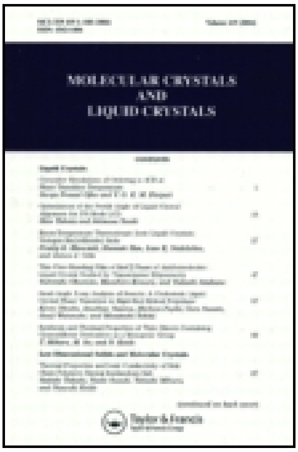

Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

Direct Optical Measurement of the Ratio K_3/γ in Nematic Liquid Crystals

Gabriella Cipparrone [a] , Danilo Duca [a] , Carlo Versace [a] , Cesare Umeton [a] & Nelson V. Tabiryan [b c]

[a] Dipartmento di Fisica, Università della Calabria, 87036, Rende (CS), Italy

[b] Institute of Applied Problems in Physics, American Academy of Sciences, 375014, Yerevan, Armenia

[c] Institute of Applied Physics, Technische Hochschule, 6100, Darmstadt, FRG.

Version of record first published: 23 Sep 2006.

To cite this article: Gabriella Cipparrone , Danilo Duca , Carlo Versace , Cesare Umeton & Nelson V. Tabiryan (1995): Direct Optical Measurement of the Ratio K_3/γ in Nematic Liquid Crystals, Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals, 266:1, 263-268

To link to this article: http://dx.doi.org/10.1080/10587259508033647

Mol. Cryst. Liq. Cryst. 1995, Vol. 266, pp. 263–268
Reprints available directly from the publisher
Photocopying permitted by license only

DIRECT OPTICAL MEASUREMENT OF THE RATIO K_3/γ IN NEMATIC LIQUID CRYSTALS

GABRIELLA CIPPARRONE, DANILO DUCA, CARLO VERSACE, CESARE UMETON
Dipartimento di Fisica, Università della Calabria, 87036 Rende (CS) Italy,
and
NELSON V. TABIRYAN
Institute of Applied Problems in Physics, Armenian Academy of Sciences 375014 Yerevan, Armenia. Present Address: Institute of Applied Physics, Technische Hochschule, 6100 Darmstadt, FRG.

Abstract We report measurements of the ratio K_3/γ performed in a nematic liquid crystal sample by means of an optical technique which exploits the "self - heterodyning" effect. The experimental setup is extremely simple and the experiment very easy to be done. Results, obtained at different values of the impinging light power, are consistent within the experimental errors and in agreement with typical values reported in literature.

INTRODUCTION

The study of the elastic constants (Frank constants) that are involved in the molecular interactions of Nematic Liquid Crystals (NLC's) is of great importance and, for the determinations of their values, different optical techniques are available[1-4]. These are generally based on light scattering or light attenuation and allow precise measurements but they are not of simple and immediate use. In fact, they require an apparatus for performing light scattering experiments or the execution of different measurement at different angles of the incident laser beam. On the other hand, when the dynamics of the NLC system is investigated, only the determination of the ratio K_3/γ is often needed[5]. In this case, an experimental technique would be extremely useful, which could allow an immediate determination of this ratio.

In this paper we present a direct measurement of the ratio K_3/γ performed in a NLC sample by means of a simple optical technique that exploits the "self - heterodyning" of a light beam in NLC's.

THEORETICAL BACKGROUND

The so called "self heterodyning" effect has been already used for other purposes[6] and is explained in details elsewhere, together with the wide range of its applications. The principle of operation is the following. When a light beam crosses a NLC with a propagation direction parallel to the optical axis of the sample (perpendicular to the NLC cell plates for a homeotropic alignment), a nonlinear phase shift $\Phi(t)$ is induced only if the light intensity I exceeds a threshold value I_F (threshold intensity for the Optical Freedericksz Transition). For $I>I_F$, the expression determining $\Phi(t)$ is[5,7]:

$$\Phi(t) = \Phi_E/[1 + (\Phi_E-\Phi_0)\exp(-2\Gamma_T t)/\Phi_0] \qquad (1)$$

where

$$\Gamma_T = \Gamma(I/I_F-1) \qquad (2)$$

$1/\Gamma$ represents a relaxation time and is determined only by the material parameters of the NLC and by the thickness of the cell:

$$1/\Gamma = (\gamma/K_3)(L/\pi)^2 \qquad (3)$$

with γ = viscosity constant, K_3 = elastic constant and L = cell thickness. Φ_E is the equilibrium value reached by the phase shift and Φ_0 is the "intrinsic" phase shift which is due to the spontaneous fluctuational perturbations in the orientation of the optical axis.

