Requirements in terms of measurement area for viewing angle optical characterization of liquid crystal displays

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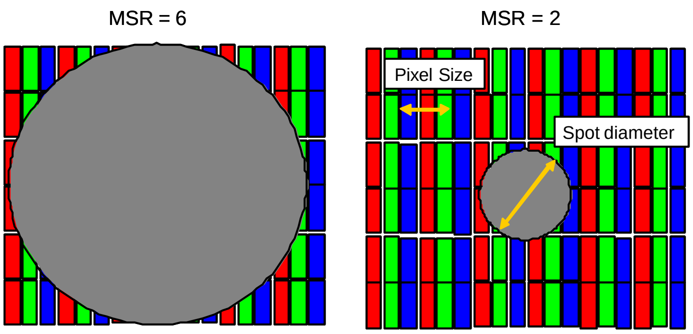
Abstract

In this paper, we present a model to calculate the influence of the measurement spot diameter MSD on the viewing angle measurements using a conoscopic instrument. This model is verified experimentally using an EZContrast instrument and the requirements for next generation of displays are presented. We show that last generation of EZContrast XL88W and L80W allowing measurement spot diameter up to 6mm can fulfill the requirements for all the FPD generations up to 80 inches diagonal.

1. Introduction

Accurate characterization of the optical emission of displays requires the integration of the measurement on a given number of pixels. This problem is true for all type of measurements and has been examined in details in terms of angle of view for a luminance meter in the VESA FPDM document (A102-1A) (1). Since the introduction of Fourier optics viewing angle measurement system by Eldim in 1993 (2), this type of instrument is now widely used for precise characterization of FPD optical emission. Nevertheless, with the continuous increase of display size, the pixel size is also increasing and requirements on Fourier optics instruments become more and more critical. This problem is schematically represented in figure 1. If the pixel size is of the order of the measurement spot diameter, the result of the measurement is expected to depend drastically on the spot position. One can define the MSR parameter as the ratio of the measurement spot diameter MSR to the pixel size (cf. figure 1). The purpose of the present paper is to define the minimum value of the MSR parameter that yields angle of view measurements quasi independent of the spot position. We first present a simple geometric model to simulate this effect and we compare it to real measurements done with an EZContrast system. Finally, we draw general conclusions about the requirements of Fourier optics systems for the future FPD generations.



$$MSR = \frac{SpotDiameter}{PixelSize}$$

Figure 1: Definition of the MSR.

2. Theoretical model

A simplified geometrical model is proposed to predict the influence of the MSR on the measurement accuracy. A vertically stripped color (RGB) display is used as display model. The black matrix width influence is neglected. A possible antiglare coating is also taken into account through a Proximity Contrast Term (PCT). Under these conditions the display signature S^d of a single color can be approximated as schematically reported in figure 2. It is equal to 1 on 1/3 of the pixel size and equal to 1/PCT otherwise. The spot signature S^s is 1 in the MSD and 0 outside. In order to evaluate the measured signal, both signatures are convoluted and the result normalized to a 1/3 ratio that would be observed for an infinite spot diameter. It is clear from figures 1 & 2 that an intensity modulation will be observed when moving the measurement spot along the horizontal direction. The intensity I measured by the instrument is given by:

$$I = \frac{100}{p\left(\frac{MSR}{2}\right)^2\left(\frac{1}{3}+\frac{2}{3PCT}\right)} \int_{surface} S^s \otimes S^d \, ds$$

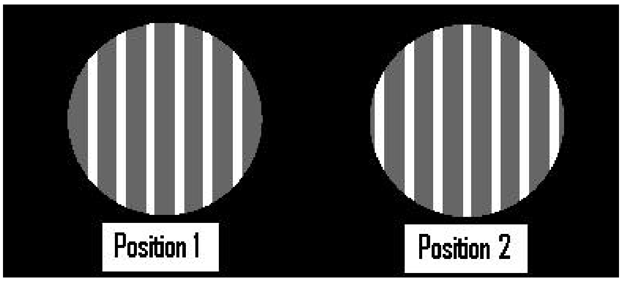


Figure 2: Schematic diagram of the geometrical model.

