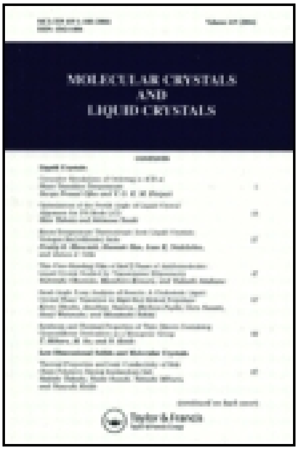

Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl16

Preliminary Results on the Elastooptic Behavior of a Cholesteric Liquid Crystal

R. Bartolino [a] , F. Simoni [a] & N. Scaramuzza [a]
[a] Dpt. Fisica Universitá della Calabria, Cosenza, Italia
Version of record first published: 14 Oct 2011.

Mol. Cryst. Liq. Cryst., 1981, Vol. 70, pp. 315–322
0026-8941/81/7001-0315 $06.50/0

Preliminary Results on the Elastooptic Behavior of a Cholesteric Liquid Crystal†

R. BARTOLINO, F. SIMONI and N. SCARAMUZZA
Dpt. Fisica Università della Calabria, Cosenza, Italia

(*Received August 5, 1980*)

We report preliminary results on the optical properties of a cholesteric liquid crystal when it is submitted to a normal stress. We see for small deformations the sample reacts elastically and the pitch decreases or increases following if we press or dilate the sample, without hysteresis. For higher stresses other physical processes take place giving also an hysteresis of the behavior.

INTRODUCTION

The optical response of a cholesteric liquid crystal (CLC) to an external mechanical action are qualitatively known,[1] but quantitative measurements are very few except for the shear effects.[2] Our purpose is also to clarify the mechanisms of the induced structural deformation in a CLC stressed parallel to the helix axis and their dynamics. Here we present some preliminary results on the effects of a normal stress on the selective reflection band: i.e. position, intensity, width. In a first approximation we expect for small deformations the CLC reacts elastically changing the average pitch of the helix. To calculate this effect we rewrite the elastic free energy of a CLC in a Landau form[3]

$$\Delta F = \frac{1}{2} k_{22} \left(\frac{2\pi}{P}\right)^2 \left(\frac{\partial u}{\partial z}\right)^2 + \frac{1}{2} k_{33} \left[\frac{3}{8}\left(\frac{\partial^2 u}{\partial x^2}\right)^2 + \left(\frac{\partial^2 u}{\partial x \partial z}\right)^2\right] \qquad (1)$$

†Presented at the Eighth International Liquid Crystal Conference, Kyoto, July 1980.
Work partially supported by the Italian CNR under contract N.79.01771.02.

(u is the layer position) the first term indicates the response of the systems formed by layers thick P(helix pitch) to a deformation normal to the layers: it is an anisotropic solid-like response. The second term represents the nematic-like response into the layers. If we impose the equilbrium condition under a normal stress by the Euler's condition, and with the restriction of small stresses $\delta/d \ll 1$ and $P \ll d$ we find:

$$\frac{\Delta P}{P_0} = \frac{\delta}{d} \tag{2}$$

of course the found dependence of the pitch is only for an average pitch. In a better approximation we should also consider that the CLC is not infinitely stiff and in this limit we induce also a vertical pitch gradient into the sample which should increase with the imposed deformation. The optical behavior of a CLC with a pitch gradient has been studied by Mazkedian *et al.*[4] They found that for gradients pitch over a critical one $\nabla_c P$ the optical properties of the CLC change strongly: the bandwidth of the reflection band increases, the band shifts through higher wavelengths and its intensity decreases.

As proved for the smectics A[5] in a process of mechanical deformations also for CLC the defects should play an important role in the stresses relaxation. In this paper we can't yet analyze in details these processes; and for the moment we use a model of a CLC as a dilated smectic A.[5] In this paper we present just static preliminary data.