The large phase shift (1) modulated over the cross - section of the beam (following the transverse intensity modulation) yields an amplitude modulation. In the steady state and for a gaussian beam profile, the pattern resulting in the far field zone is a system of bright rings whose total number is:

$$N_{tot} = \Phi_{max}/2\pi \quad (4)$$

where Φ_{max} is the maximum of the phase shift over the beam cross section, i.e. in its center. During the ring formation, it is therefore possible to rewrite eq. (1) by substituting $\Phi(t)$ with $2\pi N(t)$, where $N(t)$ is the number of rings that are formed after the time t, and corresponds to the number of oscillations that are observed in the center of the outgoing beam. In the very beginning (far from the steady state), the equation can be approximated to obtain:

$$\ln[2\pi N(t)] = \ln[\Phi_0] + 2\Gamma_T t \quad (5)$$

By plotting $\ln[2\pi N(t)]$ vs time, we have a straight line whose angular coefficient $2\Gamma_T$ directly gives K_3/γ if the cell thickness L and the ratio I/I_F are known:

$$(K_3/\gamma) = \Gamma_T/(I/I_F - 1)(\pi/L)^2 \quad (6)$$

Where the ratio I/I_F is concerned, we note that, since the beam shape does not change while varying the laser power P, I/I_F is always equal to the ratio P/P_F, which can be easily determined by using the same technique and therefore the same experimental apparatus. Indeed, by writing eq. (5) for the time values t_i and t_j which correspond to the appearance of N_i and N_j rings respectively, we get:

$$\ln(N_i) - \ln(N_j) = 2\Gamma\,[P/P_F - 1](t_i - t_j) \quad (7)$$

By experimental determination of the angular coefficient

$$\mu_{1,2} = 2\Gamma[P_{1,2}/P_F - 1] \quad (8)$$

for two different values P_1 and P_2 of the impinging power P, we obtain the threshold value:

$$P_F = (P_2\mu_1/\mu_2 - P_1)/(\mu_1/\mu_2 - 1) \quad (9)$$

EXPERIMENT

The experimental set up is shown in Figure 1. After a shutter and a calibrated system of beam splitter and power meter, the light beam from an Ar Ion laser ($\lambda = 5145$ Å) is linearly polarized and focused

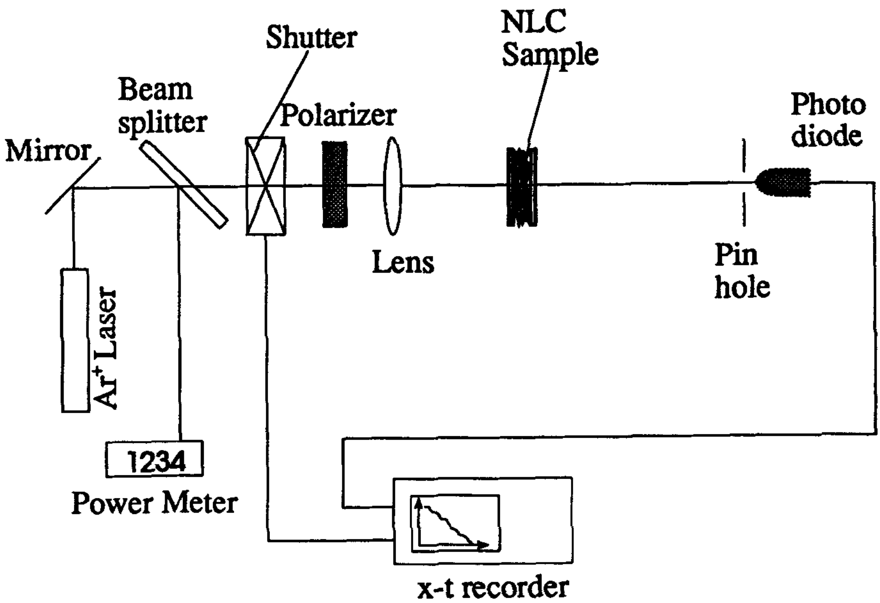

FIGURE 1 Sketch of the experimental setup.

(focal length f = 150 mm) on the 50 μm - thick cell of the homeotropically aligned NLC (E7 by MERCK). The central part of the outgoing beam is detected by a photodiode placed behind a 200 μm pinhole. The signal is then directly sent to an xt recorder triggered by the shutter.

