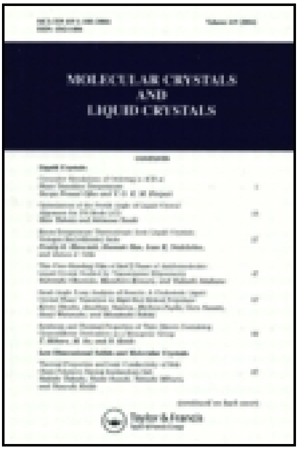

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Nostalgia about DSM

V. A. Tsvetkov [a]

[a] Moscow State Academy of Instrument Engineering and Informatics, 20 Stromynka, Moscow, 107846

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Nostalgia about DSM

V.A. TSVETKOV*

Moscow State Academy of Instrument Engineering and Informatics 20 Stromynka, Moscow ,107846

Results of comprehensive study of the DSM effect are given. The all main parameters of LCM were varied in the broadest range. A unified experimental technique was used. We did not find essential inconsistencies with the earlier published data. Simultaneously we observed a number of phenomena not described in the literature such as:tertiary DSM (DSM),non-DSM2. In detail ,experimentaly we investigated the effect of main parameters LCMs on them electrooptical characteristics. The attempt of explanation of some results is made. A idea of multilayer structure of the scattering LC layer is developed.

Keywords: DSM; DSM2; conductivity; dielectric and optical anisotropy

INTRODUCTION

The Dynamic Scattering Mode effect (DSM) was discovered long ago.

In 70-80s many works performed at different centers were devoted to it. At first sight, it looks like the effect has been thoroughly investigated [1 and its references]. However, when in late 80s an issue of practical application of DSM LCM for fog imitators for aircraft was raised, it appeared that the studies carried out by that time were of an uncoordinated nature, were mostly dedicated to various, predominantly physical aspects of the effect, with a detailed investigation of (predominantly) instabilities near the effect's threshold. It turned out that using the results of the studies was problematic.

* e-mail: tsvet@pop3.mipt.ru

Therefore, we had to carry out a comprehensive study of the effect indepedently.

It should be noted that we had at our disposal a large range of LC materials, we had an opportunity to measure virtually any required LCM parameter and we had a broad experience in handling LCM.

By 1987, when we started the present study, there had been known the basic factors affecting electrooptical characteristics, i.e. correlation between the intensity of the light transmitted through the LC layer and the voltage applied (Transmission-Voltage Curve -TVC).

Experimental

Using a unified procedure, we carried out an independent investigation of these factors by varying them in maximum possible range of measurements.

Thus it was known that TVC is affected by the following LCM physical parameters (below the parameter variation range in our experiments will be given in brackets):

-dielectric anisotropy $\Delta\varepsilon$ (from -6.3 to + 0.1),
-conductivity σ (10^{-11} to10^{-8} S^{-1} – four orders!),
-anisotropy of refractive index Δn (from 0.26 to 0.08),
-to some extent, class of chemical compounds (we used both reference LC based on azoxy compounds and pyridines and ones based on Schiff bases, tolans and cyclohexanecarbonic acids, the latter were predominantly used as dopants efficiently reducing the magnitude of Δn).

Electrooptical characteristics of DSM LC cells are affected by the following design parameters:

-original orientation (we used planar, homeotropic, homeoplanar and twist orientations),

-LC layer thickness (10 to 120 μm),

-temperature (-18 to +70°C).

For all experiments a unified TVC investigation procedure was used:

Series of LC cells were manufactured having the same type of orientation and an orienting layer with a set of different gaps; the actual magnitude of each gap was measured prior to filling the LC.

To study the effect of some LC parameter, for instance $\Delta\varepsilon$, a series of LC mixtures was made consisting of a reference LCM, for instance, a mixture of azoxy compounds (ZhK 440) with $\Delta\varepsilon = -0.36$ and a small amount of dopant with a high value of $\Delta\varepsilon$, for instance 2,3-dicyano-4-amyloxyphenyl ester of n-amyloxybenzoic acide with $\Delta\varepsilon$ =-25. Addition of this dopant in the amount of max. 30% ensures $\Delta\varepsilon$=-6.3 without virtually changing other LCM parameters important for the DSM effect, such as conductivity (σ), viscosity and elastic coefficients.

