Multispectral polarization analysis of circular polarizer stereoscopic 3D display

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Abstract

Circular polarizer stereoscopic 3D displays are characterized in depth using multispectral polarization viewing angle instrument. The polarization state of the light emitted for left and right eye of the observer are measured in addition to their angular and spectral dependence. The degree of circularity of the light and its degree of polarization are measured for all the visible range. It allows identifying precisely the origin of the imperfections of such displays and evaluating the luminance and color that should be measured through circular polarizer glasses.

Presentation Style

Presentation preference: oral

Workshop

3D: workshop on 3D/Hyper-Realistic Displays and systems.

1. Introduction

Even if researchs and developments have been intensively made on polarization based stereoscopic 3D displays for many years, all the technical problems are not solved up to now. In particular the microretarder film is one of the key elements for the properties of such displays in particular concerning the viewing angle [1-2]. The quality of the microretarder film and also of the polarizer when embedded inside the liquid crystal cell, are key points for 3D quality. Up to now very limited characterization methods have been applied to such displays. In the following, we propose to use our new multispectral viewing angle instrument to make viewing angle measurements in a large angular aperture [3]. This system provides radiance in the whole viewing angle map at different wavelengths using up to 33 band pass filters all over the visible range. These measurements are useful to understand more in depth the origin of the different imperfections. In addition we can also recalculate the luminance that should be detected with different types of theoretical glass filters and anticipate the contrast of the displays.

2. EZContrastMS system

The EZContrastMS system has been used which is capable to provide radiance in the whole viewing angle cone up to 88° incidence. On the standard system, 31 filter from 400nm to 700nm are available every 10nm. The polarization option includes three polarizer at different orientations (0, 45 and 90°) and two wave-plates at different orientation (45 and 135°). These additional elements can be positioned to obtain up to 7 polarization configurations. Seven measurements with the various polarization configurations are made automatically for each interference filter from which the Stokes vectors are derived for each incidence angle, azimuth angle and wavelength.

$$S = \begin{bmatrix} I \\ Q \\ U \\ V \end{bmatrix} = I.\begin{bmatrix} 1 \\ \rho.\cos 2\varepsilon.\cos 2\alpha \\ \rho.\cos 2\varepsilon.\sin 2\alpha \\ \rho.\sin 2\varepsilon \end{bmatrix}$$

I is the total intensity of the light. Q is the intensity of the linear polarized light. U and V represent the phase difference between the two orthogonal components of the electric field. In the common horizontal/vertical basis, U represents the horizontal linear component of the electric vector and V the vertical component. For right and left circular polarized light the difference can only be detected on the sign of the V parameter. The three parameters, polarization orientation α, polarization ellipticity ε and degree of polarization ρ can be also calculated.

3. Measurements & computations

a) Example of measurement on circular polarizer 3D display

Multispectral viewing angle polarization measurements have been performed for right view ON and left view OFF and the opposite. The viewing angle pattern obtained at 549nm is reported in figure 1. We notice a vertical modulation of the ellipticity (cf. figure 2) and also more surprisingly, a modulation of the polarization degree along the same direction (cf. figure 1). The maximum of polarization degree is about 90% even in the regions where it should be 100%. It means that the glasses filters will not completely stop the un-polarized contribution and that the contrast will be reduced. On the other hand, the Stokes parameter V that provides the sign of the polarized light is found as expected opposite for the left and right views (cf. figure 2). The modulation structure is probably due to the perspective effect induced by the microretarder film which is located on the top surface of the display (cf. figure 3). The resulting perspective effect is due to the thickness of the top glass which modulates the polarization of one view along vertical.

The dependence versus wavelength is also especially worth studying. In figure 4 we have reported the cross sections of the polarization degree and ellipticity angle versus wavelength and incidence angle for the vertical azimuth. The polarization degree is not strongly dependent of the wavelength but it is clearly higher for the right view. So the contrast will not be symmetric between the eyes. On the other hand, the ellipticity angle is strongly dependent on the wavelength. This is due to the well know dependence of the polarization rotation using a simple retarder sheet that is in 1/λ. The retarder embedded in the display is optimized for a wavelength of about 500nm. The ellipticity reduction for blue and red part of the spectrum can reach 30° and a reduction of the contrast in blue and red regions is then expected.

b) Computation with theoretical glass filters

Each glass filter is a combination of a retarder plate followed by a polarizer. Using the stokes vector measured by EZContrastMS makes it easy to extrapolate the radiance that should be detected after one or the other retarder plate for left and right view measurements (cf. figures 1-2, 4). To get a more realistic computation we have taken into account an imperfect transmittance for the polarizer sheet and a wavelength dependent phase shift for the retarder as reported in figure 5. From the spectral emission measured for each view we compute the light that will be detected after the two glass filters. The radiance and the luminance can thus be extrapolated in the entire viewing cone. Results in luminance for right view are reported in figure 6 and compared with the luminance measurement obtained with a standard viewing angle instrument including the glass filter. The agreement between computation and measurement is very good. Small discrepancies can be due to the imperfect character of the retarder and polarizer of the glass filters.

