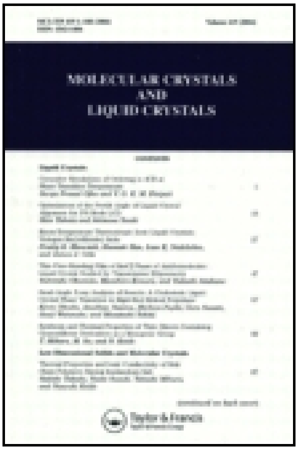

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The Optimization of LCD Electrooptical Behavior using MOUSE-LCD Software

Vladimir Chigrinov [a], Yury Podyachev [a], Georgy Simonenko [b] & Dmitry Yakovlev [b]

[a] Shubnikov Institute of Crystallography, Russian Academy of Sciences, 117 333, Moscow, Russia

[b] Saratov State University, 410 601, Saratov, Russia

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The Optimization of LCD Electrooptical Behavior using MOUSE-LCD Software

VLADIMIR CHIGRINOV[a], YURY PODYACHEV[a], GEORGY SIMONENKO[b] and DMITRY YAKOVLEV[b]

[a]*Shubnikov Institute of Crystallography, Russian Academy of Sciences, 117 333, Moscow, Russia and* [b]*Saratov State University, 410 601, Saratov, Russia*

Modeling Universal System of Liquid Crystal Displays (MOUSE - LCD) software is demonstrated for the calculation of LC electrooptical behavior and optimization of the new LCD prototypes. In our paper we will demonstrate the effectiveness of the software on various important examples enlisted below.

1. Birefringent color TN and STN-LCDs with a high brightness.
2. Fast LC shutters based on $3\pi/2$ supertwist cells.
3. One-polarizer "guest-host" LCDs with a high contrast and brightness and wide viewing angles.
4. AM-LCDs with low controlling voltages and good gray scale uniformity.
5. Subtractive STN-LCD color system with improved B/W and color contrast.

The present version of MOUSE-LCD software includes the new effective method of optical calculations (modified 2×2 Jones matrix approach) and allows for a "back flow" effect in a dynamic response of LC layer.

Keywords: electrooptical effect; modeling software; LCD; contrast; brightness; response times

INTRODUCTION

At present, many authors considered the problem of the calculation of electrooptical characteristics of LCDs, using both analytical estimations and computer programs[1,2]. The procedure of the modeling of LCD efectrooptical behavior includes two steps. First, the LC director profiles are found for varying applied voltages. The second step consists of solving Maxwell equations for the light propagating in anisotropic LC media to find the optical response of the LCD cell.

Our software module, called MOUSE-LCD was demonstrated as a useful and reliable tool for LCD-modeling[3].

The optimization of LC electrooptical response results in efficient LCD constructions with a high brightness[4,5], wide viewing angles[6], high contrast and fast response[7,8] found with the help of computer simulations.

The aim of this paper is to describe various possibilities of MOUSE-LCD software for the LCD optimization and to reveal its new features appeared recently.

MOUSE-LCD SOFTWARE

The two main MOUSE-LCD modules work as follows. The deformation program can calculate *any director distribution* with arbitrary director twist and any (non-symmetric) director tilts on the boundaries. The weak anchoring at the substrates is also taken into account. The dynamics of the deformation is estimated not only in the approximation of a pure director rotation, but also with a so-called "back-flow" effect, when six Leslie viscosity coefficients are allowed for.

The optical program is based on the efficient 4x4 and 2x2 matrix approaches to solve Maxwell equations in anisotropic LC layer.

Our recent variant includes the modified Jones 2x2 matrix method, which is more advanced as already described ones [1,2], as it does not require the small relative optical anisotropy of the LC medium[9]. Both uni and biaxial optical tensors of the LC layer are allowed for.

Another modification includes an accurate description of multiple reflections and a multi-beam interference in LCD layers, using the approach of a partial coherence[9,10]. This modification proves to be very efficient in calculating the high contrast LCD configurations[7,8]. Thus both the accuracy of the modeling and the effectiveness of the LCD optimization by MOUSE-LCD software is highly increased.