Similarly, addition of a small amount of dopant with a very low magnitude of Δn , say LC based on cyclohexanecarbonic acid(ZhK 805) with Δn =0.048, to the reference LCM allows efficient variation in the magnitude of Δn while maintaining the other LCM parameters. Naturally, all basic parameters of each material in the series were measured.

The material under study was fed into the cell, then visual inspection of the quality of the resulting orientation was made and provided the result was positive a TVC was taken. The next material studied was fed into the same cell after preliminary washing by a neutral solvent like CCl_4. After a certain number of measurements, a check measurement of the reference LCM parameters was taken and in case of a positive result the measurements in this cell continued. This procedure allowed us to take measurements in identical conditions, to eliminate multiple side effects and interference difficult to make an allowance for, and to obtain accurate, well reproducible results.

A driving voltage of specific frequency (generally 50 Hz) was provided from a control unit using a special program. Here, among the particularly important factors were rate of increasing or decreasing the driving voltage, number of steps and a possibility of fixing certain voltage levels for a long time. Thus a number of new slow processes discussed in more detail below were observed at maximum voltage increase rate of 100 mV/sec and fixation of some voltage levels for 5 to 8 minutes.

As known from the literature and confirmed by us, the type of TVC significantly depends on geometry of the experimental setup.

We experimentally proved that only at angular apertures of max. 2° it is possible to observe subtle TVC nuances.

The measurements were primarily taken in direct diverging beam. The device enabled measuring intensity drops up to 7 orders.

In addition to instrumental measurements, we performed visual observation of the objects through a scattering LC layer. The filament of the incandescent lamp and the border of transition between brightly illuminated white and black squares within 50 m from the observer were used as observation objects. From our studies it follows that the visual observation conditions (two black lines against the white background, the boundary between the white and black fields or the filament) through the LC scattering light are not directly related to the magnitude of the measured intensity.

Main results

Having studied more than 70 LCM mixtures of different classes by varying all possible control modes and design and technological conditions, we were unable to find any fundamental contradictions with the earlier published data on DSM TVC in the cases where the compound classes and measurement conditions coincided.

Considering the large variation of the investigated materials and design and technological conditions of application, as well as visual observations, we succeeded in observing a number of unknown electrooptical phenomena and made the following generalizations:

1. One can plot a **generalized (universal) DSM TVC** insignificantly different from a particular LCM TVC. Fig.1 shows such universal function of intensity of light transmitted through the LC layer vs applied 50 Hz a.c. voltage. This TVC is real except some parts of it are overdone for better demonstration. The LC initial orientation is homeotropic, laser is used as an illuminator, no polarizers, the photo receiver aperture is 0.66°. The curve is obtained at voltage smoothly increased from zero to maximum,the maximum velocity being 100 mV/sec. With increasing voltage from 0 to V_B the light intensity remains unchanged and the transmitted beam is displayed as a slightly blurred point.

• When voltage attains the magnitude V_B, the light intensity decreases and with further increase in voltage the light intensity oscillates (in absence of polarizers!). The magnitude V_B is the threshold voltage of the

B-effect for given LC. This fact is unambiguously established when polarizers are used. The number of oscillations is proportional to the magnitude Δn of the LC used and the layer thickness. Oscillation amplitudes may be up to 10%, their number can be 5 or 6.

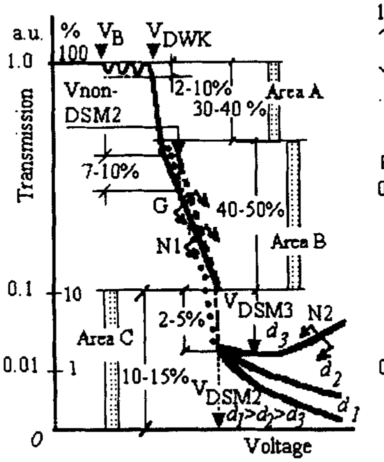

FIGURE 1 Universal function of intensity of light transmitted vs applied voltage (T-V curves).