4. Conclusion

Viewing angle measurement have been performend on polarization based 3D display using EZContrastMS. The polarization state of the light emitted by the display for right and left eye is measured versus angles and wavelength. We have found a vertical modulation of the polarization state along vertical direction and understood its origin. We have also detected a strong unpolarized components that reduces the contrast of the display. The wavelength dependence is especially useful to understand in depth the properties of the display. Using multispectral polarization measurements we have also recalculated the luminance that should be detected with theoretical glass filters and compared the results with luminance measurements. The agreement is excellent and shows that the performances cannot be improved by changing the glass filters but only by reducing the un-polarized light emitted by the display.

This study is complementary to the one proposed for the same conference on the calculation of Qualified Monocular and Binocular Viewing Spaces (QMVS and QBVS) and this is in line with our previous studies on the characterization of auto-stereoscopic 3D displays [4-6].

5. References

1. C. Lee, C. Tsai, W. Liu, H. Lin, “Fabrication of in cell microretarder & in cell polarizer for stereoscopic LCD by solution process”, Proc. IDMC , P2-16, 2009
2. Y. Wu, Y. Jeng, P. Yeh, C. Hu, W. Huang, “Stereoscopic 3D Display using Patterned Retarder”, Proc. IDMC, P2-48, Taiwan, 2009
3. P. Boher, T. Bignon D. Glinel, T. Leroux, “Viewing angle and spectral characterization of LCDs and their components”, Proc. IDW, December, 2008
4. P. Boher, T. Bignon, T. Leroux, “Autostereoscopic 3D display characterization using Fourier optics instrument and computation in 3D observer space”, IDW 08, 3D3, 2079, 2008
5. P. Boher, T. Leroux, T. Bignon, V. Collomb-Patton, “A new to characterize autostereoscopic 3D displays using Fourier optics instrument”, Electronic Imaging, San Jose, 2009
6. T. Leroux, P. Boher, T. Bignon, D. Glinel, “VCMaster3D: a new Fourier optics viewing angle instrument for characterization of auto-stereoscopic 3D displays”, SID meeting, San Antonio, 2009

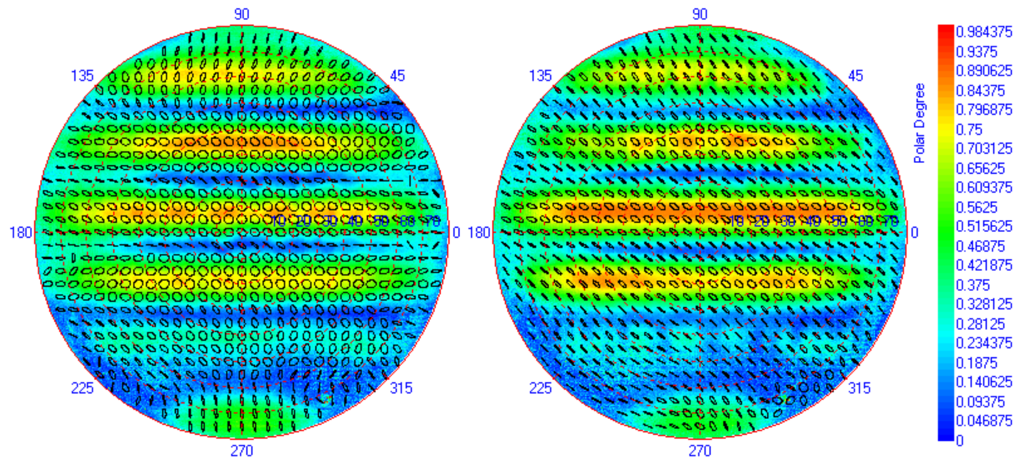


Fig. 1: Polarization state at 549nm for left and right eye views. The polarization ellipticity and the degree of polarization are reported simultaneously.

