High Spatial Resolution Optical Characterization of LCDs and their Components

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Abstract

We present a new tool to measure precisely the emissive properties of displays at the pixel level with sub-micrometric spatial resolution. It is useful to check the technological defects and their impact on the emissive properties of the displays. Backlight films and transflective and reflective displays are measured.

1. Introduction

For many years, the emission properties of displays have been investigated following the observer point of view. Viewing angle specifications drive for example the appearance of the display depending on the angular position of the observer. This type of measurement is generally made on a small region of the display. Another important property is the spatial homogeneity that is a key parameter for large size display for TV application. This characteristic is generally evaluated using a video colorimeter and dedicated algorithms have been developed to detect MURA defects and quantify their visibility for the observer (1). All these techniques are useful to quantify display specifications and provide valuable information to the potential final customer but they are essentially a-posteriori diagnostics. When some defects are detected as punctual MURA defects for example, it is difficult to relate them to specific problems occurring during the fabrication process. Attempts have been made to characterize the impact of the films microstructure on their optical properties using optical microscopy for example (2) but precise quantification in terms of luminance or color is still needed. The recent improvement of liquid crystal simulation software makes now possible detailed simulation of liquid crystal cells and comparison to high spatial resolution measurements is needed (3).

The new tool presented in this paper can help to fill this gap because it is capable to extract information on the emissive properties of the displays at pixel level in the micrometric range. The measurement accuracy in terms of color and luminance is comparable to one of the best video colorimeters, but the observation can be performed inside the pixels and new diagnostics can be made by the process engineer. In the first part, the following paper presents the new system with its capacities and specifications. Some examples of measurements on brightness enhancement film and emissive and transflective displays are given in a second part.

2. Experimental

The micro video photometer MVP is an extension of the ELDIM MURATest which has proven through years its excellent capabilities for 2D luminance and color imaging. It is composed of a 1.5M 16bits Peltier cooled monochrome CCD camera, a set of 5 color filters adjusted specifically to each sensor, and a high quality imaging optics (cf. figure 1). In addition an optional RGB LED internal illumination can be proposed for measurement on reflective objects.

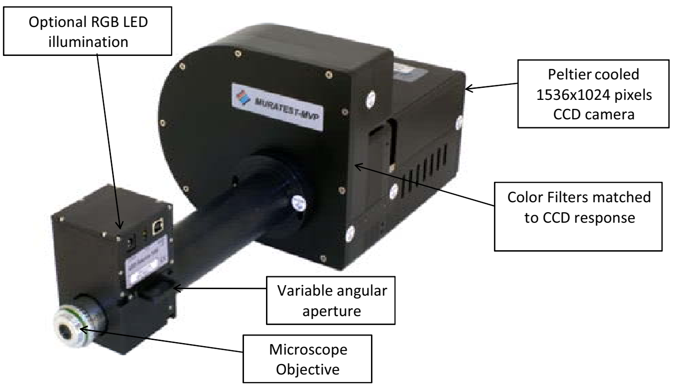


Fig. 1. ELDIM micro video photometer for high spatial resolution luminance & color mappings

One critical point is the quality of the optics and the spatial resolution. The system uses a dedicated projection eyepiece combined with a long working distance microscope objective. The optical design is telecentric on the sensor side to ensure fixed transmittance of the filters for any position in the imaging field. This feature is mandatory to maintain the same color accuracy everywhere in the field of view. The microscope objective used in the following paper has a magnification of x20 but other magnifications can be selected by the customer (from x5 to x40). With this magnification the field of view is 690x460µm and the working distance is 8.5mm. The angular aperture can be selected to ±45°, ±20° or ±10° with a manual diaphragm. The maximum spatial resolution is obtained for the larger angular aperture (see Table I), but the depth of field is also reduced to about 3µm. The spatial resolution has been verified using periodic metallic gratings deposited on glass substrates.

TABLE 1. Performances of the MVP with x20 microscope objective.