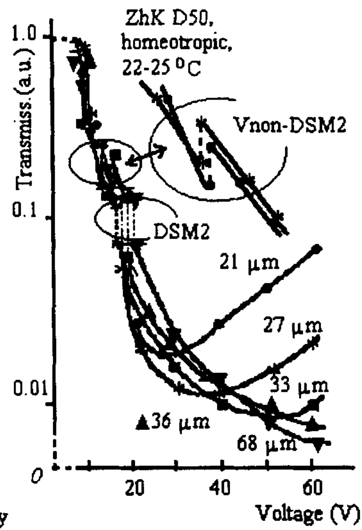

FIGURE 2 Actual T-V curves for some the LC thicknesses

The transmitted beam is displayed as blurred point rounded by a halo. The typical size of the scattering structure can be derived from the halo diameter. It turned out that this size is precisely half of the LC layer thickness. Consequently, at threshold voltage the LC layer splits into two sublayers due to reorientation of molecules in the medium layer.

The sublayer thickness is approximately equal to half of the whole LC layer. The system of two sublayers acts on transmitted light as

a scattering structure with a typical size of 1/2 of the LC layer thickness. The intensity oscillations occur due to transfer of light energy between the central spot and the halo.

- When the voltage achieves the Williams-Kapustin domain threshold,

V_{DWK}, the lignt intensity drops dramatically due to scattering on the system of cylindrical domains with chaotic direction cylinder axes.

As voltage grows, cylindrical domains become destroyed and form a system of randomly moving scattering centers that diffusely scatter light in a wide solid angle. On the display the transmitted beam is seen as a blurred point against diffusely illuminated field with monotonously decreasing intensity towards its edges. The measured intensity monotonously drops with growing voltage until it reaches a certain voltage magnitude V_{DSM2}.

• On attaining V_{DSM2} and fixing this voltage up to a few minutes, on the background of a uniformly scattering field of the LC cell, darker spots are visualized gradually filling the whole field of the LC cell. Thus there occurs a known phenomenon named secondary DSM (DSM2). With voltage invariant, the measured intensity decreases stepwise. The step size varies between 2 and 5%, depending on the LC layer thickness and its Δn and $\Delta\varepsilon$; the largest step is observed for low thicknesses and high values of Δn and $\Delta\varepsilon$.

• After the entire field has gone over to the DSM2 state, further voltage increasing leads to two possible intensity functions. In the first version described in literature, the intensity drops monotonously. In the second version, which seems to be unknown yet, following some drop, the intensity grows monotonously, i.e. here minimum intensity can be observed. The field brightening, as in the DSM2 case, starts as individual spots but here they develop comparatively quickly. Depending on the LC parameters and LC layer thickness, the height of the rise can be significant, for instance, from min. 2% to 10-15% for pre-breakdown voltage. Maximum rise is observed for small LC layer thickness, low value of Δn and high value of $\Delta\varepsilon$. For some combinations of these magnitudes we observed oscillating, rather than monotonous, nature of intensity growth.

Similarly to the DSM2 effect, we named this **phenomenon tertiary DSM (DSM3).** It looks like the DSM3 effect is thresholdless.

• The above processes occur for direct variation of voltage, i.e. for smoothly growing voltage. For reverse variation of voltage the TVC exhibits hysteresis, which is little noticeable in the area of voltage values from maximum to V_{DSM2} and clearly pronounced in the other parts of the curve. In Fig. 1 reverse TVC variation is marked by• • •. On the whole, in this case the intensity dependence is lower than in direct variation, no Williams-Kapustin domains are formed and no intensity oscillations are observed for voltages close to the B-effect threshold.

• At voltages corresponding to well-developed DSM (domains are already destroyed), but still far from V_{DSM2}, there appear more transparent areas as spots against a uniformly scattering field of the LC cell. When the voltage is fixed, for 5-8 minutes the whole field of the cell becomes more transparent and the intensity measured increases stepwise. The step size may reach 7-10% and is maximal at high Δn and $\Delta\varepsilon$, and at small LC layer thickness. This phenomenon is observed only for homeotropic orientation. After the entire field of the LC cell at fixed voltage has gone over to a more transparent scattering state, further increase in voltage leads to reduction in intensity up to the DSM2 threshold voltage(curve marked by ---).Then the TVC runs as described above. The phenomenon of brightening of the scattering structure is observed only for direct voltage variation, low rate of voltage growth and possibility to fix the required voltages for a long time.

The phenomenon of brightening of the scattering structure is observed only for direct voltage variation, low rate of voltage growth and possibility to fix the required voltages for a long time.

