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Curvature oscillations and linear electro-optical effect in a surface layer of a nematic liquid crystal

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Abstract. — Damped curvature oscillations are excited at the surface between a nematic liquid crystal and a solid substrate, from the linear coupling of an AC electric field with the flexoelectric properties of the medium. The waves are detected by a modulation ellipsometry technique. Linear-in-field oscillations of the director in the surface nematic layer have been observed. The amplitude and characteristic response time of the oscillations are defined by visco-elastic and flexoelectric properties of the medium and the overlapping of the curvature wave with the profile of the sampling optical evanescent wave. A simple model is discussed which is in good agreement with experiments performed on a compensated MBBA mixture (with zero dielectric anisotropy) and 5CB. The anchoring energy for the nematic in contact with obliquely evaporated SiO layer, as well as the sum $e_1 + e_3$ of the flexoelectric coefficients are measured, indicating a surface order parameter smaller than its bulk value.

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Introduction.

Nematic liquid crystals are centrosymmetric media. However, when they are distorted, this symmetry is broken. A flexoelectric polarization $P$ occurs which is a linear function of the curvature [1].

$$P = e_1 \mathbf{n} \text{div} \mathbf{n} + e_3 (\text{curl} \mathbf{n}) \times \mathbf{n}$$  \hspace{1cm} (1)

where $\mathbf{n}$ is the director ($n^2 = 1$) and $e_{1,3}$ are flexoelectric coefficients. When an external electric field is applied to a liquid crystal cell, it can interact with the curvature-induced polarization through the corresponding flexoelectric energy $W_f = -\mathbf{E} \cdot \mathbf{P}$. It is well known, however, that in the one-dimensional case, when the field (uniform) and the distortion are constrained to be in the same (say x, z) plane, the whole flexoelectric torque is integrated out of the volume resulting in a surface flexoelectric torque only [2]. Thus, if one applies an electric field to a cell with symmetric boundary conditions, at equilibrium, two flexoelectric torques from the opposite boundaries will cancel each other and no low field distortion can be observed. High field instabilities have been predicted [3] and observed [4-6]. For a more general three dimensional case the situation is different. The anisotropic flexoelectric torque $\sim (e_1 - e_3)$ gives rise to bulk effects [7].

If, however, one investigates the curvature (flexo-) electricity in the dynamical regime, opposite symmetrical boundaries can be decoupled. Of course, it depends on the characteristic wavelength of the distortion which must be shorter than the cell thickness. For example, if an a.c. electric field is applied to a bulk nematic, it must create an oscillating flexoelectric torque at the surface and a surface induced curvature oscillation which will decay toward the bulk. For cells thick enough there will be no interference with the corresponding curvature waves going in opposite directions from the opposite boundaries.

The aim of the present paper is to apply the modulation ellipsometry technique [8] to the investigation of the field induced curvature oscillations at the interface between a solid substrate and a nematic liquid crystal. In this case, the linear coupling of the external field with the flexoelectric properties of the nematic liquid crystal results in a linear-in-field director oscillation at the fundamental (not double) frequency of the applied field. For high enough frequencies (in fact higher than a few Hz), the curvature wavelength is short enough. In practice, one can neglect the influence of the opposite surface, even for cells as thin as 10 $\mu$m. The technique, in principle, allows one to measure the anchoring energy of a nematic at the interface with a solid substrate, to investigate surface ordering, screening of the flexoelectricity by ionic charges, etc.

Theory.