Angular aperture (°)	Numeric aperture	Spatial resolution (µm)	Depth of field (µm)
±10	0.16	2.0	29.5
±20	0.37	0.9	8.1
±45	0.71	0.5	3.2

3. Results and discussion

We present here after examples of measurements from different optical components and displays. We first show that the microstructures of films used in backlights can be observed and the impact on the optical properties evaluated. Then we present color and luminance measurements directly on the pixel structure for different LCD displays. A last example concerns the measurement of transflective displays where the emission and reflective properties can be evaluated with MVP.

a) Brightness enhancement film for backlighting

Brightness Enhancement Films (BEF) are widely used in the design and manufacture of LCD screens and large-screen TVs. They are generally used to provide maximum brightness towards the on-axis viewer. The BEF is a micro-replicated prism array as schematically represented in figure 3. Near normal incidence rays are reflected back for backlight recycling. Measurement of the angular average performances can be made easily using a viewing angle instrument like EZContrast ELDIM system. One example of such a measurement is reported in the right part of figure 4. The measurement is made with white light (CCFL emission type) and normalized to the same measurement without film. We see that along the grooves the reflection coefficient is reduced when it is increased above 1 in the perpendicular direction and at high angles. This structure is well known and can be modeled using ray tracing software.

Using MVP it is possible to check directly the microstructure of the film and the impact on the optical properties. As shown in the left part of figure 4, the prismatic structure of the BEF is perfectly seen with its small distortions along the grooves. The impact of the top and bottom angles of the prisms is also clearly seen on the light transmittance. Top angle is in particular not completely efficient to reflect back the near normal incidence light because of its rounded shape. Thanks to MVP, the impact in terms of transmittance can be quantified precisely. Also the capacity to make different measurement with variable angular aperture is helpful to check the angular performance as shown also in figure 4.

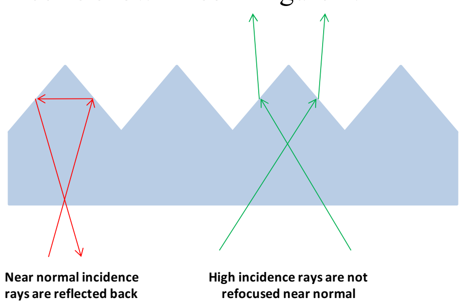


Fig. 3. ***Principle of brightness enhancement film.***

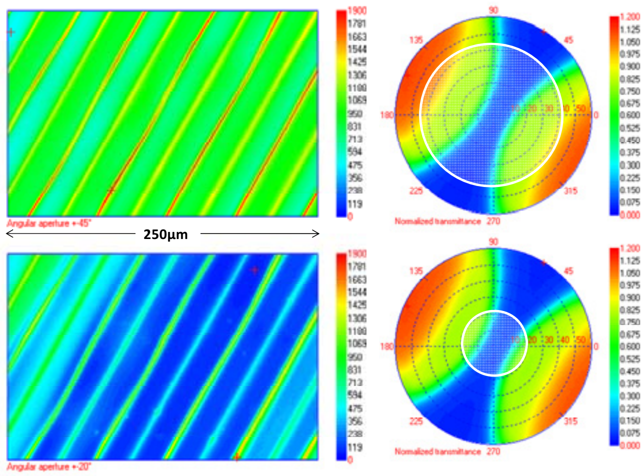
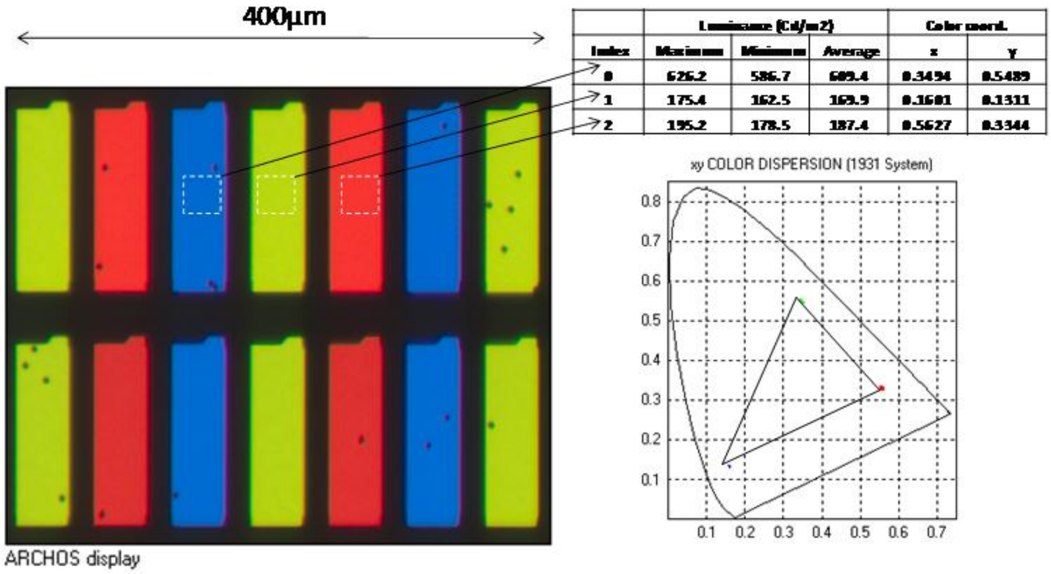