Similarly to the DSM2 effect, we named this phenomenon **non-DSM2.** It looks like this effect possesses a threshold.

2. The **effect** of the LC **layer thickness** on the TVC has been investigated. Examples of TVCs for different thicknesses are given in

Fig. 2.It can be seen that the curves do not differ significantly prior to the DSM2 threshold. In the voltage range of 12 to 14 V the non-DSM2 effect is observed. In the 15-20 V range a dramatic drop in the intensity of transmitted light due to DSM2 occurs. Under conditions of developed DSM2, increasing the voltage leads to higher light intensity (brightening - DSM3) for layer thicknesses less than 36 μm, to saturation at the thickness of 36 μm and unlimited drop in intensity at large thicknesses. For other orientations thickness dependencies are approximately of the same nature.

3. The effect of **the original orientation** on the TVC has been studied. For better comparability of results, cells of specific thickness were made

with four different orientations within each cell, namely: planar, homeotropic, homeoplanar and twist ones. The area of each section was ~ 1 cm^2. Simultaneously, to all sections the same voltage was applied, TVC measured (Fig. 3) and visual observation carried out. The results obtained can be summarized as follows.In the voltage range before the DSM2 threshold, the TVC behavior differs definitely, but without any clearly pronounced regularity, the biggest differences occurring for low thicknesses .

• The DSM2 threshold is different for different orientations. For example, it is 17 V for the homeotropic orientation and 32 V for planar. The arising time is also different, for example, 10, 25 and 45 s for homeoplanar, homeotropic and planar orientations, respectively.

• The non-DSM2 effect occurs only for homeotropic orientation and has a typical behavior when the voltage is switched off. For small thicknesses (8-15 μm) after switching off the voltage, for a long time (10-20 s) there exists a pseudoplanar orientation transiting in a spot-like manner to the original homeotropic one. For medium thicknesses (20-40 μm), after switching off the voltage there occurs a pseudoplanar orientation, that exists as spots on the field of the cell with a homeotropic orientation which emerged quite quickly. For large thicknesses (more than 50 μm), soon after the voltage is switched off the original homeotropic orientation is established.

• The impact of polarization and the original orientation is observed up to considerable magnitudes of driving voltages. Thus for twist orientation,the effect of rotation of the polarization plane can be clearly observed up to DSM2 occurrence and no rotation is observed under conditions of developed DSM2 or at higher voltages. No dependence on the polarization plane is found for the original homeotropic orientation.

Under conditions of developed DSM2 and at higher voltages no explicitly demonstrated dependence of transmission on the original orientation is observed, though the curves though the curves certainly do not coincide.

4.The **effect of electric conductivity** has been studied in a very wide range: from 2.10^{-11} to 5.10^{-8} S^{-1} .We used dopants giving different types of conductivity, such as ionic, donor, acceptor and donor-acceptor.

It has been established that the type of conductivity does not noticeably affect the TVC; that is why in most of the experiments we used accessible tetrabutylammonium bromide producing the ionic type of conductivity. The effect of conductivity on the TVC is demonstrated in two ways. First, LC with low conductivity have a very low inversity frequency,. The proximity of the frequency, at which measurements are made, to the inversion frequency and the measurement frequency itself influence the TVC type.

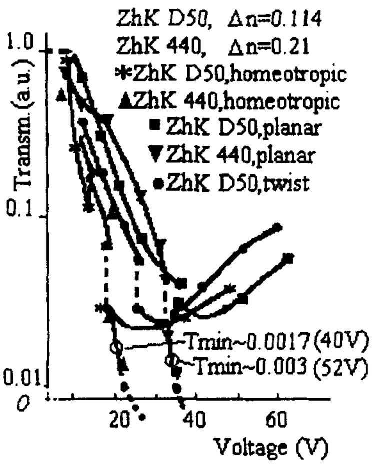

FIGURE 3 T-V curves for some initial orientations. The LC layers thicknesses are 18-21 μm.

