefore one additional Goldstone mode.[4,5] Thus the claim made in Ref. 1 that tilted hexatics should possess two Goldstone modes corresponding to splaylike and bendlike coupled in-phase motions of the tilt- and bond-angle field is incorrect. The number of additional dynamic degrees of freedom and therefore of Goldstone modes has nothing to do with the number of possible deformations (splay and bend). The interpretation of the data and the conclusions presented in Ref. 1 remain unchanged by this fact.

We found[2] for the contributions of $\delta\Phi$ and $\delta\theta$ to the generalized free-energy density [an effective Hamiltonian similar to Eq. (1) has been given by Nelson and Halperin[6]],

$$f = \tfrac{1}{2} M_{ij}(\nabla_i\theta)(\nabla_j\theta) + \tfrac{1}{2} P_{ij}(\nabla_i\Phi)(\nabla_j\Phi) + \tfrac{1}{2} N_{ij}(\nabla_i\Phi)(\nabla_j\theta) + B(\delta\Phi)^2, \quad (1)$$

and for the dissipative currents[2] related to $\delta\Phi$ and $\delta\theta$

$$Y^D = -\mu_1\nabla_i\chi_i + \mu_2(h - \nabla_i\pi_i),$$
$$Z^D = \tau(h - \nabla_i\pi_i) - \mu_2\nabla_i\chi_i. \quad (2)$$

This gave rise to the—now experimentally confirmed[1]—prediction[2] of an optical macroscopic mode[2]

$$\omega = i\tau B, \quad (3)$$

and of various truly hydrodynamic modes.[2]

We consider the experimental observation of the optical mode to be a very convincing demonstration that the concept of macroscopic variables, as it has also been put forward for other liquid crystalline phases,[7-9] for superfluids,[10-12] and for incommensurate systems,[13] is applicable in many cases and thus provides a vehicle to study theoretically and experimentally phenomena which are not truly hydrodynamic, but which give rise to excitations which relax even in the limit of very small wave numbers in a large but finite time—not only for systems close to a phase transition,[8,10] but also in the bulk of a phase.[7-9,11-13]

Support of this work by the Deutsche Forschungsgemeinschaft is gratefully acknowledged. One of us (H.P.) thanks the National Science Foundation for support of his work under Grant No. PHY82-17853, supplemented by funds from the National Aeronautics and Space Administration.

Helmut R. Brand
Fachbereich 7, Physik, Universität Essen
D4300 Essen 1, West Germany

Harald Pleiner
Institute for Theoretical Physics and Materials Department
University of California
Santa Barbara, California 93106

Received 11 September 1987
PACS numbers: 61.30.−v, 64.70.Md, 78.62.+i

[1] S. B. Dierker and R. Pindak, Phys. Rev. Lett. **59**, 1002 (1987).
[2] H. Pleiner and H. R. Brand, Phys. Rev. A **29**, 911 (1984).
[3] H. Pleiner, Mol. Cryst. Liq. Cryst. **114**, 103 (1984).
[4] P. C. Martin, O. Parodi, and P. S. Pershan, Phys. Rev. A **6**, 2401 (1972).
[5] D. Forster, *Hydrodynamic Fluctuations, Broken Symmetries and Correlation Functions* (Benjamin, Reading, MA, 1975).
[6] D. R. Nelson and B. I. Halperin, Phys. Rev. B **21**, 5312 (1980).
[7] H. R. Brand and H. Pleiner, J. Phys. **45**, 563 (1984).
[8] H. R. Brand, Phys. Rev. A **33**, 643 (1986).
[9] H. R. Brand and H. Pleiner, Phys. Rev. A **35**, 3122 (1987).
[10] I. M. Khalatnikov, *Introduction to the Theory of Superfluidity* (Benjamin, New York, 1965).
[11] R. Graham and H. Pleiner, Phys. Rev. Lett. **34**, 792 (1975).
[12] H. Brand, M. Dorfle, and R. Graham, Ann. Phys. (N.Y.) **119**, 434 (1979).
[13] H. Brand and P. Bak, Phys. Rev. A **27**, 1062 (1983).