Results

A typical experimental trend of $\ln[2\pi N(t)]$ vs time is reported in fig. 2, which refers to a measurement performed at $P/P_F = 1.86$. It is evident that the linear approximation expressed by eq. (5) is good. The determination of the ratio K_3/γ has been performed for four different values of the impinging power P over the threshold level P_F whose value, by means of the above mentioned technique, has been estimated to be $P_F = (188 \pm 6)$ mW. The obtained results, reported in table 1, are consistent within the experimental error ($\approx$ 5%). They are also in agreement with typical values reported in literature for NLC's, which give $K_3 \approx 10^{-7}$ dyn and $\gamma \approx 10^{-1}$ P.

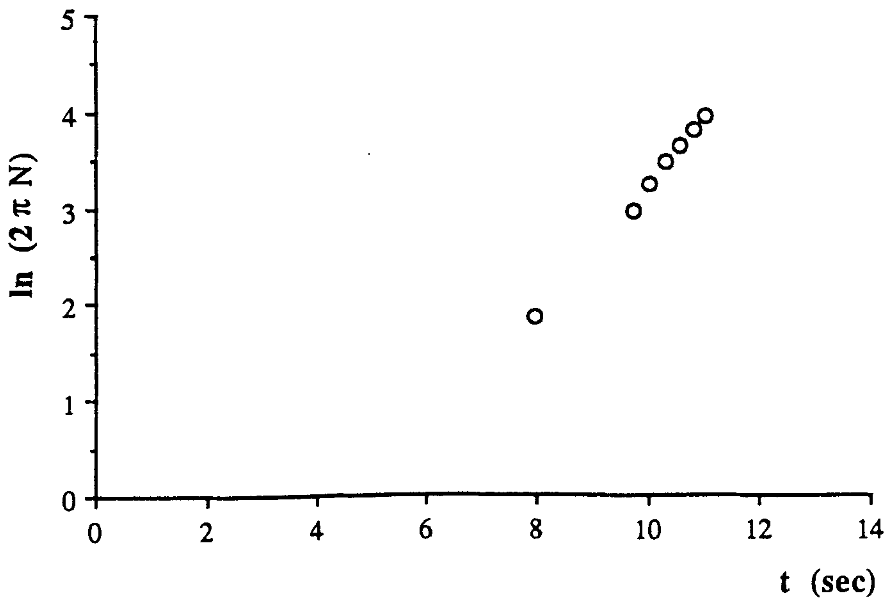

FIGURE 2 Typical trend of $\ln[2\pi N(t)]$ vs time.

TABLE 1. Obtained values of K_3/γ for different values of P/P_F. Experimental errors are 3% for P/P_F and 5% for K_3/γ.

P/P_F	1.33	1.60	1.73	1.86
$K_3/\gamma \times 10^6$ (cgs units)	1.001	1.037	1.026	1.048

CONCLUSIONS

We report measurements of the ratio K_3/γ performed in a nematic liquid crystal sample by means of an optical technique which exploits the "self - heterodyning" effect. The experimental setup is extremely simple and the experiment very easy to be done. Results, obtained at different values of the impinging light power, are consistent and in agreement with typical values reported in literature for NLC's.

ACKNOWLEDGEMENTS

This work is partially supported by M.U.R.S.T, Italy. G. Cipparrone, D. Duca, C. Versace and C. Umeton are also with Consorzio INFM, unità di Cosenza, Italy. The researches of N.V. Tabiryan are supported by A. von Humboldt Foundation (Germany).

REFERENCES

1. E. Miraldi, L. Trossi, P. Taverna Valabrega and C. Oldano, Il Nuovo Cimento, 66B, 179 (1981).
2. E. Miraldi, C. Oldano, P. Taverna Valabrega and L. Trossi, Mol. Cryst. Liq. Cryst. Lett., 82, 231 (1982).
3. J. P. van der Meulen and R. J. J. Zijlstra, J. Physique, 45, 1347 (1984).
4. C. Versace, V. Formoso, D. Lucchetta, D. Pucci, C. Ferrero, M. Ghedini, R. Bartolino, J. Chem. Phys., 98, 8507 (1993).
5. N.V.Tabiryan, A.V.Sukhov, B.Ya.Zel'dovich, Mol. Cryst. Liq. Cryst., 136, 1 (1986).
6. G.Cipparrone, D.Duca, C.Umeton and N.V.Tabiryan, Phys. Rev. Lett., 71, 3955 (1993).
7. H. Hsiung, L.P. Shi and Y.R.Shen, Phys. Rev. A, 30, 1453 (1984).