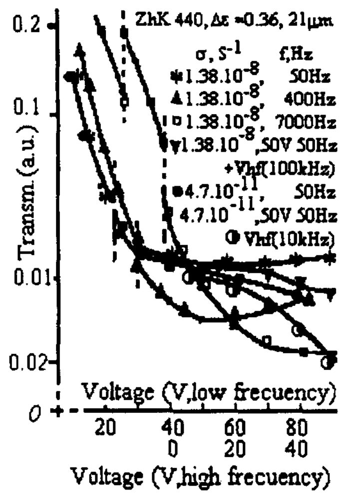

FIGURE 4 T-V curves for some σ

First, LC with low conductivity have a very low inversity frequency,. The proximity of the frequency, at which measurements are made, to the inversion frequency and the measurement frequency itself influence the TVC type

Secondly, after at the expense of the increased conductivity the frequency of inversion is obtained enough large (for example, more than 200 Hz at frequency of measurements 50 Hz), the change of conductivity even on three order does not result (as it surprised) to a regular or even noticeable change in the TVC in the voltage range up to the developed DSM2

(Fig.4). One can see insignificant deepening of transmittance minimums as conductivity grows (drops) and the DSM2 threshold lowers.

5. The **effect** of the **driving voltage frequency** has proved to be very strong and in some cases quite unexpected even for frequencies that are distant from the inversion frequency.

• It seems that the very notion of the inversion frequency should be further specified. Thus, during the experiments we found out that the inversion frequency is not so much the property of the LC material as the LC material, its original orientation and the LC layer thickness combined. This phenomenon is exhibited as follows. If a driving voltage, for instance 40 V at 50 Hz, is simultaneously applied to an LC cell with four different orientations, then in all sections DSM2 will be observed. Increasing the voltage frequency while maintaining the voltage frequency results either in a decrease or even disappearance of scattering. Thus we trespass the inversion frequency.

• The most interesting thing, however, is that for the same LC material and the same thickness but different orientations, the frequencies, at which the scattering disappears, significantly differ! The difference may be on the order of 1 kHz and even more. It is to be noted that within one section the scattering disappears non-uniformly, in large spots with smudged edges. The cells of different thicknesses show the same picture, but here the scattering disappearance frequency is much different, the difference may be 1 – 1.5 kHz. This brightening picture is qualitatively observed for any conductivity but it is exhibited most vividly at a high conductivity when the inversion frequency varies between 20 and 50 kHz.

• We have found that at any frequency under conditions of developed DSM3,a simultaneous application of a higher-frequency voltage one can again increase the scattering (unbend the curve downwards) and even get a new, significantly lower minimum, unattainable when only one frequency is used. The examples are given in Fig. 4. The applied frequencies, at which new minimums are attained, are different and can be considerably higher than the inversion frequency, for instance 70 to 100 kHz, the inversion frequency being 15 kHz.

6. In contrast to conductivity, **the dielectric anisotropy affects** the TVC in a noticeable and regular way. Thus, as $\Delta\varepsilon$ changes from the original –0.36 to –6.3 for the LC mixture ZhK440, the TVC more and more

evidently shows the non-DSM2 effect, the DSM2 threshold decreases from 24 to 15 V, transmission minimums deepen . A similar trend can be seen when Δε increases to positive values up to 0.1. The non-DSM2 effect is not virtually observed at Δε > |0,36|. It should be noted that the transition over zero Δε is not a remarkable point. The scattering takes places by Δε>0 but the thresholds for the DSM and DSM2 effects are higher. It seems from Δε>0.1 that the DSM is absent at all and the scattering begins from the DSM2.The minimum magnitudes are small.

7. The effect of **optical anisotropy** .

Optical anisotropy of the LC material does not participate directly in the physical processes of formation of the scattering centers. But owing to the optical anisotropy the scattering centers are visualized and therefore the TVC is a function of its magnitude. An example is given in Fig. 6, where LCs of similar conductivity, close Δε (except ZhK D50) are chosen. All LCs are compositions of three classes of compounds: tolanes (Tol), pyridines (D50) and cyclohexanecarbonic acids (ZhK 805). Let us assume that their physical and chemical parameters are close, except the magnitude of Δn .