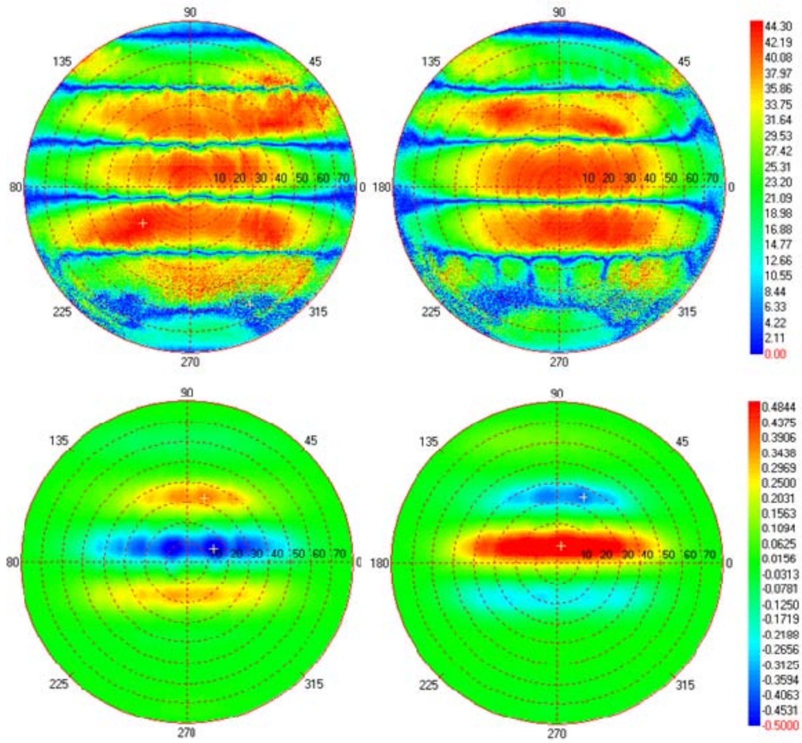


Fig. 2: Ellipticity angle (top) and Stokes parameter V (bottom) at 549nm for left and right eye views.

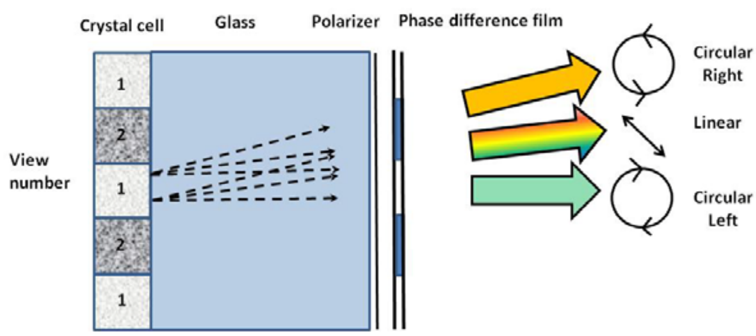


Fig. 3: Schematic cross section of a stereoscopic3D display: when view 1 is ON state and view 2 OFF state light is circularly polarized near on axis but change of polarization state along vertical direction due to perspective effect.

