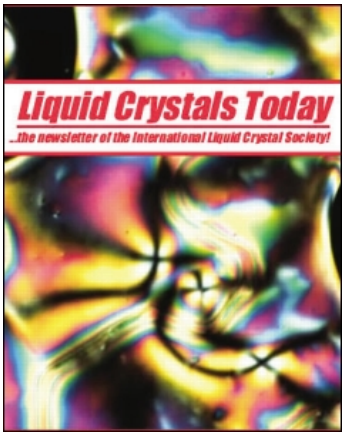

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Liquid crystals

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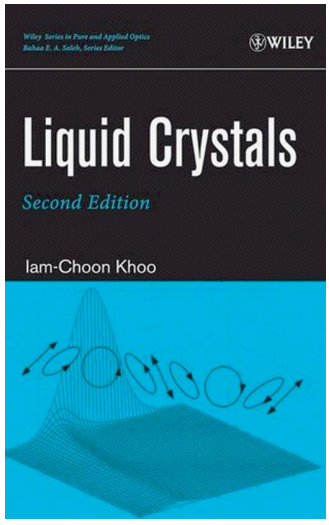
Book Review

Liquid crystals, by Iam-Choon Khoo (2nd edition), Wiley, 2007, 364pp. €128,30 (hardback), ISBN: 978-0-471-75153-3.



This book contains a strongly focused account of modern applied optics and non-linear optics (NLOs) of nematic/cholesteric and (to a small extent) smectic liquid crystals, despite the broad-sounding title, which suggests a more general introduction to liquid crystals. As might be anticipated, the book strongly reflects the interests and expertise of its author. A title that is of course too long, but which might better have described the contents, could be 'Linear and non-linear optics of thermotropic calamitic liquid crystals and their application in non-display devices'.

Some introduction to liquid crystals is of course provided, and this is the topic of the book's first four chapters. I will come back to these later as I would like to start with the chapters dealing with the optics of liquid crystals, which constitute the unique part of this book. Chapter 5 gives a description of light scattering in liquid crystals, unusual in its coverage among liquid crystal text books. After general introductory sections, Raman, Brillouin and Rayleigh scattering are in turn considered specifically. The basic optics and electro-optics of thermotropic nematics follow in chapter 6, with a very brief summary of the basic polarisation optics, the Frederiks[1] transition, a condensed summary of display modes (not going beyond Twisted Nematic) and some examples of non-display applications. A few pages are also devoted to electrooptical devices from ferroelectric smectic liquid crystals. The chapter unfortunately shows some signs of carelessness, for instance forgetting cubic phases in the statement that all crystal phases are optically anisotropic, a few typos (e.g. missing angles in Figure 6.9), and ambiguous definitions of some concepts. There is also no attempt to actually explain why the polarisation plane is guided by the twisted director structure. However, this chapter also has its highlights, such as the nice descriptions of optically addressed spatial light modulators and tunable frequency selective planar structures towards the end.

In chapter 7 the formalism for analysing the optics of liquid crystal devices (LCDs) numerically is presented (Jones and 4×4 matrix methods as well as the finite-difference time-domain technique). The alternative Poincaré sphere analysis is not mentioned, presumably as it is less useful in simulations and numeric modelling. I think this is a pity, since it is a much more pictorial approach that allows even a non-optics expert to understand the optics of twisted and supertwisted nematic cells, as well as simpler components, such as phase plates. The most interesting part of this chapter is in my opinion the coverage of negative-index materials (NIMs). This very hot field is one where liquid crystals may come to play an increasingly important role in the near future and it is thus excellent that Khoo includes this in his book. I would in fact have preferred an even richer treatment, explaining a bit more the physics behind the systems so far presented (for instance, while NIMs from nematics doped with spherical core-shell particles are mentioned, the author does not tell how these nanoparticles endow the nematic with NIM properties) and what would be required for future, enhanced liquid crystal-based NIMs. Many liquid crystal researchers are today considering using liquid crystals in the production of NIMs or various photonic crystal structures and it would have been welcome if the book would have had more visionary outlooks from one of the foremost experts in the field, containing suggestions on which

[1] I use the spelling that follows from a direct transcription from the Russian alphabet, as promoted by Sluckin, Dunmur and Stegemeyer in their recent monograph on the history of liquid crystals (*Crystals that flow*, Taylor & Francis, 2004).

ways to go. Such guidelines would have been most helpful, e.g. for chemists and materials scientists who often do not have the required optics expertise. Perhaps they will find their way into the third edition of the book.