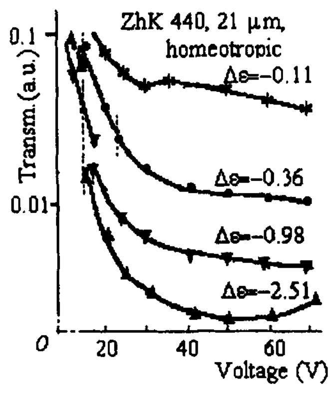

FIGURE 5 T-V curves for some Δε

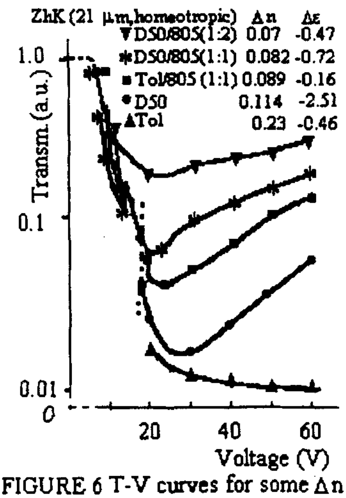

FIGURE 6 T-V curves for some Δn

Experiment interpretation

In the sections above we presented quite a large number of experimental data. Space does not permit detailed interpretation of all of them. However, it seems quite possible to present a model for processes of restructuring the scattering LC layer upon application and variation of driving voltage.

The relevant literature provides description of the following processes:

-detailed study is available for threshold effects of various kinds of domains;

-it is affirmed that upon exceeding certain threshold regular domains are destroyed, there begins chaotic motion of liquid crystal fragments that scatter light, the scattering center size diminishes with voltage – it is this particular phenomenon is called DSM;

-on attaining some higher voltage on the scattering field there appears another more scattering structure as spots – this phenomenon is named DSM2.

The model we propose does not contradict to the known facts and includes them. But in addition, it allows explanation of most of the electrooptical processes described above. Fig. 7 shows a sequence of electrooptical processes by the example of an LC cell with original homeotropic orientation as the richest in terms of variety of phenomena. Presented here are cross sections of layers, the shape of the light spot on the display after transmission through the LC layer, exaggerated distribution of intensity across the spot.

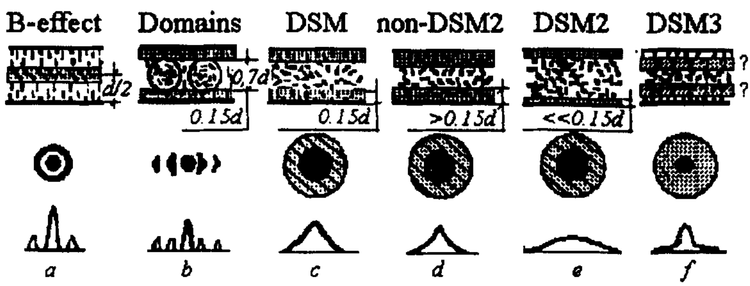

Fig.7. Cross-section of the LC cell (top),the spot shape (middle) and the intensity distribution on the spot (bottom).

Let us first discuss the whole sequence of processes (facts), and in the course of the discussion we will support the arguments proceeding from the above-mentioned experimental observations. So, the sequence is as follows.

1.On increasing the voltage up to the threshold of the B-effect there occurs a reorientation of the medium LC layer that is split into two sublayers. Both sublayers are homeotropic and divided by a thin layer with a tilt or even planar orientation. The radiation transmitted through the LC layer has a shape of a spot surrounded by a halo.

The halo's angular size φ can be defined with a high degree of accuracy by formula $\sin \varphi = 2\lambda / d$, where λ is the light wavelength, d is the LC layer thickness.

Consequently, the halo diameter is precisely defined by a typical size d/2 (two equally thick sublayers). As voltage increases, virtually all LC layer becomes planar, the sublayers and the scattering structure with the characteristic size d/2 disappear. The halo disappears as well.

2. When the voltage attains the magnitude of Williams Kapustin-domains, they appear as "worms" with a chaotic direction of the domain axis (in the originally homeotropic orientation). Their typical period (independent of the original orientation?) is somewhat lower than the LC layer thickness (generally 0.7-0.8d) and slightly diminishes with voltage. The radiation transmitted through the LC layer produces a diffraction pattern with a central maximum and diffraction maximums of the order $\pm$m for original planar orientation or circular maximums (or segments thereof) for homeotropic orientation. The diffraction system period is 0.7-0.8d.

From the assumption of symmetry it follows that the domains should be located in the middle of the layer. Consequently, near each substrate there is an LC layer about 0.15d thick, that remains in a steady state not participating in the circular motion. Thus there exists a three-layer structure (Fig.7b).