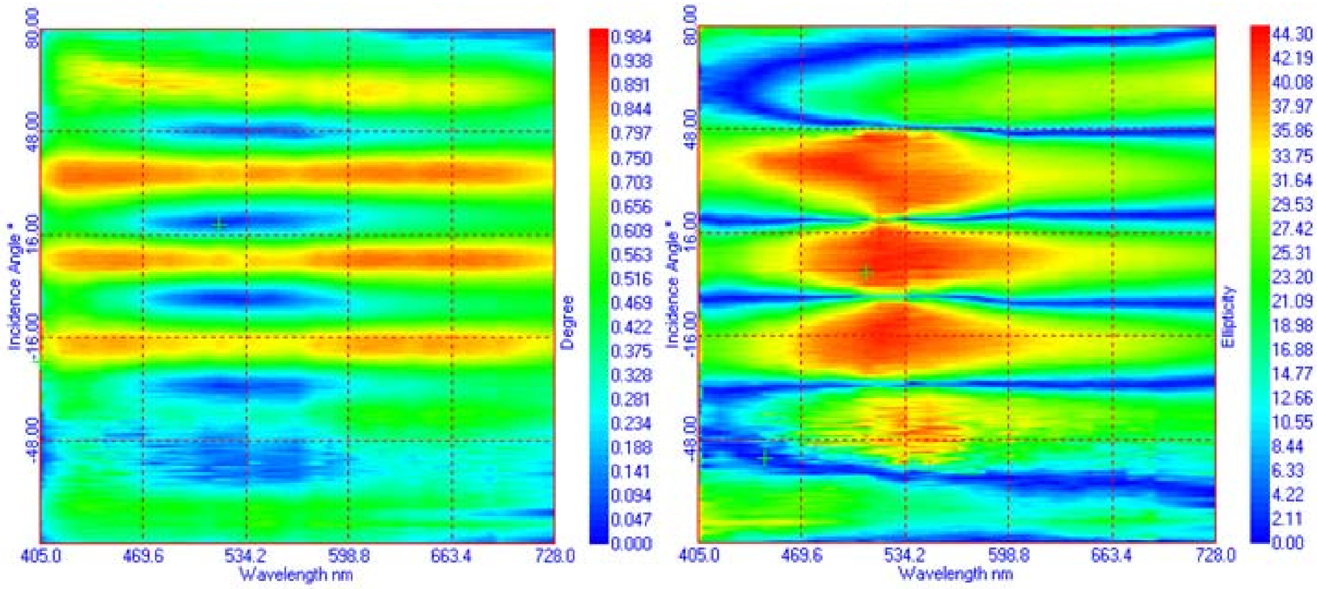


Fig. 4 Polarization degree (left) and ellipticity (right) for left view versus wavelength and incidence angle along vertical azimuth.

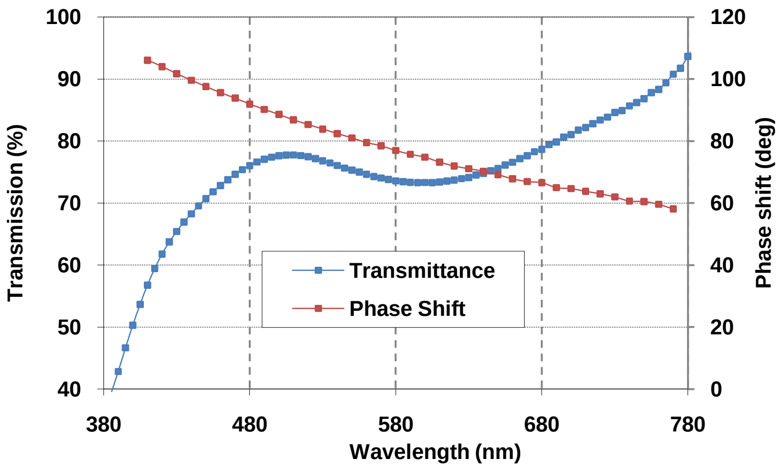
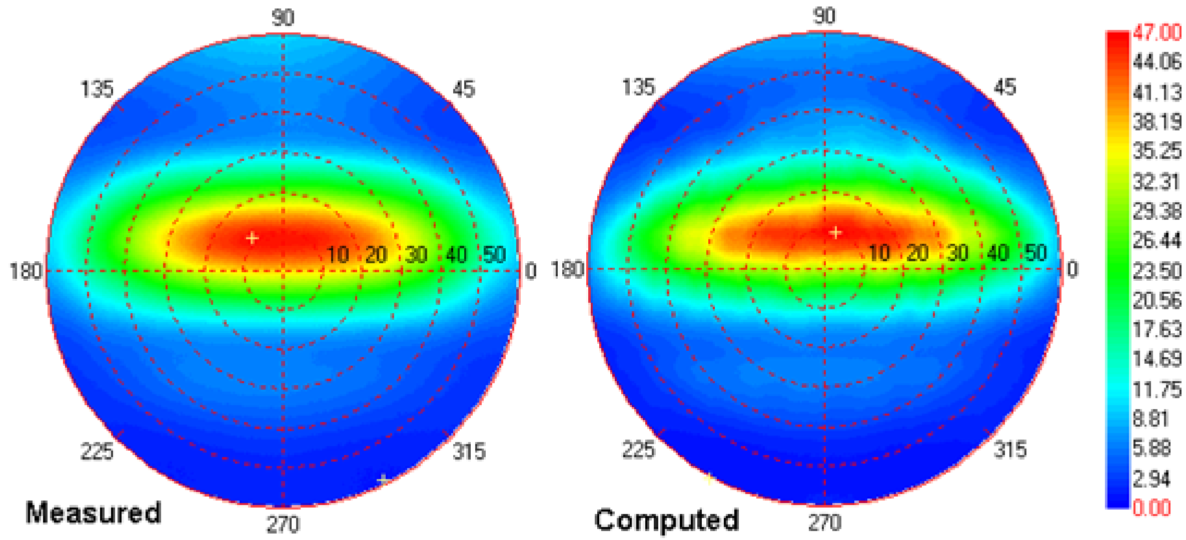


Fig. 5 Measured transmittance and phase shift of the polarizer and retarder used to simulate the glass filters for luminance computation using multispectral polarization measurements.



<u>Figure 6:</u> Luminance for right view using right glass filter: comparison between luminance measurements (left) and computation using multispectral polarization measurements and theoretical glass filter (right).