Fig. 4. MVP and EZContrast measurements on brightness enhancement film: large angular aperture (top) and limited angular aperture (bottom).



	Luminance (Cd/m2)			Color coord.	
Index	Maximum	Minimum	Average	x	y
0	626.2	586.7	609.4	0.3494	0.5489
1	175.4	162.5	169.9	0.1601	0.1311
2	195.2	178.5	187.4	0.5627	0.3344

Fig. 5. Color measurement on small LCD display

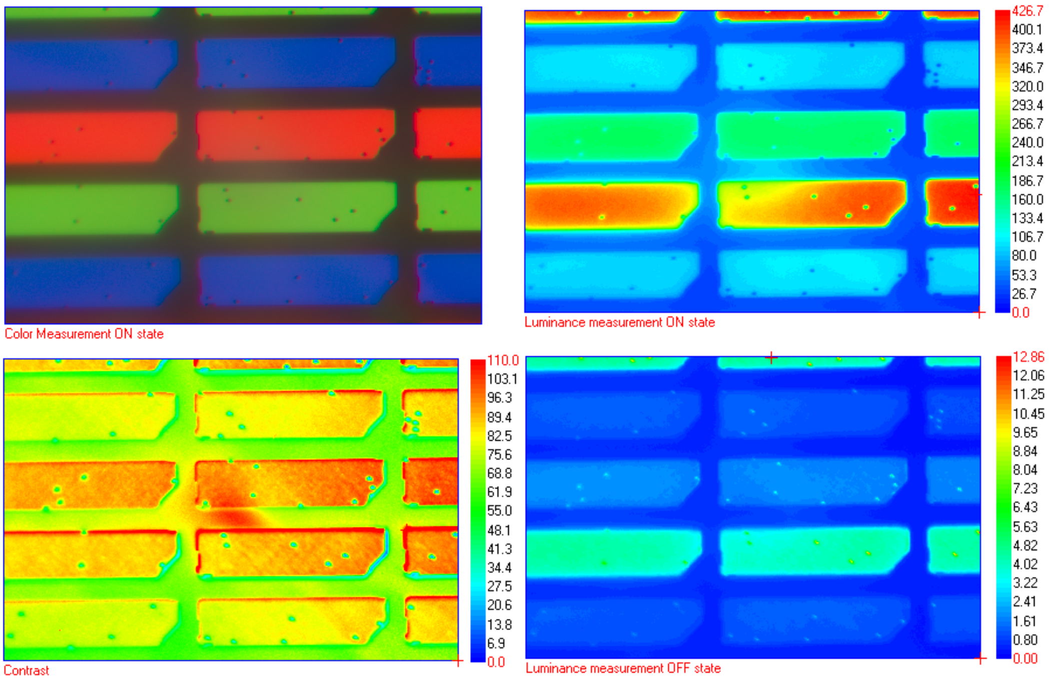


Fig. 6. Color & luminance measurement on 15' LCD display

b) Emissive LCD displays

Luminance and color properties of the LCD displays can be checked directly inside the pixel. In particular the homogeneity of the emissive properties on the surface of the pixel can be useful to estimate the quality of a fabrication process. We give here after two examples of measurements on two types of LCDs. The first one is a small LCD of an ARCHOS system (cf. figure 5). We see easily all the details of the pixel structure of the screen and the color homogeneity can be checked at pixel level. Random location of the spacers is also observed. Another example concerns a 15' LCD for PC (cf. figure 6). Here a quite large luminance variation can be detected inside the pixels both for ON state and OFF state. The contrast is limited by the spacers which act as light traps for ON state and light leakage for OFF state. The limited contrast of blue pixels is also pointed out.

c) Transflective displays

Transflective displays incorporate elements of both transmissive and reflective displays. These screens use backlighting to illuminate display indoors but also reflective surface to produce readable images outdoors. The pixels of the traditional transflective LCDs are separated into emissive and reflective sub-pixels (cf. figure 7). The emissive sub-pixels are transmitting the backlight illumination and the reflective sub-pixels are reflecting light from the environment. In the case studied here 1/3 of the sub pixels are emissive and 2/3 are reflective (cf. figure 7).