3. The velocity of the circular motion within the domain increases with voltage and on attaining certain magnitude the laminar circular motion is disturbed, the vortexes are destroyed and the LC volume comes to turbulent motion imparting a scattering appearance to the LC layer .

It is this particular phenomenon that is named DSM. At least, immediately after the vortex destruction threshold the turbulent mass volume does not differ much from the previous vortex volume, i.e. its thickness is approximately equal to 0.7d (Fig. 7c). Consequently, in this case there also exists a three-layer structure: two ordered transparent layers near the substrates and one turbulent scattering layer in the middle of the sample. With reference to the pieces that the earlier circular vortexes split into, let us put forward the following consideration. They split into pieces of irregular shape and all possible sizes permitted by the LC physical parameters and layer thickness for the following reasons.

- First, there is no mechanism restricting the size or shape (except thickness). The size of the piece cannot exceed the vortex diameter, i.e. top limitation. Second, the scattering takes place through 360° . Back scattering can occur when the scattering center size is less than the wavelength. Here back scattering, though very low, observed by a super-sensitive device or eye, takes place immediately after the DSM threshold.
- Consequently, upon destruction vortexes form pieces (scattering centers) whose maximum size is not more than the LC layer thickness and minimum size less than the light wavelength. It is to be noted that all intermediate center sizes are present too, because the scattering indicatrix is solid, monotropic, and gap-free up to 0 for any angle. Another matter is that for different applied voltages the correlation between the number of centers varies for different size. Thus, immediately after the vortex destruction (minimum voltage) the number of large centers is bigger, because the main scattering occurs within a narrow cone around the central direction. As voltage increases, the scattering takes place within a wider cone, hence the number of small scattering centers increases. Generally, the measured change in intensity of the light transmitted through the LC layer occurs at the expense of intensity redistribution along different directions due to changed proportion between the number of scattering centers of different size.

4.As voltage increases, the number of small scattering centers requiring higher energy losses for formation grows. Simultaneously, involvement of the previously transparent, maintaining the original orientation near the substrates scattering centers into the formation process becomes more and more probable.

A model of such entrapment can be demonstrated by observing the DSM process in a planar structure consisting of comb electrodes with mutually penetrating teeth and located on one of the substrates. On application of voltage between the combs, in the space between the teeth there is the scattering part of the LC, while above the teeth there is a portion of the LC with original orientation, and they are separated by a relatively narrow transient region. As voltage increases, the transient region shifts towards this or that side.

5. When the voltage attains the magnitude of V_{DSM2}, a process called the DSM2 starts developing. On the scattering field of the LC cell there occur more intensively scattering spots that gradually fill the whole field. The transmitted light intensity at fixed voltage drops stepwise. For the same LC layer thickness a more scattering structure may result either due to formation of smaller scattering centers or due to thicker scattering medium (optical path). It is difficult to imagine a mechanism that would enable a stepwise change in the center size and assume two different values at fixed voltage. But reserves for stepwise increasing the optical path can be available provided the LC wall layers are involved in the process of formation of scattering centers (Fig. 7e). The optical path length can be enlarged by almost 30% if the layers are fully exhausted. Two facts testify in favor of such way of the process development.

- First, prior to emergence of the secondary DSM, in the polarized light one can discover the effect of the original orientation on the TVC, which means that there are considerable wall layers preserving the original orientation. On appearance of DSM2, no impact of the original orientation can be found, consequently there are no even least significant wall layers preserving the original orientation. The first and the nearest to the substrate surface layers most probably under no circumstances broke away from the surface but their total thickness is extremely small, and their contribution to the TVC is negligible.
- Second, if with increasing voltage only the center size changed but the wall layers remained uninvolved, the TVCs for the LC layer of the same thickness but different orientation would coincide. In reality, however, they though slightly but evidently differ.
- An additional argument in favor of existence of the boundary layer restructuring is the following fact. If in case of original homeotropic orientation the driving voltage is switched off at the moment when DSM2 has developed through only part of the cell, the LC relaxes to the original orientation in different ways. In the parts where DSM2 has not developed yet, the original homeotropic orientation is established immediately. In the parts where DSM2 has developed, immediately after switching off there occurs pseudo-planar orientation that comes back to

the original homeotropic orientation very slowly (sometimes it takes a few seconds). In the first case the boundary layer has not been destroyed and serves as an orienting seed in the relaxation of the disordered medium layer. In the second case its structure is destroyed and relaxation takes place without the orienting seed. For some unknown reasons this leads to an azimuthally non-ordered planar orientation; by the way, this orientation is similar to one taking place when no measures for surface orienting treatment are taken at all.