2 EXPERIMENTAL SET-UP

We prepare a planar sample of CLC by rubbing in a parallel way two plat optical glasses. The thickness of the sample is regulated by six steel screws; this way also the parallelism is insured, and it was made better than 10^{-3} to avoid induced dislocation effects on the elasticity.[6] The sample is temperature independent at room temperature, however it was controlled in an electric oven at 30°C ± 0.1°C. To look at the optical properties of the CLC we built up a standard reflection spectrometry system, using a Jobin-Yvon monocromator with f = 150 cm. and a resolution in the visible range of 0,1 A°. The unstressed sample spectrum was made at different angles to reach the Bragg condition. The mechanical stresses has been produced in the following way: one of the glasses containing the sample was sealed directly to the holder (also in steel to avoid holder deformations) the other one is sealed on the translator which is formed by ten sealed piezoelectric rings, and it is sealed again to the holder. The translator deformate itself when an electric field is applied, with a roughly linear deformation 45A°/V. In Figure 1 we have drawn in a short way our experimental set-up. Experiments were made with circularly polarized or un-

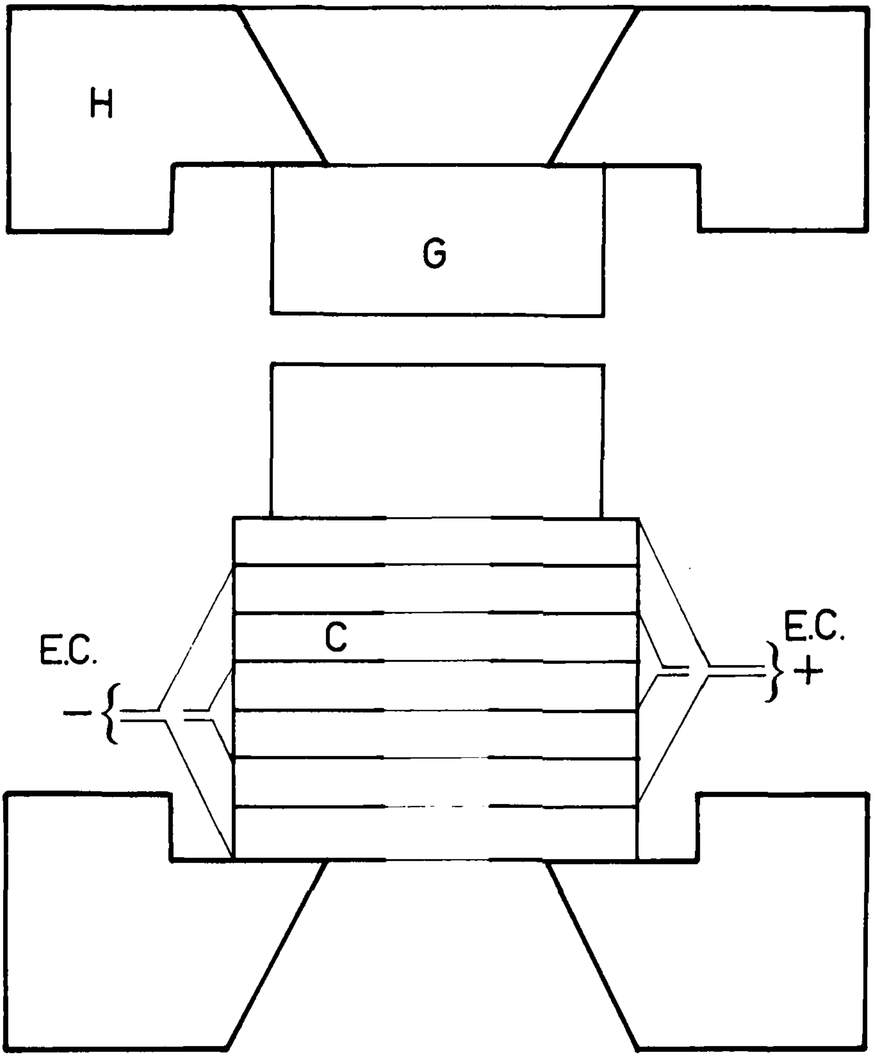

FIGURE 1 Schematic of experimental set up. H. Sample holder; G. Optical glasses; C. Ceramic translator; E.C. Electrodes.

polarized light without any appreciable difference in the results. The spectra of the reflected light were analyzed taking into account the spectral response of the used photomultiplier at 56 CVP. The quality of the alignment and the presence of defects has been analyzed with a polarizing microscope. The sample (a cholesteric mixture) is particularly pressure sensitive and temperature independent as prepared by C. Germain of the Orsay group.

