A Liquid Crystal as a Solvent in Infrared Spectroscopy

TORBEN STROYER HANSEN

Chemical Laboratory V, University of Copenhagen
Copenhagen, Denmark

(Z. Naturforsch. **24 a**, 866—867 [1969]; received 23 April 1969)

A technique to obtain infrared absorption spectra of orientated molecules, dissolved in a liquid crystal, which is placed in a strong magnetic field, is described. The degree of orientation of 4,4′-dihexoxyazoxybenzene is measured at various temperatures. The maximum degree of orientation of 4-bromobenzonitrile and 4-cyanobenzoic acid is measured in a 10% solution in 4,4′-dihexoxyazoxybenzene to be 0.35 and 0.55, respectively.

The infrared spectra of 4-bromobenzonitrile (BBN), and 4-cyanobenzoic acid (CBA) were obtained in a 10% solution in 4,4′-dihexoxyazoxybenzene (HAB), to investigate the orientational effect of the liquid crystal in its nematic phase on the solute.

(HAB) has its mesomorphic state in the temperature range from 81 °C to 130 °C during heating, and from 130 °C to 76 °C during cooling, this state being of the nematic type [1]. When in the nematic phase the molecules may be orientated in a strong magnetic field. At the same time the molecules near a surface are strongly influenced by the structure of the surface. To obtain the best orientation, one may take advantage of combining both effects. Because of the strong absorption from the liquid crystal, one has to use a thin layer sample, but this means, however, that the surface effect is very strong. This surface orientation effect may be controlled by treating the surfaces in a special way.

The sample was placed between two KBr plates, the sample thickness determined by a teflon space, being 0.06 mm. The KBr plates were first polished very carefully, and then heated to about 100 °C, and coated with a thin layer of the liquid crystal on the inner side. The coating was wiped off with a piece of washleather, moving the washleater in one direction only on the plates. Two KBr plates, treated like this, wiped in the same direction, were used around a teflon spacer as a sandwich cell.

The cell was mounted in the gap of a permanent magnet, in such a way, that the wiping direction coincided with the direction of the magnetic field. This direction would then be the orientation direction. The magnetic field was determined to be about 4300 gauss.

The infrared spectra were recorded on a Perkin-Elmer model 21 spectrophotometer, equipped with a sodium chloride prism. The temperature of the sample was measured by a chromel alumel thermocouple, mounted in a small hole in one of the KBr plates. The temperature was kept constant within ±1° during the recording of the spectrum.

The orientation degree S was determined by the equations

$$S = (D_{\parallel}/D_{\perp} - 1)/(D_{\parallel}/D_{\perp} + 2)$$

for absorption bands with the transition moment parallel to the orientation direction, and

$$S = (D_{\perp}/D_{\parallel} - 1)/(D_{\perp}/D_{\parallel} + \tfrac{1}{2})$$

for absorption bands with the transition moment perpendicular to the orientation direction [2–4]. $D_{\parallel}$ and $D_{\perp}$ are the extinctions of the absorption bands in the spectra in polarized light, polarized parallel and perpendicular to the orientation direction respectively.

As polarizer a gold wire grid on a silver bromide plate was used. The polarization ratio $I_{\perp}/I_{\parallel}$ was very small, 0.005 at 2000 cm^{-1}, and it was, therefore, not necessary to correct for imperfect polarization.

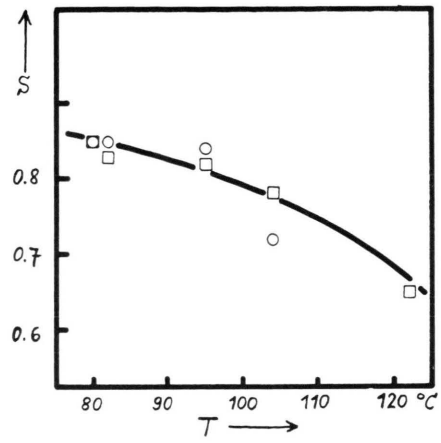

Fig. 1. Orientation degree of 4,4′-dihexoxyazoxybenzene. Measurements are made at two different frequencies. □ at 780 cm^{-1}, and ○ at 800 cm^{-1}.

According to MAIER and ENGLERT [2] the orientation degree is strongly dependent on the temperature. The best orientation is obtained at a temperature just above the crystal-nematic transition temperature. The best orientation degree of (HAB) was determined at 80 °C to be $S_{max} = 0.85$ (Fig. 1). This is quite normal for this type of molecule [2]. The best orientation degree of (BBN) in a 10% solution in (HAB) at 80 °C was determined to be $S_{max} = 0.35$. This is normal too for a solute in a liquid crystal [5]. But the best orientation degree of (CBA) at 80 °C was determined to be $S_{max} = 0.55$, which is much more than expected. The explanation may be, that (CBA) is dimerized, and as a dimer nearly is a liquid crystal itself, contrary to (BBN), and it can, therefore, be orientated to a greater extent than (BBN).

As a solvent in infrared spectroscopy a liquid crystal is seldom very good, due to its own strong absorption.

[1] W. MAIER and G. ENGLERT, Z. phys. Chem. NF **19**, 168 [1959].
[2] W. MAIER and G. ENGLERT, Z. Elektrochem. **64**, 689 [1960].
[3] A. SAUPE and W. MAIER, Z. Naturforsch. **16 a**, 816 [1961].
[4] V. D. NEFF, L. W. GULRICH, and G. H. BROWN, Mol. Cryst. **1**, 225 [1966].
[5] G. ENGLERT and A. SAUPE, Mol. Cryst. **1**, 503 [1966].