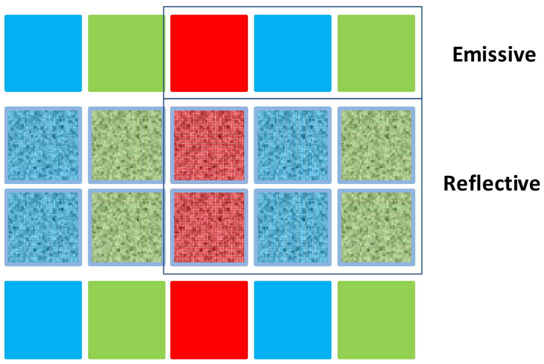


Fig. 7. Structure of a transflective Ipod display: 1/3 of the pixels are emissive and 2/3 reflective.

We have studied independently the two working modes. A color measurement of the emissive mode is reported in figure 8. We see that light diffusion inside the reflective part plays some role in the emissive properties. In addition the contrast on the blue pixels is really smaller than for green and red. The reflective properties are checked with white internal illumination (A illuminant type). Results are reported in figure 9. The morphology of the reflective mirror is clearly seen with the area where the color filter has been suppressed to increase the reflection factor. The homogeneity of the luminance and color can be estimated within the pixels.

4. Summary

We have presented our new micro video photometer that can measure precisely the luminance and color properties of any kind of display with real sub micron spatial resolution. Special care has been taken to get excellent color accuracy even at this resolution. The system can work at different angular aperture which can be useful to check emissive properties as shown in the case of brightness enhancement films. Internal LED illumination is also available to check reflective properties at the same scale.

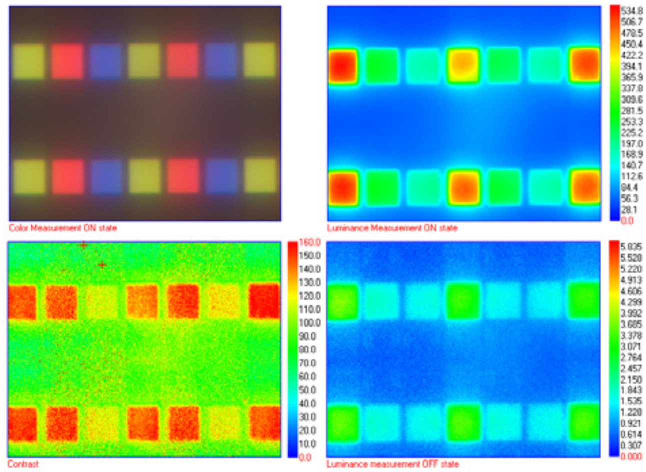


Fig. 8. Luminance and color measurement of a transflective Ipod display in emissive mode

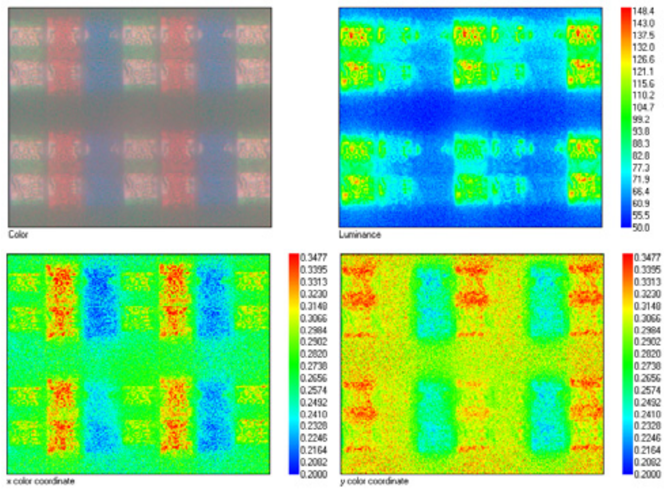


Fig. 9. Luminance and color measurement of a transflective Ipod display in reflective mode

5. References

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