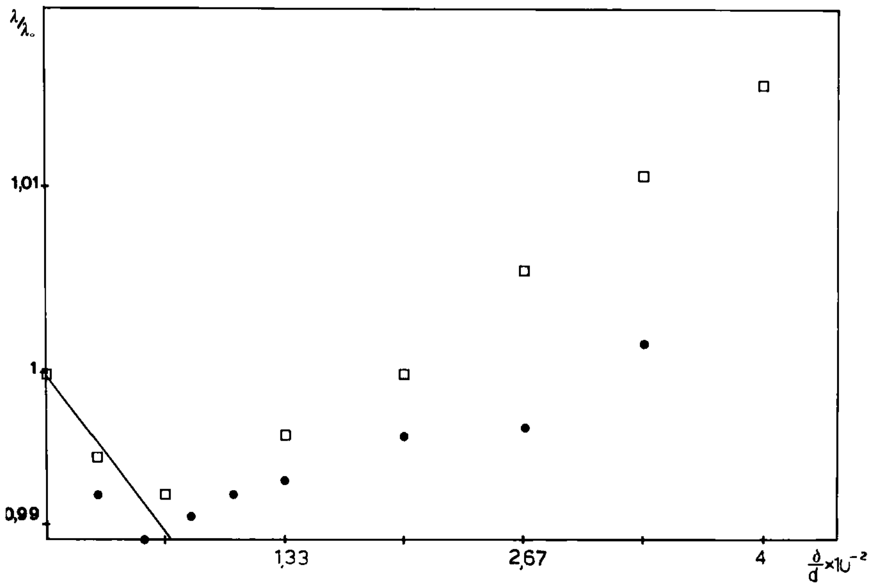

FIGURE 2 Relative peak displacement of the reflection band λ/λ_0 vs relative deformation δ/d for compressions of the sample.

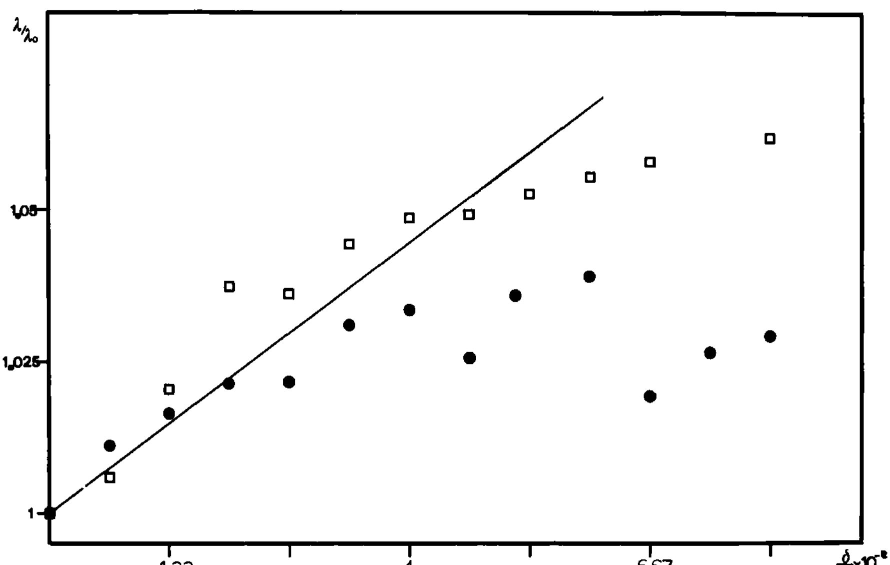

FIGURE 3 Relative peak displacement of the reflection band λ/λ_0 vs the relative deformation δ/d for dilations of the sample.

3 RESULTS

We present data for a 75 μm thick sample. First in Figures 2 and 3 we report the results for the Bragg's peak relative displacement λ / λ_0 vs the modulus of the relative deformation δ/d (δ being the total free ceramic displacement and d the sample thickness), both for compressional (f2) or dilative deformations (f3). In Figure 2 we see in a small range of compressions ($\delta \sim P_0$) the reflection peak shifts linearly towards shorter wavelengths, then for compressional displacement higher than, roughly the initial pitch ($\delta > P_0$) the behavior changes and still increasing the compression the peak shifts towards higher wavelengths. In Figure 3 instead we see when we dilate the sample the reflection peak goes ever to higher wavelengths, linearly up to $\delta \sim 3P_0$ then it tends to a saturation. In both cases a linear response is present in the behavior; instead an hysteresis takes place when the response is no more linear.

In Figure 4 are shown the results for the peak intensity, the dots are relative to compressional spectra of Figure 2 and the squares to dilative spectra of Figure 3, we see that for the linear region of Figures 2 and 3 also the peak intensity changes regularly then for compressions it begins to decrease.