Possible applications of the software module include any simulations of LC cells electrooptics, taking into account:

-real LC parameters (elastic moduli, dielectric constants, viscosity coefficients, helix pitch);

-LC cell configuration (cell thickness, director twist angle, tilt angles on the boundaries, anchoring energy);

-construction of the LC unit (characteristics of polarizers, phase retardation plates, both uni and biaxial, color filters, double LC-cell configuration, reflective mirrors in ideal variant);

-any possible configuration of the driving voltage, i.e. static and multiplex driving conditions.

We demonstrate the possibilities of the computer module simulations in a real time schedule. We may see how to obtain the high contrast and brightness and to evaluate the angle dependence and characteristic response times of the LCD for various electrooptical modes.

OPTIMIZATION RESULTS

We will give in this section some LCD constructions, which were optimized using MOUSE-LCD software.

Birefringent color TN and STN LCDs with high brightness

A very interesting configuration, consisting of the STN-LCD with the two phase retardation plates specially adjusted for each basic pixel Green (G), Red (R) and Blue (B) was proposed in [4] (Fig.1). By a special choice of the angles τ and σ of the phase retardation plates C_1 and C_2 with respect to the projections of the LC directors onto the substrate plane n_1 and n_2 (φ is a supertwist angle) and the phase differences δ_1 and δ_2 it is possible to get the three basic birefringent colors in the off state of the STN-LCD display pixel, which will switch to the black in the on state. As the phase retardation plates are transparent, the efficiency of the color STN-LCDs can be considerably increased, thus enabling to use the low power of the backlighting system. The phase retarders must be very small and adjust the size of the STN-LCD pixel, so the technology based on photoanisotropic layers looks very promising in this case. Moreover the photoanisotropic layers can be used both for the aligning and the local phase shifting of STN-LCD pixels, so the principally new way of STN-LCD technology is opened[11].

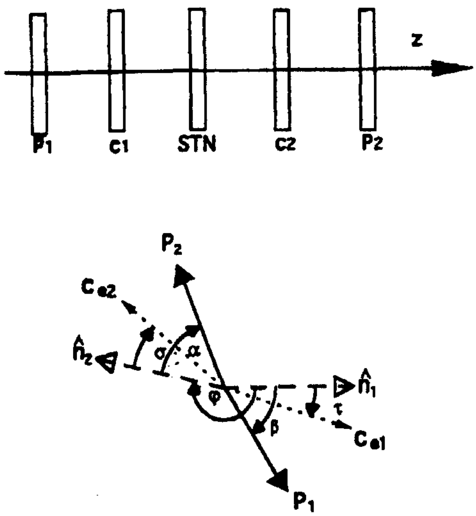

FIGURE 1. Configuration of a new color STN-LCD with phase retardation filters and birefringent colors[4]: P_1, P_2-polarizers, Ce_1, Ce_2-phase retardation plates, n_1, n_2- projections of the LC director onto the substrate plane,φ-the LC supertwist angle.

The corresponding TN-LCD configuration consists of the three polarizers $P_1 \parallel P_3$ and $P_2 \perp P_1$, TN-cell and the the two phase retardation plates, placed symmetrically with respect to the polarizer axis P_1 (Fig.2). In the "off" state the TN cell rotates the polarization of the light to the angle of $\pi/2$, it comes through the intermediate polarizer and the two phase retardation plates ΔC, placed at the optimal angle $R_0 \approx \pi/8$ and gets a color with the peak wavelength λ, provided that $\Delta nd = \lambda/2$, where Δn and d are the optical birefringence and the thickness of the each phase retarder respectively.

