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► To cite this version:

M. Dumitru, I. Popescu, M. Honciuc. LOW POWER CW LASER LIGHT IN NEW NONLINEAR OPTICAL MATERIALS. Journal de Physique IV Proceedings, 1991, 01 (C7), pp.C7-757-C7-760. 10.1051/jp4:19917203 . jpa-00250884

HAL Id: jpa-00250884

<https://hal.science/jpa-00250884>

Submitted on 1 Jan 1991

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LOW POWER CW LASER LIGHT IN NEW NONLINEAR OPTICAL MATERIALS

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Abstract—The liquid crystal smectic C-type properties of some fatty acids and their mixtures with cholesterol were proved. By using low power lasers (He-Ne) nonlinear optical effects, depending on the cholesterol percentage, were obtained.

1.-Introduction

A great number of experimental data indicate that the liquid crystal state is characteristic of some complex molecular structures belonging to the living matter.

It was proved that many fatty acids exhibit a smectogenic behaviour^{1/}. An example is the arachidic acid $\text{CH}_3(\text{CH}_2)_{18}\text{COOH}$ — a saturated fatty acid, constituent of phospholipides. At room temperature, it is a white crystalline powder, but within $70 - 75,3^\circ\text{C}$ it exhibits a smectic C mesomorphism (Fig.1.a). The arachidonic acid — an unsaturated fatty acid (four double chains at 5,8,11 and 14 C) — is a constituent of the biological membrane and a forerunner of the prostaglandines. It exhibits a mesogenic behaviour between $4 - 20^\circ\text{C}$. At higher temperature, it decays; at room temperature it is a yellowish oleous liquid.

By means of electric measurements, some dielectrical properties of these substances were emphasized; they present a certain conductivity, too. The same investigations, performed on the fatty acid-cholesterol mixtures, in different percentages by weight, show that:

- the cholesterol enhances the mesomorphic range with $10 - 15^\circ\text{C}/2/$;
- the cholesterol influence on the saturated acid was different in comparison with the unsaturated one ^{2/}.

Taking into account these observations, other saturated and unsaturated fatty acids were subject of the same investigations:

- the lauric acid $\text{CH}_3(\text{CH}_2)_{10}\text{COOH}$ — a saturated fatty acid, displays a smectic C* mesomorphism within the interval $40 - 46^\circ\text{C}$;

- the elaidic acid (the trans-isomer of the oleic acid) — an unsaturated fatty acid (a double chain at 9-10 C), is a smectic liquid crystal between $41 - 51^\circ\text{C}$ (Fig.1.b).

The electric measurements performed for these acids led to similar conclusions as those previously exposed.

By studying a great number of works published until now (see, for example,^{3/}), one can observe that the materials which are neither pure metals, nor dielectrics — like semiconductors and liquid crystals — exhibit a great optical nonlinearity. Our idea is to use low optical power lasers, which should be able to excite such a great optical nonlinearity. Indeed, external self-focusing of a He-Ne laser

a)

b)

Fig.1.-Microstructural aspects of some fatty acids with smectogenic behaviour: a)- a saturated fatty acid (the arachidic acid); b) an unsaturated fatty acid (the elaidic acid). Cell thickness $d=13,5 \text{ } \mu\text{m}$

beam was obtained for TEM_{00} and TEM_{01} modes. Again, the cholesterol percentage influenced differently the optical behaviour of the saturated and unsaturated acids, respectively.

2.-Electric measurements

Current-voltage plots $I=I(U)$ at constant temperature for pure acids and for mixtures were obtained. When the cholesterol is added, the area of the hysteresis increases for the saturated acids (Fig.2.a,c), but decreases for the unsaturated ones (Fig.2.b,d). The same results were obtained for the other two acids.

Other characteristic measurements: $I=I(t)$, t being the time; $I=I(\omega)$, where ω is the frequency of the a.c. applied field; $I=I(\theta^\circ\text{C})$, performed for pure acids and for mixtures, confirm the previous conclusions [2,4].

a)

b)

Fig.2.-Current-voltage plots $I=I(U)$. a)- arachidic acid; b)- arachidonic acid

Fig.2. Current-voltage plots $I=I(U)$. c)- 2-1 arrachidic acid-cholesterol mixture; d)- 1-2 arrachidonic acid-cholesterol mixture

3.-Nonlinear optical behaviour

The nonlinear optical effects, obtained with a He-Ne laser (HNA 188-RDG, $\lambda = 6328 \text{ \AA}$, $P_{\max} = 20 \text{ mW}$) are in accordance with the former ones.

Fig.3.-Diffraction power P_D of the focused laser beam, when the sample was outside the focus (1) and just in the focus (2); α -incidence angle

Fig.4.-Nonlinear focal length of an elaidic acid sample versus temperature ($l_{\text{div}} = 1.55^\circ \text{C}$)

A great optical nonlinearity was observed for the samples of arrachidonic acid. Because the refractive index in the center of the beam differs from that one at the edge of the beam, the sample behaves like a convergent lens and a spatial self-phase modulation takes place. A ring pattern can be observed on a screen in far field /4/. In arrachidonic acid-cholesterol mixtures this effect is null. In arrachidic acid the result is also negative, but in its mixtures a distortion of the wave-front was observed.

Fig.5.-Nonlinear focal length f versus the beam divergence D . $d_1=8,5\mu\text{m}$; $d_2=7,5\mu\text{m}$; $d_3=6,5\mu\text{m}$; $d_4=5,5\mu\text{m}$; $d_5=4,5\mu\text{m}$ (elaïdic acid). A-arrachidonic acid sample

In elaïdic acid the effect is positive, but in lauric acid no ring pattern was obtained; this one appears in some of its mixtures with cholesterol [4/].

For the unsaturated acids other measurements were made, too: the diffracted power P_D as a function of an incidence parameter of the light focused beam on the liquid crystal cell with arrachidonic acid (Fig.3); the "nonlinear focal length" of an elaïdic acid sample as a function of $^{\circ}\text{C}$., when being heated and cooled (Fig.4); the "nonlinear focal length" of samples containing both unsaturated acids versus the beam divergence D , measured on the screen (Fig.5).

4.-Conclusions

New smectic liquid crystals for nonlinear optics were obtained and studied: saturated and unsaturated fatty acids and their mixtures with cholesterol. Their electric and nonlinear optical behaviour is differently influenced by the cholesterol. We think the explanation is related to the generation of a space charge induced by the presence of the cholesterol.

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