In Figure 5 are reported the reflection bandwidth for the same cases. Here we see that when the sample follows a linear response the bandwidth remains

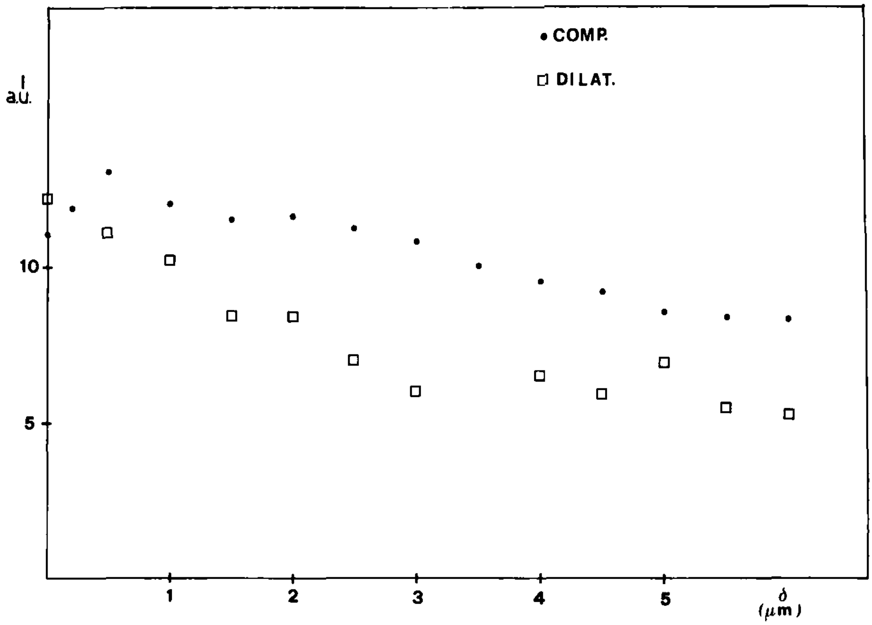

FIGURE 4 Peak intensity vs the deformation. The dots are for compressions, the squares for dilations.

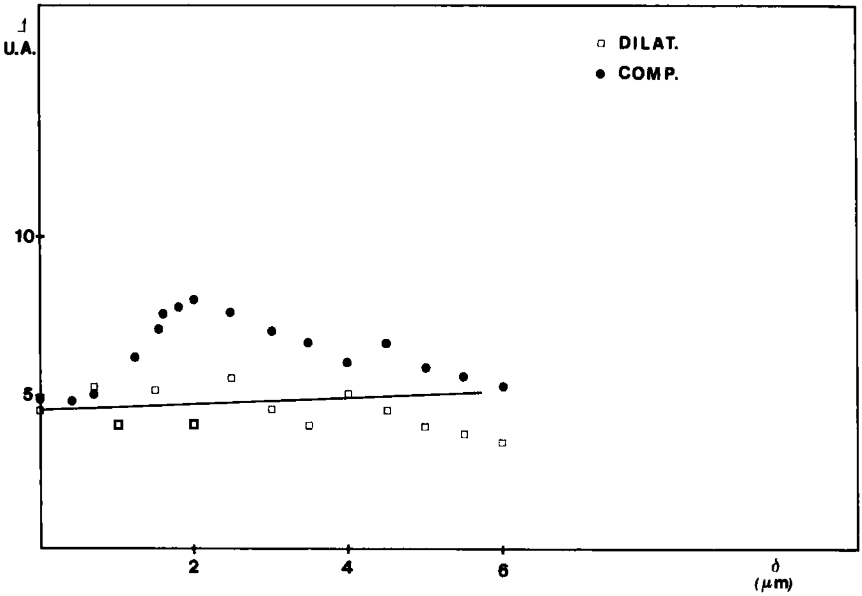

FIGURE 5 Reflection bandwidth vs the deformation. The dots are for compressions, the squares for dilations.