3. Experimental results

We have measured a small FPD with a pixel size of 280µm using an EZLite instrument and three different spot sizes (0.30, 1 & 2 mm). The panel is fixed and the measurement head is moved along the panel with a 30µm step. Each luminance measurement is integrated on ±5° along the normal direction where the influence of the MSR is maximized. The normalized measured intensities versus the spot position for the three spot sizes are reported in figure 3. The position is not absolute but only relative. One can see that the spot size has a strong influence on the result with periodic variation produced by the display structure which becomes much larger when the spot size is reduced. In the case of figure 3, the MSR vary from 1.07 to 7.14. It is clear that the measurement conditions are not acceptable except for the 2mm spot size where the MSR parameter is higher than 7.

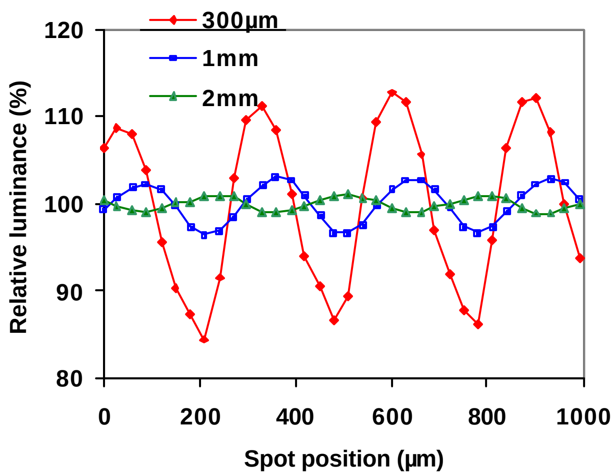


Figure 3: Experimental normalized intensity versus spot position for three different measurement spot sizes.

We have simulated these data using the model describe above. An example of simulation is reported in figure 4 versus the spot relative position for the 2mm measurement spot. In figure 5, the standard deviation of the intensity versus SMR is also reported with the corresponding data of figure 3. We can see that the model agree quite well for the measurements made with the three spot sizes. The conclusion is that for a **measurement accuracy better than ±1%, a SMR above 6 is necessary** otherwise the average of the measurement spot is not sufficient to avoid fluctuations.

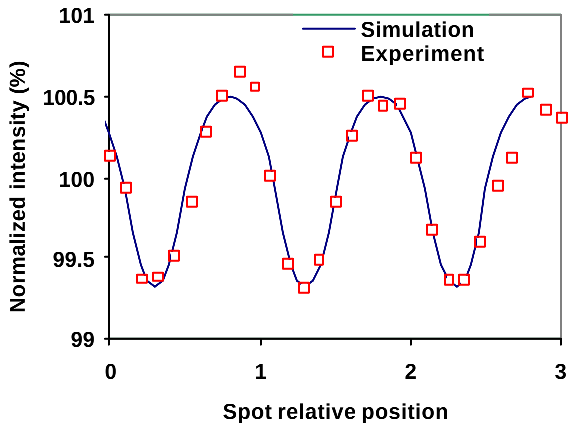


Figure 4: Experimental and simulated normalized intensity versus spot relative position for a SMR of 7.1

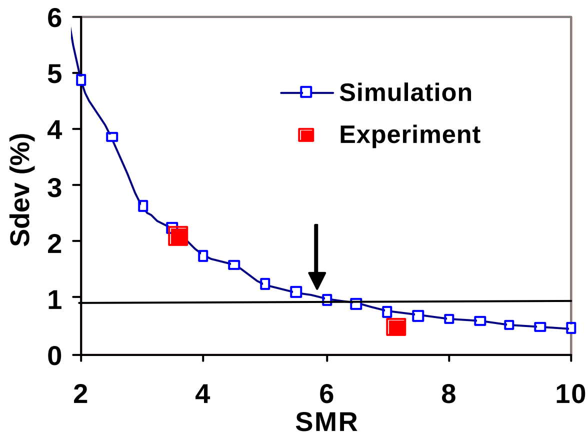


Figure 5: Standard deviation on the intensity versus spot ratio and measurement values for the two spot size 1 and 2mm.

