Chapter 16

X-RAY STUDIES OF THERMOTROPIC LIQUID CRYSTALS

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1. Introduction

Thermotropic liquid crystals are characterized by three types of order: orientational order, positional order and bond orientational order\(^1\). These can be short range order, quasi long range order or long range order. X-ray diffraction studies serve to probe the types and extent of the order. Such studies not only enable us to understand the structure of the mesophase, but also permits us to investigate how fluctuations associated with shortrange smectic-like order develop close to phase transitions. With the advent and extensive development of the high resolution X-ray scattering techniques, we are now in a position to measure correlation lengths extending to a few micrometers. This resolution, coupled with the ability to achieve a millikelvin temperature control, have led to a variety of new results which are fundamentally important in our understanding of condensed matter. In this chapter, we shall describe in some detail three important results: 1) observation of algebraic decay of positional order in smectic-A; 2) critical divergence of anisotropic correlation lengths near the nematic-smectic-A transition and 3) a new type of critical point involving two smectic A phases of the same symmetry.

2. Algebraic Decay of Positional Order in Smectic A: Landau-Peierls Instability

It has been known theoretically for some time that translational order as it occurs in a solid, cannot exist in two dimensions because it is destroyed by thermally excited fluctuations\(^2\). Thus, for crystalline solids the lower marginal dimensionality \(d^*\) is two.

This is the spatial dimension at which thermal fluctuations prevent the establishment of the long-range order. For many systems \(d^*\) is two, and this is one of the reasons for the intense current experimental and theoretical interest in two-dimensional materials. For these systems it is predicted that a transition occurs to a state of quasi-long range order in which the positional correlation functions do not extend to infinity, but decay algebraically as some power of the...
Fig. 1. Schematic representation of smectic A. The picture on the left is a classical picture. The figure on the right is a more correct representation of the smectic A: a density modulation which is sinusoidal. [Ref. 9]

Fig. 2. Longitudinal line profile for the smectic A phase of 80CB, direct beam and simulated profile of smectic A if it had true long range order. [Ref. 9]

Fig. 3. Top: Susceptibility $\sigma_0$ and the longitudinal and transverse correlation lengths above the smectic A phase of 40.7. The value of $q_0$ is 0.222 Å$^{-1}$. Bottom: Comparison of the longitudinal correlations data for 80CB obtained for X-ray diffraction (solid circles) and light scattering (open circles). [Ref. 11]