# Polarization imaging for characterization of LCDs and their components.

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## Abstract

We present a new imaging polarimeter that provides the full polarization state of the light emitted by any source in the same way as chromaticity for a video-colorimeter. The wavelength is selected by a band pass filter an each wavelength can be available in the visible range. Some measurement examples are presented on backlight with BEF film and LCD displays. The homogeneity of the crystal cell rotation inside a LCD is also measured for the first time.

## Presentation Style

Presentation preference: oral

## Workshop

Workshop on LC Science and Technologies (LCT).

## 1. Introduction

Recently ELDIM has introduced the ability to measure spectral radiance and polarization state of the light in its Fourier optics viewing angle instruments (1). Up to now imaging polarization has not been used to characterize display homogeneity. It is surprising since LCD are essentially polarization modulators but no practical system was available up to now. In the present paper we introduce a new imaging colorimeter UMaster that can also make imaging polarimetry. Some technical details are given hereafter with some first results on imaging polarization.

## 2. Imaging colorimeter & polarimeter

Imaging polarimeter UMaster is based on a 1.6M pixels Peltier cooled CCD sensor with true 16-bit analog digital converter. Different imaging objectives are available (with 8° or 16° maximum angular aperture). High spatial resolution objectives are also available. Each objective is telecentric on the sensor side to be independent on the working distance and to ensure the same transmittance of the filters everywhere on the image. Two motorized filter wheels in front of the sensor allow measurements with different polarizer positions (0, 45 and 90°) and additional quarter wave-plate (45 and 135°). Wavelength is selected with a band pass filter (FWHM 10nm). Measurements can be made at any wavelength in the visible range. In the following measurements are made at 550nm. UMaster can make also standard luminance and chromaticity measurements with the same setup. For polarization imaging seven measurements with various polarization configurations are made automatically to derive the Stokes vector for each pixel of the image:

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

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 also be calculated.

## 3. Measurement results

### *a) Backlight with BEF film*

Optimizing the LCD performances makes it important to characterize precisely the backlight properties in terms of homogeneity and angular emission. These characterizations are generally made with video colorimeters and viewing angle instruments but only on the luminance and chromaticity. In fact, even if the first element of the liquid crystal cell is a polarizer, the polarization state of the light emitted by the backlight is also important because it drives really the performances of the liquid crystal cell. The backlight measured hereafter includes a BEF layer on its surface. If the intensity of the light (Stokes vector S0 on figure 1.a) does not show any specific feature, a pseudo periodic structure is detected on the ellipticity, orientation and polarization degree across its surface (cf. figure 1b, 1c and 1d). This behavior comes probably from the BEF film and can have an important impact on the homogeneity of the LCD build with this backlight.

### *b) LCD in OFF state*

Improving OFF state is crucial for enhancing contrast across wide viewing angles. Viewing angle polarization measurements on LCDs have shown a close correlation between the luminance contrast and the degree of polarization of the light detected in OFF state [2]. The same type of measurement on the entire surface of the display gives new information. We give hereafter the example of a 15’ LCD which was measured for ON state and OFF state at 550nm. For ON state the light is quasi fully polarized with very small local deviations. On the contrary, measuring OFF state allows seeing some of the imperfections of the display as shown in figure 2. Most of the light emitted by the display is not polarized (cf. figure 2.b), and the small polarized component is probably resulting from imperfections of the polarizers or the liquid crystal cell. It present some inhomogeneities in the polarization ellipticity and polarization orientation as shown in figures 2.c and 2.d.