Let us discuss in more details the simplest model for the curvature oscillations electrically induced at the interface between a nematic and a solid substrate. Figure 1 shows the geometry discussed. We consider a semi-infinite pure dielectric nematic medium (no ionic processes) with negligible dielectric anisotropy $\varepsilon_s = 0$. The distortion is constrained to be only in the X, Z plane. The torque balance equation for the bulk contains only the elastic and viscous terms and has the familiar form of a diffusion equation :

$$-K \frac{\partial^2 \theta}{\partial z^2} + \eta \frac{\partial \theta}{\partial t} = 0$$ \hspace{1cm} (2)

where $\theta = \theta_0 + \delta \theta$ includes a static pretilt angle $\theta_0$ and the dynamic variation $\delta \theta$ induced from the surface Assume for simplicity $\theta_0$ uniform in the cell. $K$ is a combination of the bend
and splay elastic moduli, and \( \eta \) is an effective viscosity (mostly rotational viscosity, with some correction from back-flow). Taking the Fourier transform for \( \delta \theta \):

\[
\delta \theta = \delta \theta(z) \exp(i \omega t) = \delta \theta^s \exp(i \omega t) \exp(i q z)
\]

we obtain the dispersion relationship:

\[
Kq^2 = i \omega \eta = 0
\]

with solution

\[
q = [-1 + i] \left( \frac{\omega \eta}{2 K} \right)^{1/2} = [-1 + i] q_\omega.
\]

Equation (2) describes the decaying curvature wave with the space variation:

\[
\delta \theta(z) = \delta \theta^s \exp(-q_\omega z) \exp(-izq_\omega z).
\]

The surface amplitude of the director oscillation \( \delta \theta^s \) is still to be calculated. \( \delta \theta^s \) will be generated at the surface by the flexoelectric effect and plays the role of a boundary condition for equation (2).

To calculate the magnitude \( \delta \theta^s \), we write the torque balance equation at the surface. It includes a destabilizing, linear-in-field flexoelectric term \( H_{\text{flexo}} \) and two stabilizing ones, one coming from the anchoring of the director at the surface and the other taking into account the visco-elastic reaction of the medium (integrated out from the bulk to the surface). For the director having the form \( \sin \theta, 0, \cos \theta \), equation (1) gives:

\[
H_{\text{flexo}} = -\frac{e_1 + e_3}{2} E \sin 2\theta^s
\]

where \( \theta^s = \theta_0 + \delta \theta^s \). We use a sufficient low field \( E = E_m \exp(i \omega t) \), and an oblique initial director orientation \( (\theta_0 \neq 0, \theta_0 \neq \pi/2) \) so that we remain in the low distortion approximation.
\[ \delta \theta^s \ll \theta_0. \] In equation (6), we can just replace \( \theta^s \) by \( \theta_0 \). This approximation is not valid for \( \theta_0 = 0 \) (homeotropic orientation), or \( \theta_0 = \pi/2 \) (planar orientation). In this case, \( \Pi_{\text{flexo}} \) would write as:

\[ \Pi_{\text{flexo}} = -\frac{e_1 + e_3}{2} E \sin 2 \delta \theta^s \] (6')

we discuss this situation later.

For small surface angular deviations around the equilibrium orientation \( \theta_0 \), the stabilizing torque coming from the anchoring energy may be taken in the Rapini form:

\[ \Pi_{\text{anch}} = \frac{\partial}{\partial (\delta \theta^s)} \frac{K}{2 L} (\delta \theta^s)^2 = \frac{K}{L} \delta \theta^s \] (7)

where \( L = K/W_s \) is a characteristic length defining the anchoring energy \( W_s \). The viscoelastic surface reaction of the liquid crystal can be integrated from equation (2). Using equation (4), we find:

\[ \Pi_{\text{rel}} = -K \frac{\partial \theta^s}{\partial z} = -K i q \delta \theta^s = (1 + i) q_\omega K \delta \theta^s \] (8)

The torque balance equation for the amplitude of the director oscillation at the surface reads:

\[ -\frac{e_1 + e_3}{2} E_m \sin 2 \theta^s + K [L^{-1} + (1 + i) q_\omega] \delta \theta^s = 0. \] (9)