6. In a similar way one can explain the mechanism of formation of more transparent (less scattering) areas in places with developed non-DSM2. In contrast to the DSM2 effect, here on attaining certain threshold, the partial step-like enlightenment occurs due to decrease in the thickness of the medium scattering layer (Fig. 7d) rather than due to the difficult to explain step-wise growth in the size of the scattering centers. This may happen as follows. LC molecules with negative anisotropy tend to align perpendicular to the applied field. At certain voltage magnitude this tendency starts realizing despite the counteracting effect of the current carriers moving in the LC layer. The oriented perpendicular to the field LC molecules form ordered non-scattering planar layers with the result that the scattering layer thickness decreases and hence for the same size of scattering centers the intensity of transmitted light increases. The evidence of the availability of planar layers is the different ways of LC relaxation to the original orientation after switching off the voltage. In parts with developed non-DSM2 first azimuthally degenerated planar orientation is formed that is relatively slowly transformed into the original homeotropic one. The fact that this five-layer structure is observed only for original homeotropic orientation, significant value of $\Delta\varepsilon$ and is not observed for other orientations, even homeoplanar, where at least one homeotropic boundary layer is present, is another argument in favor of potential realization of such five-layer structure.

7. Let us discuss the processes occurring for voltages corresponding to the developed DSM2, and for higher voltages.

As noted above, for higher voltages, depending on the LC physical parameters and the LC layer thickness, the TVC may either show an unlimited drop in the transmitted light intensity (for large thicknesses) or a clearly pronounced growth (for small thicknesses).

The latter phenomenon is called DSM3.

The growth in the transmitted light intensity probably occurs at the expense of the increased size of the scattering centers. However, this is difficult to ground in view of the high applied and increasing voltage. The second - and probably the only – possibility is a diminished optical path on which the scattering occurs, the LC layer thickness being the same. Diminishing of the optical path may happen due to the formation of uniform nonscattering layers at the expense of a part of scattering volume. Monolayers from the LC molecules that remain coupled with the substrates whatever the action may be, can serve as seed crystal for formation of uniform layers. The formation of a multilayer structure is confirmed by the fact that it is formed in a spot-like way, just as in the case of DSM2, but considerably faster (second fractions). When the voltage is switched off at the moment when spots of a new structure have covered not the entire field of the cell, then the parts with the new structure immediately relax to the original orientation. This means that the wall layers destroyed in the DSM2 have regenerated in part. As mentioned above, the parts with developed DSM2 and destroyed wall layers first form a pseudoplanar orientation and only then relax to the original orientation.

Today we have not enough experimental evidence to answer the question: what is the structure and mechanism of formation of the new (other than for the non-DSM2 effect) multilayer structure like? We just note that its formation occurs for any original orientation as distinct from non-DSM2 occurring only for homeotropic original orientation.

Consequently, the electrooptical effect named DSM virtually has several different stages. At each stage a different multilayer scattering structure is formed.

The other experimentally observed physical phenomena, such as non-DSM2, DSM3, etc., will be explained elsewhere in view of the limited space.

CONCLUSION

1. A large scope of experimental studies of one of the first and most impressing (and seemingly well investigated) electrooptical effect in LC – DSM – has been given. The research was carried out for a reasonably maximum range of measurements of LCM and driving

voltage parameters.The data presented here constitute a good food for thought for theoretical physicists.

2. The electrooptical characteristics observed earlier by other researchers have been confirmed or further specified.
3. A number of previously unknown phenomena, among them non-DSM2, DSM3,the relation of the DSM2 threshold from the layer thicknes and their initial orientation and others, have been observed.
4. Explanations have been given for some of the experimental facts, in particular availability of multilayer scattering structures at different stages of the electrooptical effect has been shown.
5. Many of the observed facts require further theoretical interpretation.

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