### *c) LCD without top polarizer*

Polarization analysis of the light emitted by LCDs is also very informative on the efficiency of the liquid crystal cell as polarization modulator. An efficient way to follow in details the crystal cell switching is to remove the top polarizer of the LCD and measure the polarization state versus grey level. This type of study has already been done using multispectral viewing angle system [3], giving a complete picture of the crystal cell rotation versus incidence, azimuth and wavelength. We have made the same experiment here using the UMaster system to check if the crystal cell behavior is homogeneous all over the panel. Some results obtained at 550nm are reported in figure 3. In the panel under investigation, the top polarizer was aligned along the +45° direction. The polarization state should be perfectly linear along -45° direction for OFF state and also perfectly linear along +45° direction for ON state. As shown in figure 3, the OFF state (grey level 0) is characterized by a strong polarization degree which is quasi homogeneous on the display surface. There is nevertheless small ellipticity at the bottom right corner of the display. When increasing the grey level values the ellipticity increases up to around 25° for grey level 128 and then decreases again to very low value for ON state but this behavior absolutely not homogeneous on the display surface. In addition, some small inhomogeneities appear in ON state which are probably characteristic of some misalignments of the liquid crystal layer. The polarization direction follows the required behavior from ON state to OFF state but with the same type of inhomogeneities correlated with ellipticity. Finally the unpolarized light increases with the grey level from very small values for OFF state to quite large values for ON state. This type of behavior measured for the first time must be analyzed in more details and correlated with the manufacturing technology, but it will be certainly helpful in the future to increase the performances of such panels.

## 4. Conclusion

In this paper we have presented a new instrument that allows making polarization imaging in the same way as luminance or chromaticity using video-colorimeters. Promising results have been shown for backlight and LCD measurements. The paper will try to investigate more practical application of this brand new instrument.

## 5. References


1. P. Boher, T. Leroux, T. Bignon, D. Glinel, “New multispectral Fourier optics viewing angle instrument for full characterization of LCDs and their components”, SID, Los Angeles (2008)
2. P. Boher, ”Cheks of polarization shed light on LCD characteristics”, Display Devices, Spring (2008)
3. P. Boher, T. Bignon, D. Glinel, T. Leroux, “Viewing angle and spectral characterization of LCDs and their components”, IDW, Niigata, Japan (2008)