4. Working distance and spot size

Even if an angle of view measurement system is generally a quite complex combination of lenses, the first front lens dimension obey to very simple geometrical considerations (cf. figure 6). The front lens diameter depends on the maximum angle achievable by the instrument and on the working distance. A working distance as high as possible is generally preferable for practical considerations. Nevertheless for large angle of view instruments the requirements in terms of lens diameter become critical. One can see in figure 7 that a system working up to 80° can be made with a working distance of 5mm quite easily. On the contrary, if the maximum angle is pushed up to 88° a working distance of 1mm gives already quite large front lens (60mm).

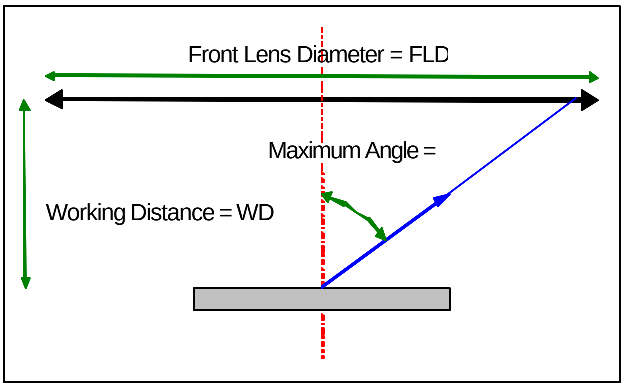


Figure 6: Geometry of the Fourier optics.

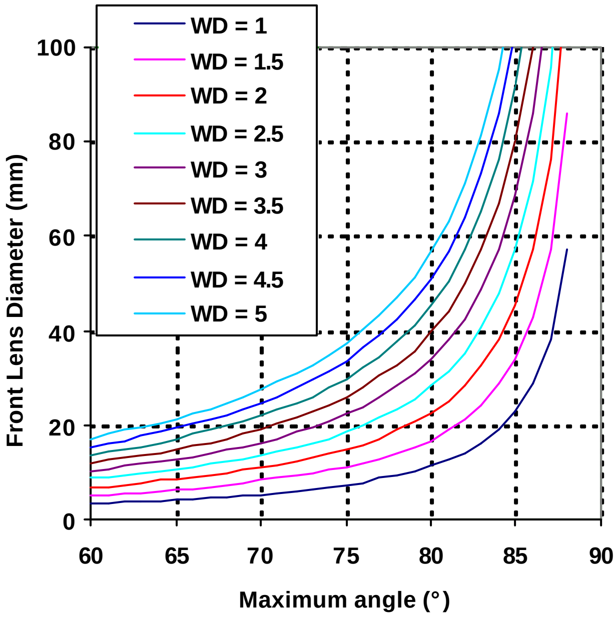


Figure 7: Front lens di ameter versus maximum angle and working distance.

A schematic drawing of the angle of view system is reported in figure 8. All the light beams coming from the sample surface at an angle ? with the normal of the surface are collected and focused on what is called the Fourier plane (cf. figure 8). Each light beam is received at the same azimuth and at a position x = F tan(?). The Fourier optics is generally an achromatic combination of different lenses (6 to 9) that allows measurement in the visible range. The first lens diameter obeys to the considerations reported above. In the practical Optical Fourier Transform (OFT) instrument, the Fourier plane is imaged on the CCD sensor with an additional relay lens (cf. figure 8). The spot size measurement is represented by an iris which is the complex conjugate of the surface of the sample and located somewhere before the imaging sensor (cf. figure 8). It is in fact controlled independently from the angular aperture (ELDIM patent [3-4]).