In the previously described approximation, the amplitude of the director oscillations at the surface is:

\[ \delta \theta^s = \frac{(e_1 + e_3) E_m \sin 2 \theta_0}{2 K [L^{-1} + (1 + i) q_\omega]} \] (10)

In the case of the strong anchoring, \( q_\omega \ll L^{-1} \), equation (10) predicts surface oscillations in phase with the electric field, with amplitude:

\[ \delta \theta^s = (e_1 + e_3) E_m \sin 2 \theta_0/2 W_s. \] (11)

A decrease in the anchoring energy as well as an increase in frequency \( \omega \) result in a crossover of the two characteristics lengths \( L \) and \( q_\omega^{-1} \) and in a phase shift between the field and the director oscillation at the surface. In the limit of a very weak anchoring, the oscillations should present a phase lag of 45° with the field, with amplitude:

\[ \delta \theta^s = \frac{(e_1 + e_3) E_m \sin 2 \theta_0}{2(\sqrt{2}) K q_\omega} \] (12)

As soon as \( q_\omega \) is known, one can calculate the anchoring energy from the amplitude \( \delta \theta^s \) (for known \( e_{1,3} \)) or from the phase shift predicted by equation (10). Note that \((e_1 + e_3)/2 = S_S \bar{e} \), where \( S_S \) is the surface order parameter modulus, and \( \bar{e} \) the material flexoelectric constant. Equations (5) and (10) define the bulk curvature oscillation in a nematic liquid crystal induced by an electric field from the surface. This oscillation can be detected optically in the form of a linear-in-field electro-optical effect. The best way to probe a surface layer optically is to use the light total reflection technique. In the case of a light
incidence at a grazing angle (higher than total reflexion angles for both polarizations), an evanescent wave of amplitude $\sim \exp(-q_\lambda z)$ is created close to the solid-nematic interface. Note that one can chose such a geometry that only the extraordinary wave is sensitive to the expected change in nematic director tilt. Calling $n_e(\sim 1.72)$ the corresponding index of refraction, at grazing incidence, $q_\lambda$ is approximately given by:

$$q_\lambda = \frac{2\pi}{\lambda} (n^2 - n_e^2)^{1/2}$$

where $n$ is the (large) index of the glass, and $\lambda$ the vacuum wavelength of light. The polarization of the evanescent wave is almost normal to the surface. In principle, it is possible to calculate the director deviation angle from the changes in the azimuthal angle of the totally reflected light polarization ellipse [8].

The ellipsometric signal produced by the director tilt is proportional to the convolution of the static shape of the evanescent wave and the shape of the curvature wave (Fig. 1). The resulting integral:

$$I = \int_0^\infty \exp[-(q_\omega + q_\lambda)z] \cos q_\omega z \, dz$$

normalized to its maximum value for $q_\omega = 0$, (i.e. $I_0 = 1/q_\lambda$) is easily calculated as:

$$\frac{I}{I_0} = \frac{q_\lambda (q_\omega + q_\lambda)}{q_\omega^2 + (q_\omega + q_\lambda)^2}.$$

$I/I_0$ is a decreasing function of $q_\omega$, from 1 ($q_\omega = 0$) to zero ($q_\omega \to \infty$). One finds $I/I_0 = 1/2$ for $q_\omega = q_\lambda/\sqrt{2} \sim 1/\lambda$. For low frequency excitation, when $q_\omega \ll \lambda^{-1}$, the optical ellipsometry probes the actual amplitude $\delta \theta^s$ at the surface. In the high frequency limit when $q_\omega \gg \lambda^{-1}$ the director oscillations and the corresponding changes in the refractive indices are averaged out and we expect a dramatic decrease in the amplitude of the linear electro-optical effect. Since $q_\lambda$ is constant and $q_\omega$ (for a given material) depends only on the frequency of the applied field, the previously discussed frequency crossover will determine the characteristic time of the linear electro-optical effect. Taking as a qualitative criterion $I/I_0 = 1/2$, we arrive at:

$$f_c = \frac{\omega_c}{2\pi} = K_i(\pi \eta \lambda^2).$$

Note that no dephasing is expected from this geometrical convolution.