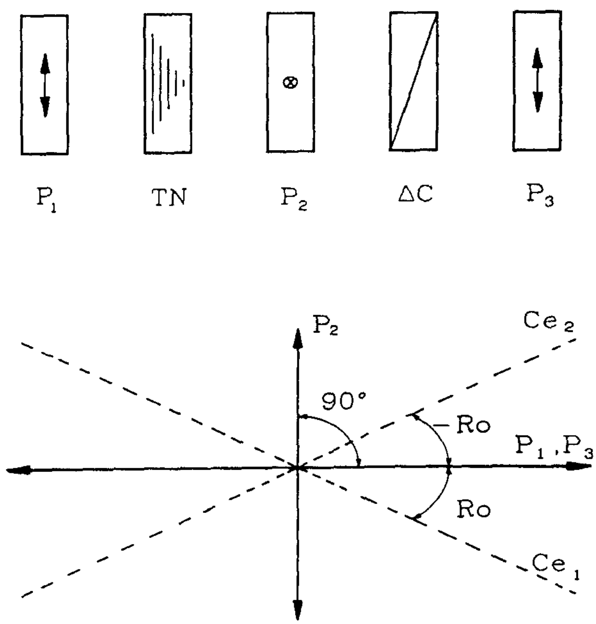

FIGURE 2. Birefringent TN-LCD color cell with the three polarizers $P_1 \parallel P_3$ and $P_2 \perp P_1$ and two symmetrically placed phase retardation plates Ce_1 and Ce_2.

We think, that this birefringent color system, which we estimate using MOUSE-LCD software could be also very helpful in the efficient color AM-LCD without isotropic dye filters, as the transmission of the LCD is increased almost 10 times.

Certain problems exist in viewing angle dependence of the birefringent colors of TN and STN-LCDs, but in some cases, e.g. in LCD projection devices they are not so important.

<u>Fast LC shutters based on $3\pi/2$ supertwist cells</u>

$3\pi/2$ supertwist cells are well known as the basic construction for the Supertwist Birefringent Effect (SBE)[11]. The switching times of this configuration in the regime of the multiplex driving, which is conventional for the high information content LCDs is rather high and usually exceeds 100 ms. The switching is slow, because it takes place between the LCD configurations having almost the same free energy, as the two volages U_{on} (selected voltage) and U_{off} (non-selected voltage) are very close to each other.

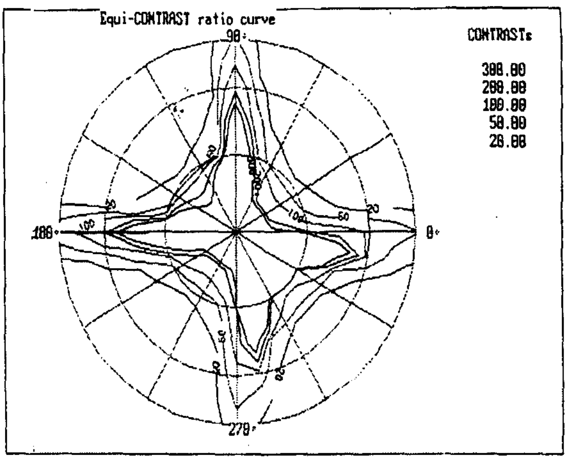

FIGURE 3. Equi- contrast ratio curves for $3\pi/2$ cells.

The situation is quite the reverse in the case of static addressing of $3\pi/2$ supertwist cells, when $U_{on} >> U_{off}$. Very fast switching can be obtained with the characteristic rise times less, than 1ms and decay time 2-3 ms[7]. At the same time $3\pi/2$ cells provide very high contrast ratio and transmission both for the normal and oblique light incidence. The corresponding equi-contrast ratio curves, calculated with the help of MOUSE-LCD software[3] are shown in Fig.3. The fast shutters, based on $3\pi/2$ supertwist cells can be successfully used in 3D displays with TV or video-images, simultaneously used by several viewers[11].

Other types of optimal LCD configurations, obtained by MOUSE-LCD software

The effectiveness of our software for LCD optimization is confirmed by some other LCD constructions enlisted below.

