Simulation model of light polarization films for LCD backlight design

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Abstract: The article is devoted to elaboration of the computer model of scattering polarization film like DBEF, methods of measurements and reconstruction of the film polarization parameters and using the model to design LCD backlight systems.

Keywords: polarization, DBEF simulation, LCD backlight system

1. Introduction

Illuminating systems of LCD displays require not only designed luminance distribution over the display surface but also specifically designed state of polarization of light illuminating the TFT matrix. To obtain required light polarization state the illumination systems use polarization films placed just under the TFT matrix. The only disadvantage of most of films is absorption of the part of light (usually 40-45%) which polarization does not coincide with the polarization the film produces. Therefore the efficiency of the backlight illumination system is reduced in about two times. Solution that allows not reducing efficiency of backlight illumination system can be found in special DBEF polarization films [1]. The films reflect light which polarization is out of film one instead of its absorption. As a result the reflected light returns to the backlight system where it is depolarized and goes back to DBEF. Finally, after multiple reflections from DBEF the light takes proper polarization state without significant absorption. The problem is that computer model of the DBEF film is very complex. Such film not only polarizes light but also scatters passed and reflected light. Moreover, manufacturers hide internal film structure that makes impossible elaboration of accurate mathematical model of the film. Therefore the possible solution can be in elaboration of semi-empirical model of the polarized light scattering based on measurements the polarized film BSDF. The article presents results of measurements and reconstruction of polarized BSDF of DBEF and using the polarized BSDF in the design of the LCD display backlight.

2. Model of the polarized BSDF

Physically accurate light simulation of devices with DBEF films is possible if we can construct physically correct computer model of the polarized BSDF of the film. There are two ways to construct the model: the first way is to solve wave equation for the film microstructure and the second way is to measure parameters of polarized light scattering. Unfortunately the first way is impossible due to lack of precise information about the film structure and the only possible solution is to measure the polarized BSDF.

In our opinion the most optimal solution for backlight devices is storing the results of BSDF measurements as 5D table of Mueller matrix. Muller matrix provides correct transformation of light ray polarization when effects of the coherence are not important. For complete polarized BSDF reconstruction we need 16 independent BSDF measurements done for different parameters of linear and circular filters placed in the illumination and observation channels of measuring device. However, taking into account linear character of DBEF polarization [2] we can reduce number of measurements to four independent ones done for different orientations of linear polarization filter in illumination channel. In this case the Mueller matrix has the following view:

$$M = \frac{1}{2}\begin{pmatrix} \tau_{\max} + \tau_{\min} & \cos(2\delta)(\tau_{\min} - \tau_{\max}) & \sin(2\delta)(\tau_{\min} - \tau_{\max}) & 0 \\ \tau_{\min} - \tau_{\max} & \cos(2\delta)(\tau_{\min} + \tau_{\max}) & \sin(2\delta)(\tau_{\min} + \tau_{\max}) & 0 \\ 0 & -2\sin(2\delta)\sqrt{\tau_{\min}} & 2\cos(2\delta)\sqrt{\tau_{\min}} & 0 \\ 0 & 0 & 0 & 2\sqrt{\tau_{\min}} \end{pmatrix}$$

Parameters $\tau_{\min}$, $\tau_{\max}$ and δ of the matrix are calculated on the base of BSDF measurements done for orientations of linear polarization filter in the illumination channel equal to 0°, 90°, 45° and 135°. Note that one of the measurements for 45° or 135° is superfluous and was used as an addition control of BSDF measurement correctness.

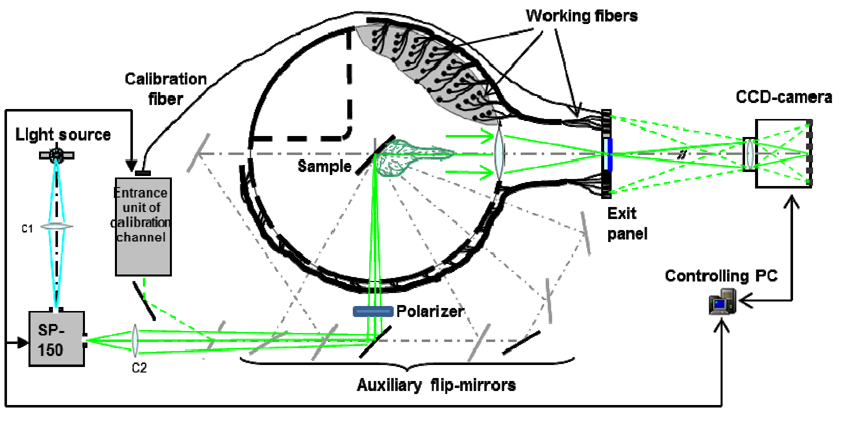

Fig. 1. General scheme of measurement installation

3. Polarized BSDF reconstruction on the base of direct measurements

The measurements of DBEF sample were performed using Integra's Spectral Scatterometer (fig. 1).