Let us discuss now briefly the homeotropic alignment situation $\theta_0 = 0$ (or equivalently the planar one $\theta_0 = \pi/2$). The surface torque equation is:

$$-\frac{e_1 + e_3}{2} E_m \sin(2 \delta \theta^s) + K[L^{-1} + (1+i)q_\omega] \delta \theta^s = 0.$$  

For small field, the solution is $\delta \theta^s = 0$. There exist a field threshold:

$$E_m^\text{th} = \frac{K[L^{-1} + (1+i)q_\omega]}{e_1 + e_3}$$

above which a non zero oscillating $\delta \theta^s$, of arbitrary sign, is allowed. This would be in fact the AC version of the DC flexoelectric instability long ago predicted by Helfrich [3], and more
recently observed [4-6]. We shall not discuss this situation any further, since it does not correspond to our experimental geometry. The very simple model presented above can be generalized to take into account various other phenomena:

1) For very low frequencies and very thin cells, the destructive interference of the waves originating from the two opposite surfaces must be taken into account. This will result in the vanishing of all unidimensional distortions under discussion.

2) The quadratic coupling of the field with dielectric anisotropy must be taken into account for the case $\varepsilon_a \neq 0$. It will result in a non-linear equation for the curvature and more complicated shape of the curvatures waves.

3) Ionic processes can screen the electric field in the sample, and increase the field near the surface. This effect must be taken into account for rather conductive substances or when $q_w^{-1}$ compares with the Debye screening length.

4) Non-symmetric boundary conditions gives rise to a d.c. component of the distortion which is not averaged out and would dominate at low frequencies.

Experimental technique.

A scheme of our experimental set-up is shown in figure 2. The principal element is a liquid crystal cell consisting of a prism with high refractive index ($n = 1.806$) and an optically polished glass plate, both covered with SnO$_2$ electrodes. A nematic liquid crystal of zero dielectric anisotropy $\varepsilon_a$ at room temperature is prepared, by mixing MBBA (methoxy benzylidene butyl aniline $\varepsilon_a = -0.5$) with 4-heptyl-4'-cyanophenyl benzoate $\varepsilon_a = +9$). The mixture has a measured $\varepsilon_a = +0.07$. This nematic is oriented homogeneously (by rubbing a polyvinyl alcohol layer on the electrodes), homeotropically (with chromium distearylchloride surfactant) or with a molecular tilt $\theta_0 = 72^\circ$ (using SiO evaporation at a grazing angle). The cell is installed on an optical bench and an ellipsometry technique is used to detect angular oscillations of the nematic orientation at the surface.

Fig. 2. — The experimental set-up. 1 : laser, 2 : polaroids, 3 : liquid crystal cell, 4 : $\lambda/4$ plates, 5 : photodiode, 6 : lock-in amplifier, 7 : oscilloscope, 8 : function generator.

The principle of the optical modulation ellipsometry method we use has been described in details in a previous paper [8]. Beyond total internal reflexion (TIR) a light beam totally reflected from isotropic media undergoes a phase shift which depends on its polarization, transverse electric (TE) or transverse magnetic (TM), and on the refractive indices of the materials. Using an interference technique, one can measure the phase difference induced on the two beams after TIR. One uses for instance an incident laser beam with a linear polarization rotated by $45^\circ$ from the place of incidence, to produce two (TE and TM) beams
of equal amplitudes and phases. After TIR, the phase difference produces an elliptically polarized reflected beam. The measurement of the ellipticity allows the determination of the refractive index (or the thickness) of the material at contact with the high index glass prism.