After these on the whole still relatively general optics chapters, the rest of the book contains its most important and most original content. Chapters 8–10 cover three different categories of NLOs in liquid crystals: laser-induced orientational NLOs, mechanisms driven by thermal or density gradients, and electronic optical non-linearities. The effects considered in chapter 8 are the induction of orientational order in the isotropic phase, director reorientation in the nematic phase (optical Frederiks transition) and photorefractivity. In chapter 9, the author instead considers the effects originating in laser heating or electrostrictively induced density variations, whereas chapter 10 deals with electronic transitions following upon absorption of laser light.

After these three applied chapters on NLOs in liquid crystals, the title of chapter 11, 'Introduction to non-linear optics', comes as a bit as a surprise. The chapter begins with the development of the formal treatment of non-linear polarisation and refractive index changes in a relatively general manner, but then follows an introduction to more specific non-linear optical effects, such as wave mixing, phase conjugation, self-focusing and self-phase modulation. The chapter ends with coverage of stimulated scattering. The book closes with chapter 12, giving a number of examples of the non-linear optical phenomena in liquid crystals introduced in chapter 11 (as well as some others), together with some discussion of the application possibilities. A topic of great current interest that unfortunately is not covered in the book, but that would have fitted well, is lasing using chiral liquid crystals. Again, this could be a valuable addition for a third edition.

On the whole, chapters 8–12 constitute a valuable reference for persons working in non-linear optical applications of liquid crystals and I see these chapters as the main reason for acquiring this book. The chapters are not written for beginners or non-physicists, however. A thorough understanding of mathematical physics, optics and basic quantum mechanics is a requirement for understanding and appreciating the contents. The threshold is not lowered by two aspects that are general characteristics of this monograph: throughout the book, explanations are generally highly condensed, derivations often jumping over implicit steps, and pictures are relatively scarce and often rather spartan in content. While advanced readers might appreciate the resulting concise treatment, less experienced readers could have difficulties.

Coming back to the book's title, it is a somewhat bewildering choice. 5CB and E7 are the materials appearing in the vast majority of experiments described. Discotic liquid crystals are never mentioned, not even in the discussion of optical compensation films for displays. Lyotropic liquid crystals are given one third of a page of this 364 page book. The book does not contain any texture examples and equally absent are defects. While the author's choice to select certain aspects of liquid crystal science would not even have been worth a mention had it not been for the book's title, the first four introductory chapters in fact contain some problems that cannot be ignored. Some descriptions are rather difficult to understand, a few parameters and concepts used in discussions, equations and derivations are not defined, or defined much later than their first appearance, and there are some rather unusual statements. An example of the latter is the classification of liquid crystals into the three classes thermotropic, lyotropic and polymeric. I at least cannot think of any polymeric liquid crystal that is not either thermotropic or lyotropic (or both). Other illustrative examples are found in chapter 2, which begins with the sentence: 'Generally speaking, we can divide liquid crystalline phases into two distinctly different types: the ordered and the disordered'. In the same vein, the author writes on page 25: 'An important distinction between liquid crystals and ordinary anisotropic or isotropic liquids is that, in the isotropic phase, there could exist a so-called short-range order, that is, molecules within a short distance of one another are correlated by intermolecular interactions'. I find these views of the relations between isotropic and anisotropic and between short- and long-range order rather surprising and in fact quite confusing. A final example is the opening sentence of chapter 6: 'Perhaps the most studied and applied property of liquid crystals is their light-scattering ability'. While scattering mode displays were indeed the first LCDs, they have since long been replaced by non-scattering devices.

There are some printing errors and some equations and figures that unfortunately are flawed. Examples are the diagram of free energy versus order parameter in Figure 2.6 where the low-temperature ordered phase has a lower order parameter than it has at the first-order transition temperature to/from the disordered phase, the unequal dielectric constants parallel and perpendicular to the director said to be measured in the isotropic phase in Figure 3.5 and the drawing of refractive indices versus temperature for 5CB in Figure 3.7 with continuous inclined lines extending from the isotropic–nematic transition, giving the impression that this would be of the second order.

The elastic energy expression for a cholesteric (Equation (4.4)) lacks the chiral term and in the discussion of the corresponding expression for a chiral smectic (Equation (4.76)) the reader gets the impression that K_1, K_2 and K_3 would have their usual meaning, as known from nematics. In the case of a few pictures borrowed from other sources (e.g. Figure 4.3 from de Gennes) the author forgot to provide the reference. It is clear that the author's passion lies in the realm of optics, whereas this general introduction to liquid crystals unfortunately has not received the same attention as the later chapters of the book.

Summarising, I.-C. Khoo's book should be a highly useful resource for physicists working with linear and, in particular, non-linear optics of liquid crystals, mainly for non-display applications. Despite its title it should not be understood as a general introduction to liquid crystals. While the introductory chapters are not fully convincing, the book finds its strength in the modern and rich coverage of NLOs of liquid crystals, constituting the major part of the book.

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