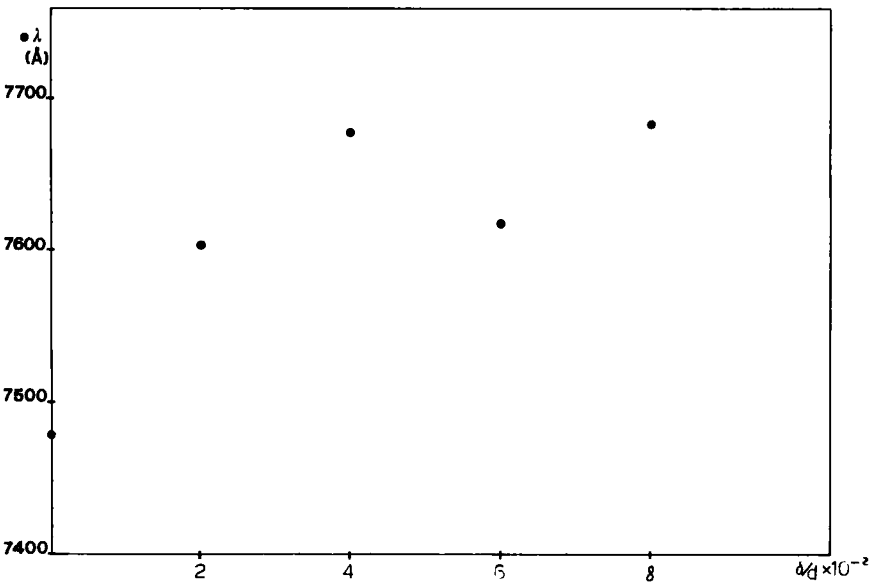

FIGURE 6 Hysteresis effect. Reflection peak measured after switching off an increasing deformation.

roughly constant. Then for the compressional case it begins to grow, and for higher deformations it decreases in both cases.

Finally in Figure 6 we report some examples of hysteresis in the behavior, when a departure from the linearity appears. In this case when we take off the deformation the peak's position doesn't come to the initial position for a lot of time (which depends on the deformation amplitude). We see in Figure 6 the peak's position just after the field is switched off for different values of the deformation. An increase of the zero displacement is observed, increasing the deformation.

DISCUSSION

A linear behavior of the elastooptic response of a CLC when submitted to mechanical strains is observed in agreement with Eq. (2). In Figures 2 and 3 are in fact reported the straight lines deduced from Eq. (2). For the compressional case a departure from such a behavior is observed for $\delta \sim P_0$. In our model we could deduce that the pressure is transmitted through the sample with a gradient, inducing a pitch gradient. Following the Mazkedian's calculations the pitch gradient plays a role on the optical properties when ($\Delta P/P_0 = (\Delta n/n)^2$), by an approximate calculation (with usual conditions $n \sim 1.5$ and $\Delta n \sim 0.2$) we find $\Delta P/P_o \sim 10^{-2}$ which is in a very good agreement with the found value. Then for the compressional case we measure the critical gradient pitch, this is the first experimental observation[7] of the effects of a pitch gradient on the optical properties of a CLC. Qualitatively all the reported data (peak position, intensity and bandwidth), are in agreement with this model in a small range of deformation: for higher pressures nonlinear effects occur.

In the dilative case we don't see this effect: we could explain easily our results, following the proposed models in smectics *A*. Defects can relax the induced stress, by adding locally some layers. This relaxation impeaches the pressure gradient formation. In conclusion we have found a range of mechanical deformations in which the CLC behaves elastically. Departure from this behavior can be explained by a gradient pitch or by defects climb. Further investigations are under way to better clarify this point and will be reported.

Acknowledgments

Aknowledgments are due to C. Germain from Orsay for the sample preparation, and to G. Durand and F. Rustichelli for helpful discussion.

References

1. (a) For a general reference see P. G. De Gennes, *The Physics of Liquid Crystal*, (1974); (b) I. Jànossy, Hungarian Academy of Sciences, *KFKI-1979-68* (1979).

2. (a) U. D. Kini, *J. de Phys.*, **40**, C3–62 (1979); (b) D. F. Ciliberti, G. D. Dixon and L. C. Scala, *Mol. Cryst. Liq. Cryst.*, **20**, 27 (1973).
3. P. G. De Gennes, *The Physics of Liquid Crystals*, 245 (1974).
4. S. Mazkedian, S. Melone and F. Rustichelli, *J. Phys.*, **36**, C1–283 (1975).
5. R. Bartolino and G. Durand, *Phys. Rev. Lett.*, **39**, 1346 (1977).
6. R. Bartolino and G. Durand, *Mol. Cryst. Liq. Cryst.*, **40C**, 117 (1977).
7. See also F. Simoni, R. Bartolino and C. Garcea, Kyoto Conference, (1980).