To apply this standard ellipsometric technique to the nematic liquid crystal, which is optically anisotropic, we orient the director (planar or oblique) in the plane of incidence, which is now a symmetry plane for the whole system. (The director orientation is known from the rubbing or the evaporation directions). The two TE and TM beams become respectively ordinary (o) and extraordinary (e) polarized. If one knows the corresponding main refractive indices \( n_o \) and \( n_e \), the measured phase shift difference from the two TIR beams allows the calculation of the surface director tilt for a thick enough and uniformly oriented nematic interfacial layer. When an AC electric field is applied on the nematic material, one expects a forced oscillation of the surface director, i.e. a modulation of the TIR induced ellipticity, synchronous with the field. The surface director oscillation amplitude is calculated from the measured ellipticity modulation.

In practice (Fig. 2), we illuminate the glass-nematic interface with a He-Ne laser beam \( (\lambda = 6328 \ \text{Å}) \). The angle of light incidence \( (\phi = 80^\circ) \) is larger than the total reflection angles for both (o) and (e) laser polarizations. This provides a relatively short penetration length for the evanescent waves. A quarter wave plate converts the linear laser polarization into a circular one. A polarizer is then oriented at 45° from the incidence plane, to generate the two equal amplitude (o) and (e) beams. The totally reflected laser beam is analyzed by a quarter wave plate and a rotating analyzer. The \( \lambda/4 \) wave has one of its eigen axes rotated at 45° from the plane of incidence, to convert the elliptical polarization into a linear one. The rotation of the analyzer from this 45° orientation, which results in maximum transmitted intensity, measures the phase shift between the two reflected beams, i.e. would allow in principle to control the average surface tilt angle \( \theta_0 \). The surface orientation is modulated by an electric field \( E = E_m \cos \omega t \) from a signal generator, with frequency \( f = \omega/2 \pi \) from 0.5 Hz to 200 Hz, applied to the cell electrodes. The linear in field electro-optical modulation of the reflected beam appears at the frequency \( f \), the first harmonic of the field. To observe this modulation, the reflected beam intensity is detected by a photodiode and recorded on a lock-in amplifier, synchronously with \( E \).

To evaluate the angle of deviation of the surface director, we measure first the DC intensity of the reflected light versus the angular orientation of the analyzer (Fig. 3, curve 1), with respect to the plane of incidence. In absence of reflection induced phase change, the Malus law would give a sine wave with maximum and minimum at 45° and 135°. Here, we observe a phase shift of 20°. Using the formula of reference [8], we can check the value \( \theta_0 = 72^\circ \), in agreement with the expected value.

We now measure the amplitude of the AC detected current at frequency \( f \), versus the analyzer angular orientation (Fig. 3, curve 2). This amplitude is proportional to the derivative of curve 1, i.e. its maximum is dephased by 45°. Knowing the slope of curve 1, we can determine the absolute change in phase induced by the electric field [8]. We then calculate the corresponding change in refractive index for the extraordinary wave and finally the director deviation \( \delta \theta \) close to the prism surface. All our reported data have been taken by keeping the orientation of the analyzer along the direction of maximum AC signal.

The linear-in-field electro-optical response was also observed for pure MBBA \( (\varepsilon_a = -0.5) \) and 5CB (penty1 cyanobiphenyl) \( (\varepsilon_a = +8) \). In the case of small applied field the behaviour of the latter is very similar to that of zero dielectric anisotropy MBBA. For higher field the quadratic electro-optical effect which, in all cases, is observed at the double frequency of the applied field, influenced the field response at the first harmonic. We have also performed comparative pulse measurements of the linear effect and the Freedericks transition (for doped MBBA and 5CB) which allow the absolute sign of the linear effect to be determined.
Results and discussion.