The monochromator SP-2155 with a computer control of a wavelength selects a narrow wavelength interval from the lamp light so that the light emitted from its exit slit is nearly monochromatic.

A number of auxiliary flip-mirrors allow illuminating the DBEF sample under fixed set of incidence angles (for BRDF measurement). Mirror position on Fig. 1 corresponds to incidence angle 45 degree. After reflection from an auxiliary mirror the light is polarized by passing through the polarizer. In case of BTDF measurement the angle of incidence is controlled by rotation of the sample holder. The orientation of the plane of polarization for light incident on the sample is provided by corresponding rotation of polarizer.

The sample itself is placed in the center of metallic hemisphere with holes in which the input ends of fibers are fixed. The output ends of fibers are combined in the exit panel.

The measurements of polarized BSDF are carried out separately for a number of fixed orientations of entrance polarizer. Finally, the measurement allowed reconstructing whole model of DBEF.

4. Design of illuminating system of LCD backlight with DBEF

To check correctness and to show the advantages of DBEF usage two similar schemes of backlight devices were simulated, see Fig. 2. Both schemes are typical backlight devices with standard elements: LGP (Light Guiding Plate) with microstructure on bottom face; LED array, reflector box and BEF (Brightness Enhancement Films). In the first scheme the simple linear polarization filter (LPF) produces linearly polarized emission on LGP output. In the second scheme advanced DBEF is used for the same goal.

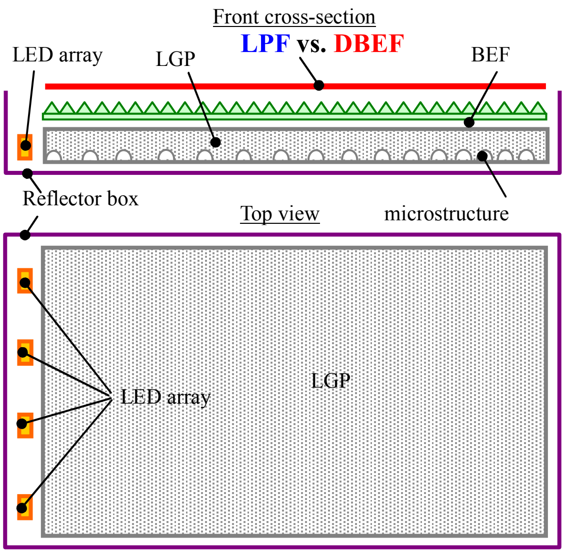

Fig. 2. Schemes of typical backlight device.

Fig. 3 shows simulation result (outgoing luminance distribution) of both schemes. The result represented in pseudo-color shows advantage of DBEF solution. DBEF increases level of mean luminance in about 1.5 times that corresponds to real device measurements.

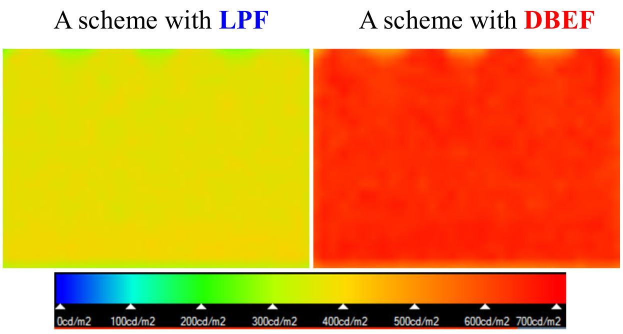

Fig 3. Output luminance distribution in pseudo color

5. Conclusion

Polarized BSDF model is elaborated. It is demonstrated the computer simulation of backlight devices with DBEF is possible and the simulation results agree with experiment. The elaborated software Specter provides physically accurate simulation of polarized scattering phenomena in optical devices. Moreover not only simulation but also design of backlight devices with DBEF is possible with help of Specter software.

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6. Reference

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