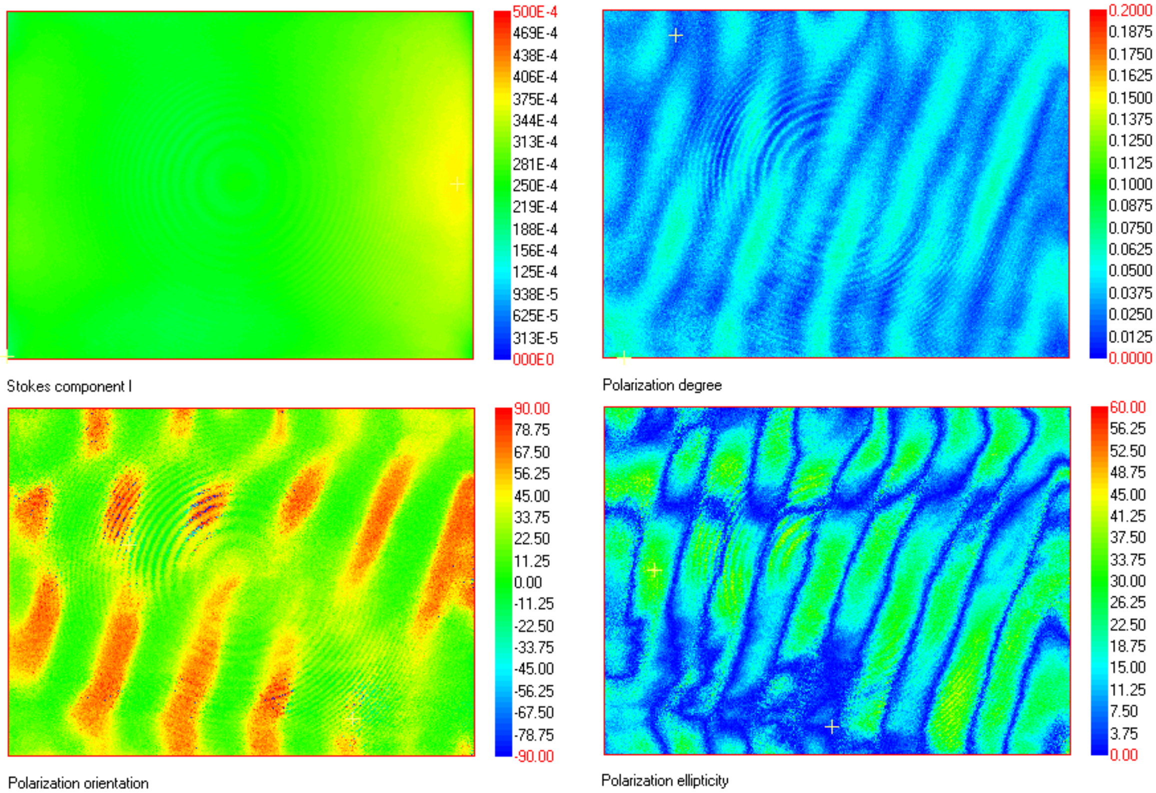


**Fig. 1: Imaging polarization of a LCD backlight with BEF film measured at 550nm**

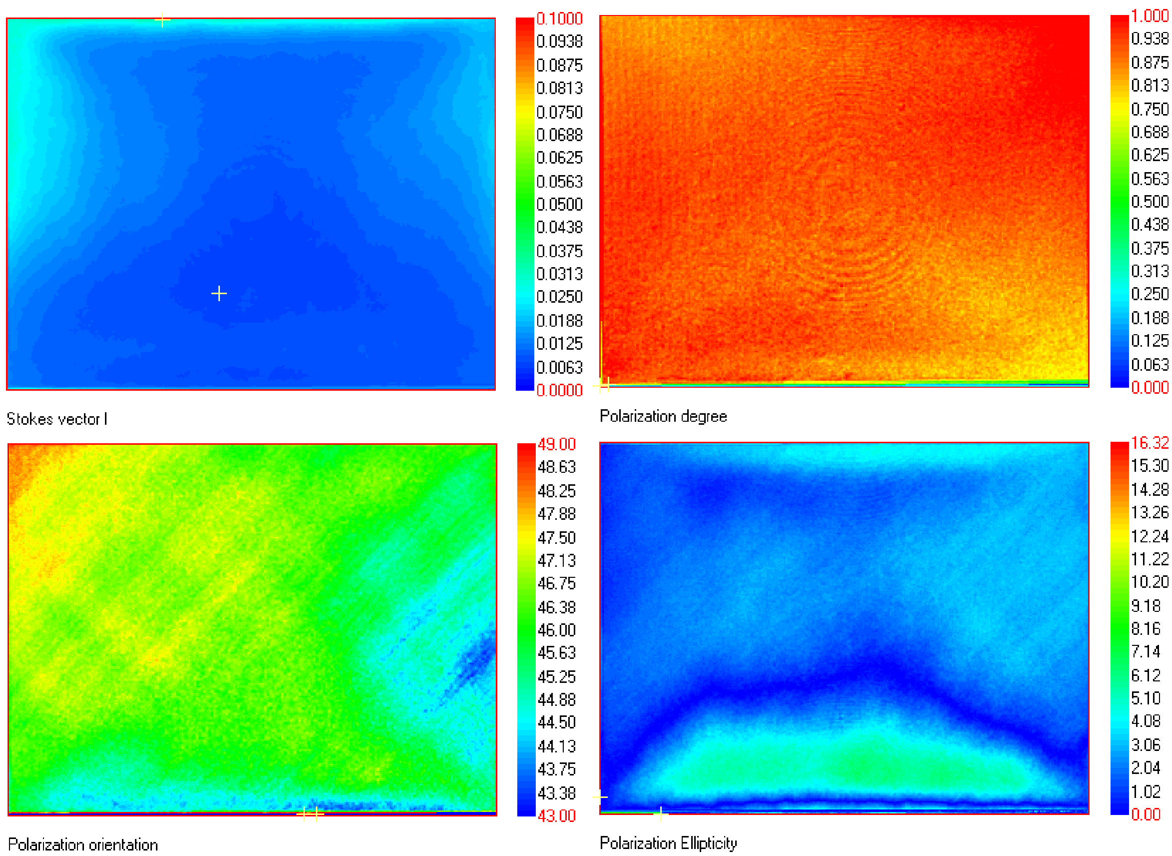


**Fig. 2: Imaging polarization of a LCD in OFF state measured at 550nm**