The temperature behaviour of the linear-in-field electro-optical response from the surface nematic layer is shown in figure 4. It is clear that the effect is produced by the field-induced orientation of the director because it decreases dramatically at the nematic-isotropic transition. It should be noted, however, that the modulation remains non-zero in the isotropic phase also. Additional experiments have shown that a small modulation is also observed in ordinary liquids such as ethanol and water and results probably from an electrochemical modulation of the optical properties of the SnO$_2$ electrode. The effect depends considerably on the director orientation in the sample. For the homogeneous and homeotropic orien-

![Figure 3](image-url)

Fig. 3. — The intensity of light reflected from the LC-prism interface (curve 1) and the amplitude of the linear-in-field light modulation (curve 2) versus the angular position of the analyzer (compensated MBBA mixture, tilted orientation $\theta_0 = 72^\circ$, voltage $U = 7.5$ V rms, frequency 60 Hz). The incident beam polarization and an axis of the second $\lambda/4$-plate are at $45^\circ$ from the light incidence plane.

![Figure 4](image-url)

Fig. 4. — Temperature dependence of the amplitude of the linear electro-optical effect in its maximum for the angular position of the analyser at $135^\circ$ (5 $\mu$m thick cell, compensated MBBA mixture with a tilted orientation, $U = 4$ V rms, 270 Hz).
tations, the modulation intensity is more than one order of magnitude less than for the tilted orientation with the uniform tilt angle \(\theta_0 = 72^\circ\). This dependence of the amplitude \(\delta \theta^2\) on the pretilt angle \(\theta_0\) is in agreement with equation (10) which shows that there is no flexoelectric torque for \(\theta_0 = 0\) or \(\theta_0 = \pi/2\).

Our experimental data allow the calculation of the amplitude of the field-induced director deviation \(\delta \theta^2\). For example, at \(f = 60\) Hz, \(U = 7.5\) V rms, using the compensated MBBA mixture, \(\theta_0 = 72^\circ\), \(T = 20\) °C, thickness \(d = 30\) \(\mu\)m, the amplitude \(\delta \theta^2\) is of the order of \(1.5^\circ\). Let us compare this value with the one predicted by equation (10). If we take \(K = 6 \times 10^{-7}\) dyn, \(E_m = 11.8\) CGS units, \(\sin 2\theta_0 = 0.588\) we find: \((e_1 + e_3) L = 4.5 \times 10^{-9}\) cgs.

The frequency dependence of the modulated light intensity due to the linear electro-optical effect at various applied voltages is shown in figure 5 for the compensated \((e_a = + 0.07)\) MBBA mixture with the tilted orientation \(\theta_0 = 72^\circ\). One can see that the characteristic time of the effect is about 0.5 ms (the critical frequency is \(f_c = 300\) Hz) and independent of the applied voltage. The conductivity of the material is approximately \(\sigma = 6 \times 10^{-10}\) (\(\Omega\) cm\(^{-1}\)). The special experiments performed on strongly conductive MBBA \((\sigma = 10^{-8}\) (\(\Omega\) cm\(^{-1}\)) gave approximately the same relaxation time. The thickness of the cell was varied in the limits of 5-30 \(\mu\)m and no thickness dependence of the amplitude (at the field strength fixed) or characteristic time was observed. We can compare the experimental value of the characteristic frequency \(f_c\) with that predicted by equation (13). Taking \(\lambda = 0.6\) \(\mu\)m and \(K = 6 \times 10^{-7}\) dyne, we have from equation (13): \(\eta = 0.2\) p, a reasonable value for the effective viscosity.

![Frequency dependence of the linear electro-optical switching at various applied voltages (compensated MBBA, cell thickness 10 \(\mu\)m). The cut-off frequency is noted by an arrow.](image)

The sign of the linear effect was determined by comparison of the electro-optical response to short d.c. pulses. In the latter case for materials with \(e_a > 0\) the field-induced deviation of the director from the Freedericks transition is well known. The director tends to be oriented parallel to the field, that is toward the cell normal. The sign of the linear effect appears to be opposite for MBBA and 5CB. When we apply a positive voltage to the prism electrode (the field is directed into the liquid crystal along positive \(z\)) we find the director going toward the normal for MBBA and outward of the normal for 5CB. This difference in signs is also in
agreement with the previously measured difference in the signs of the flexoelectric coefficients for these two substances [9].