In a smaller frequency range it may be possible to investigate a single absorption band, like in this case the nitrile group absorption, in order to determine the degree of orientation of a solute. Because of the preparation technique, it may be difficult to make identical samples, with respect to the orientation effect of the plate surfaces. This is important in thin layer samples. Furthermore, it is difficult to measure the extinction D accurately enough, especially at low extinctions. Therefore, the reproducibility of S was not better than 5%.

Zur optimalen Auskopplung bei gefalteten Lasern hoher Verstärkung

D. ROSENBERGER

Forschungslaboratorium München der Siemens AG

(Z. Naturforsch. **24 a**, 867—869 [1969]; eingegangen am 29. März 1969)

The optimum transmission coefficient and power output of folded high-gain lasers are calculated assuming homogeneous line broadening and a uniform distribution of the unsaturated gain over the cross section. The results are applied to CO_2 lasers with high mode density.

1. Einleitung

Mit den derzeitigen Anregungsverfahren für CO_2-Laser ist die pro Längeneinheit erzielbare Ausgangsleistung auf etwa 80 W/m begrenzt. Beim Bau von Hochleistungs-CO_2-Lasern ist man deshalb auf lange Entladungsrohre angewiesen, die aus bautechnischen Gesichtspunkten in der Regel als mehrfach gefaltete Strecken ausgeführt werden.

Da bei den im 10-μm-Bereich zur Verfügung stehenden metallischen und dielektrischen Spiegelschichten mit Reflexionsverlusten von 2—3% zu rechnen ist, werden vor allem bei kürzeren Lasern, die mit niedrigem Auskoppelgrad arbeiten, durch Faltung die Gesamtverluste relativ stark erhöht, was zu einer Änderung des optimalen Koppelgrades und einer Reduzierung der Ausgangsleistung im Vergleich zu einer ungefalteten Strecke führt.

In der folgenden Arbeit werden der optimale Auskoppelgrad und die maximale Leistung von gefalteten Lasern hoher Verstärkung in Abhängigkeit vom Gesamtgewinn der gefalteten Strecke berechnet. Die Spiegelverluste und die Zahl der Faltungsstrecken treten dabei als Parameter auf.

Für den ungefalteten Laser ist das Problem von RIGROD [1] behandelt worden. Das in [1] verwendete eindimensionale Modell wird auch der folgenden Rechnung zugrunde gelegt. Es wird demnach ein n-fach gefalteter, in der Transversalebene unbegrenzter Resonator betrachtet, in dem sich plane Wanderwellen, die nur durch Reflexionsverluste geschwächt werden, in $+z$- und $-z$-Richtung ausbreiten. Die Intensität am Ort z wird als Summe der Teilintensitäten $S+$ und $S-$ der einander entgegenlaufenden Wellen angenommen. Die Kleinsignalverstärkung sei innerhalb des betrachteten Volumens konstant.

Die Ableitung gilt zunächst für homogen verbreiterte Linienprofile. Wie in [1] gezeigt ist, lassen sich die Ergebnisse jedoch auf inhomogene Linien übertragen, wenn diese auf Grund hoher Stoßrelaxation und hoher Modendichte quasihomogen entleert werden.

2. Theoretische Betrachtung

Im folgenden werden der optimale Auskoppelgrad und die maximale Ausgangsleistung mehrfach gefalteter Laser bei symmetrischer und asymmetrischer Auskopplung berechnet.

Für den Verstärkungskoeffizienten $g(z)$ gilt nach den oben gemachten Voraussetzungen

$$g(z) = g_0/(1 + s_+ + s_-), \tag{1}$$

wobei g_0 der Kleinsignal-Verstärkungskoeffizient und $s_{+(-)}$ eine normierte Leistung ist.

Wegen $$\frac{1}{s_+}\frac{\mathrm{d}s_+}{\mathrm{d}z} = g(z) = -\frac{1}{s_-}\frac{\mathrm{d}s_-}{\mathrm{d}z}$$

folgt [1] $$s_+ \, s_- = \text{const} = c\,. \tag{2}$$

In einem aus n Teilstrecken aufgebauten Resonator schließt sich der Lichtweg nach $2n$ Reflexionen (Abb. 1). Die erste Teilstrecke werde von den Spiegeln 0 und 1 mit den Reflexionskoeffizienten r_0 bzw. r_1, die k-te Strecke von den Spiegeln $k-1$ und k begrenzt ($k = 0, 1, \ldots, n$). Für eine in (+)-Richtung laufende Welle

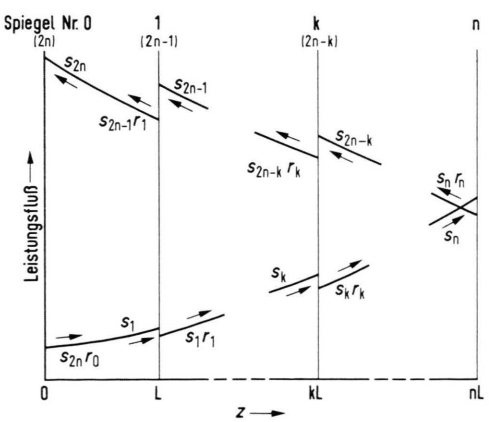

Abb. 1. Laserintensität in einem gefalteten Resonator.

[1] W. W. RIGROD, J. Appl. Phys. **36**, 2487 [1965].