One-polarizer GH-LCD with a high brightness and wide viewing angles

One-polarizer construction of a transmissive «guest-host» LCD with a phase retardation plate was proposed[6]. The application of a phase compensator in GH-LCDs and optimization of LC layer thickness, twist angle and dichroic dye concentration allows to get a maximum contrast and transmission and wide viewing angles together with minimum response times. The optimized GH-LCD construction could be in particular useful for the triple GH-LCD configurations with subtractive colors[11].

AM-LCDs with low controlling voltages and gray scale uniformity

Different variants of low-voltage AM-LCD were analysed using MOUSE-LCD software[12]. The following electrooptical LC modes were estimated: (i) Electrically Controlled Birefringence, ECB-LCDs; (ii) Twisted Nematic, TN-LCDs ; (iii) Hybrid Aligned Nematic, HAN-LCD with a homeotropic and planar LC alignment on the substrates; and (iv) Twisted Hybrid Aligned Nematic, THAN-LCDs. Both phase compensated and double cell LCD constructions were allowed for. It was shown, that both HAN and THAN-LCDs are good candidates for

AM-LCDs with low driving voltages and power consuption, high brightness and contrast and a good gray scale uniformity.

Subtractive STN-LCD color system with improved B/W and color contrast

The system consists of three subsequently placed STN-LCD cells, where each cell can switch between a white state and three subtractive color primaries, magenta, yellow, or cyan. Using eight switching combinations, three basic colors, red, green, and blue could be realized together with white and black states. The subtractive color system allows us to avoid using conventional RGB filters, which absorbed more than 95% of the light passed through them[11].

The optimization of the subtractive color system can be made by replacing the color polarizers to the neutral ones and applying three identical STN-LCD, but with phase retardation plates specially adjusted on the front and back side of each STN-LCD cell [5]. In this case both the average contrast and color saturation can be improved almost two times. We used MOUSE-LCD software for the purpose.

CONCLUSION

Modeling Universal System of LC Electrooptics (MOUSE-LCD) software was demonstrated for the evaluation of LCD characteristics. Some examples of its effectiveness, including the new LCD construction with a high brightness and contrast, wide viewing angles and fast response times were given. The system proves to be a useful tool of the LCD optimization.

Acknowledgements
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References

[1] M.E. Becker "LCD Optical Performance Modeling", *SID'98 Application Seminar A2,* 1998.
[2] J. Kelly "LCD Performance Modeling", *SID'97 Application Seminar A2,* Boston, USA, 1997.
[3] V.G. Chigrinov, Yu.B. Podyachev, G.V. Simonenko, D.A.Yakovlev, SID'98 Digest, p.564 (1998).
[4] D.A.Yakovlev, G.V.Simonenko, V.G. Chigrinov, M. Schadt. Digest of Eurodisplay'93, p.17 (1993).
[5] V.G. Chigrinov, G.V. Simonenko. *SPIE Digest,* v.2407,p. 291(1995).
[6] V.G. Chigrinov, G.V. Simonenko, Abstracts of ECLC'99, Greece, 1999.
[7] S. Belyaev, V. Chigrinov, N. Malimonenko, A. Miroshin, *Digest of Projection Display Conference,* San-Jose, California, p.241 (1995).

[8] V.P. Sevostyanov, G.V. Simonenko, D.A. Yakovlev, V.A. Brezhnev, S.A. Studentsov, *Photonics and Optoelectronics,* v.82, p.78 (1997)..
[9] D.A. Yakovlev, "New elements of the theoretical description of the optics of a stratified media", *Candidates Dissertation,* Saratov State University, Saratov, Russia, 1998.
[10] M. Born and E. Wolf, "Principles of Optics", *Pergamon Press,* NY, 1980.
[11] V.G. Chigrinov, "Liquid Crystal Devices: Physics and Applications", *Artech House,* Boston-London, 1999.
[12] V.G. Chigrinov, S.V. Belyaev, N.V. Malimonenko, N.M. Shtykov, M.I. Barnik, unpublished results.