On measuring the frequency curves shown in figure 5 with our lock-in amplifier we followed the phase shift between the applied field and the optical response. For all the curves shown we observed two phase shifts: one from 90° to zero in the 40-80 Hz domain, and the other from zero back to 90° around 5 KHz. The absolute value of the phase shift is not accurate, due to the imperfection of our lock-in amplifier and the weakness of the signal. The frequency range of this phase shift contains anyway an useful information. The 40-80 Hz region corresponds to the charge relaxation frequency of our nematic material and is indicative of an ionic screening effect, not described by our present model. The \( f_d = 5 \text{ kHz} \) dephasing frequency can be now interpreted as the cross-over: \( q_a(f_d) \cdot L \sim 1 \). As we know that, for \( f_c = 300 \text{ Hz} \), we have \( q_a(f_c) \lambda \sim 1 \), we immediately deduce:

\[
\left( \frac{L}{\lambda} \right)^2 = f_d/f_c \quad \text{i.e.} \quad L = \lambda \frac{f_d}{f_c}^{1/2}
\]

This results in \( L \sim 1 \, 500 \AA \), or a maximum surface energy

\[
W_s \sim K/L \sim 10^{-6}/0.15 \times 10^{-4} \sim 6 \times 10^{-2} \text{ erg/cm}^2.
\]

With this value of \( L \), we can now deduce the flexoelectric coefficient. We find:

\[
(e_1 + e_3) L = 4.5 \times 10^{-9} \text{ cgs, i.e. } e_1 + e_3 = 3 \times 10^{-4} \text{ cgs}.
\]

This value is half of the bulk measured value for MBBA [10]. We can explain this lower value by a decrease of the surface order parameters \( S \) on the SiO evaporated surface. Recent measurements [11] indicate indeed that at this rough interface, the surface order parameter can drop from its bulk value \( S = 0.6 \) down to \( S_s = 0.3 \) or 0.2. Note that the parameters \( K \), which has been introduced for convenience to define \( L \), has nothing to do with the real curvature constant at the surface and should not be affected by the change of \( S \) at the nematic SiO interface.

Conclusion.

In presence of an electric field, the flexoelectric polarization of a nematic liquid crystal leads, in principle, to a curvature distortion. As flexoelectricity is mostly of quadrupolar origin, this distortion can be described by the action of two surface torques on the cell boundaries. For DC field and uniformly oriented nematic cells, these torque cancel exactly and no effect is expected in low field. For AC fields, on the other hand, one expects a decoupling of the two boundaries: each surface torque gives rise to forced curvature oscillations, linear in field, and damped on their wavelength. Using an ellipsometric technique, we have observed these AC field induced oscillations of the surface orientation, which result in a linear electro-optic effect. The model allows to measure independently the anchoring energy of the nematic, the flexoelectric coefficient and the effective viscosity. Our results, a relatively weak surface anchoring and flexoelectric constant (\( L \sim 1 \, 500 \AA \) and \( e_1 + e_3 = 3 \times 10^{-4} \text{ cgs} \)) can be explained by a decrease of the order parameter \( S_s \) at the rough SiO nematic interface.

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References

IBM-PC in the Laboratory
B. G. THOMPSON et A. F. KUCKES

(Cambridge University Press, 1990) 245 p., £ 35.00, $ 49.50.

Le but de ce livre est de donner une introduction à l'utilisation des IBM-PC pour des expériences de laboratoire : les utilisations visées sont aussi bien le contrôle d'expériences que l'acquisition ou le traitement de données.

En fait, plus que vers les expériences de recherche, le livre est orienté vers les expériences de travaux pratiques. Comment les auteurs l'indiquent dans leur introduction, il est en fait directement issu d'un programme expérimental d'Université et sa structure est beaucoup plus celle d'un polycopié de TP plutôt que d'un véritable livre.