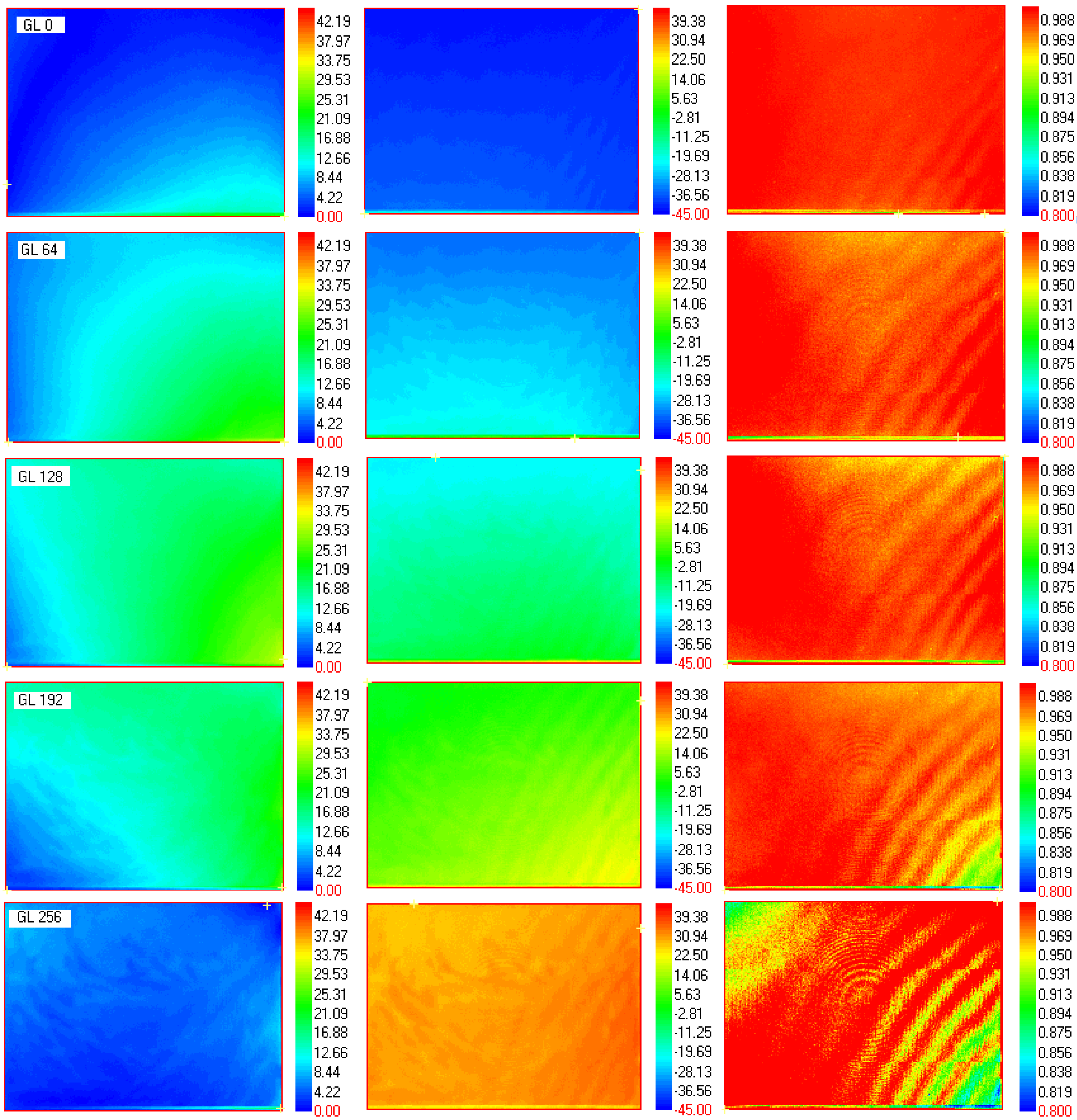


**Fig. 3: Polarization ellipticity (left), polarization orientation (center) and polarization degree (right) of a LCD without top polarizer and versus the grey level (0, 64, 128, 192 and 256).**