Cela n'est nullement condamnable mais la réalisation qui en a été faite nuit à la lisibilité de l'ouvrage : sur chaque sujet les auteurs indiquent tout ce qui est nécessaire à la réalisation et à la compréhension d'une expérience bien précise avec un matériel déterminé et seulement cela. On est ainsi un peu surpris de trouver pèle-mêle le code de couleurs de résistances, une théorie complète des forces hydrodynamiques en trois pages, puis plus loin celle de la conduction de la chaleur et une théorie de l'échantillonnage et de l'ajustement de données. On suppose par ailleurs l'utilisation d'un matériel bien déterminé, en particulier pour les cartes d'acquisition John Bell et on ne précise d'ailleurs pas la façon dont la connexion et l'utilisation peuvent être faites en pratique.

Les auteurs ne nous paraissent pas prendre suffisamment de recul par rapport à leur sujet et ne donnent pas une vue claire des différentes applications des PC en laboratoire, que ce soit à travers des cartes additionnelles ou à travers l'interconnexion d'appareils extérieurs. On aurait également aimé voir discuter l'utilisation des différents langages et programmes pour ces applications alors que seuls turbopascal et l'assembler (et encore à travers debug) sont discutés. Le livre apparaît enfin un peu vieillot compte tenu de l'évolution ultra-rapide des matériels dans ces domaines : il a semblé-t-il été peu modifié par rapport à sa première édition.

En conclusion, cet ouvrage assez confus et mal organisé ne me paraît pouvoir être utile qu'à des enseignants qui voudraient mettre en place des travaux pratiques presque identiques à ceux proposés par les auteurs.

J. P. Hulin.

Atomic collisions. Electron and Photon Projectiles
Earl W. McDANIEL


This book, and a forthcoming volume concerned mainly with heavy particle projectiles, constitute a bold attempt to give an up-to-date survey of the large and ever-expanding literature in the field of atomic collisions. Professor McDaniel, who is well known in this field for his research into ion collision physics and his book « Collision Phenomena in Ionised Gases », has succeeded admirably in this difficult task and in one of his main stated aims — to produce a book useful both as a text and a reference work. This is an authoritative, accessible and well-balanced work which will find much use at advanced undergraduate and graduate levels and for established workers in the field. Each chapter is supplemented by a large and varied selection of problems which are particularly valuable for tutorial purposes. The hints on where to find solutions will be of benefit to both teacher and pupil.

After two introductory chapters, the remaining six hundred pages of the volume are devoted to chapters on scattering theory (including a section on classical calculations), the elastic scattering of electrons by neutrals, excitation and de-excitation of neutrals by electrons, ionisation of neutrals, collisions of electrons with positive ions and, finally, photon processes. By breaking the subject down into processes in this manner the author is able to describe the mechanisms involved in the various types of collision and many illuminating discussions of their physical origin can be found interspersed in the
For experimentalists the chapter on theory, which contains a summary of many of the methods and approximations currently applied in atomic collision work, is particularly welcome. In addition there is ample discussion of theoretical aspects in many of the individual sections and chapters. This aspect contributes greatly to the accessibility of the book since, in a sense, it is composed of several near self-contained parts.

In addition to the more traditional areas of atomic collision physics which are covered the book also contains descriptions of some which are relatively new. These include collisions involving polarised particles, synchrotron radiation sources, free electron lasers, low energy positron collisions, and laser cooling and trapping. Throughout the shear breadth of the subjects covered means that much material has had to be omitted, though this is compensated by the comprehensive lists of references which can be found at the end of each chapter. Even since this book has been completed there have been significant advances in many areas of atomic physics. This does not detract from the text but is more witness to the vitality of the field. This excellent book will be used as a standard for many years to come and we look forward to the publication of its companion volume.

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