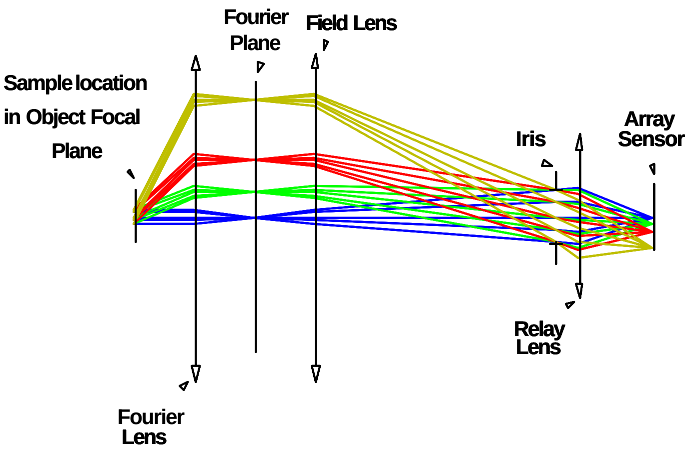
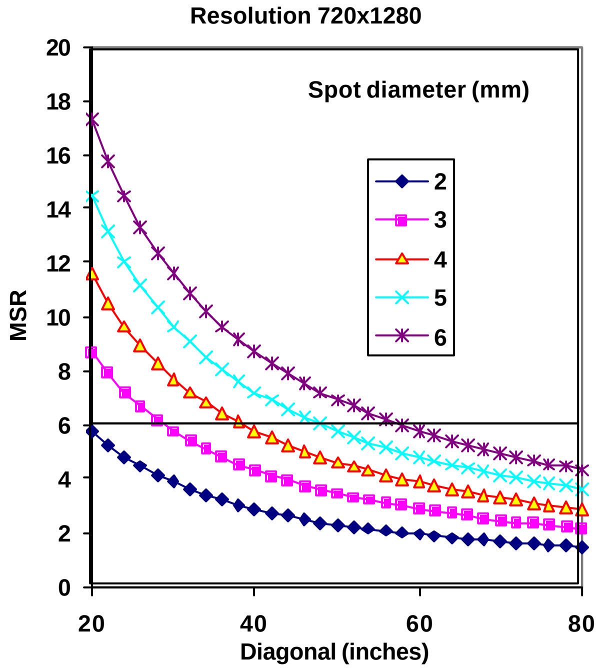


Figure 8: Principle of the angle of view system.

5 Requirements for FPD characterization

Using the geometrical model presented above that has been confirmed experimentally we can predict which MSD will be necessary depending on the display diagonal and resolution. Some values are reported in figure 9 for 16/9 format screens and two screen resolutions. We can see that a 2mm MSD can only fulfill the requirements for panels up to 25-30inches. On the contrary a 6mm MSD is likely to measure accurately large size panel up to 60inches with 720x1280 resolutions or 80inches panel with 1080x1920 resolutions.



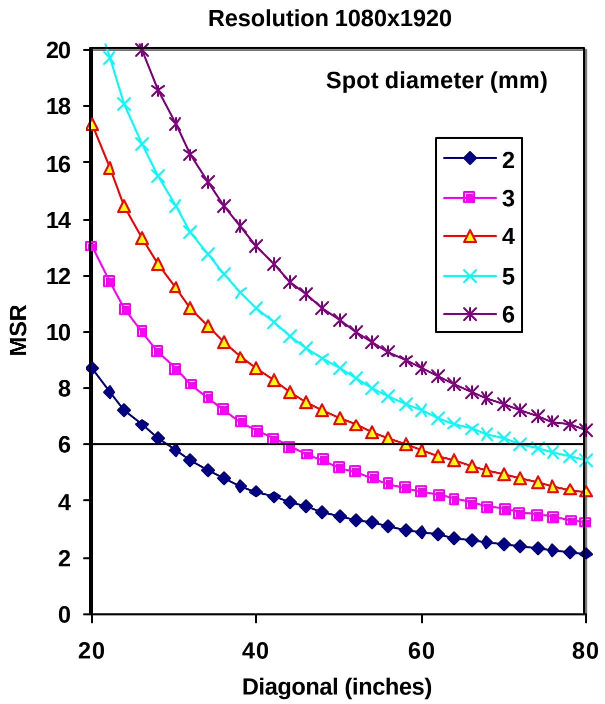


Figure 9: MSR versus display diagonal for different spot size diameters: (a) for 720x1280 resolution and (b) or 1080x1920 resolution.

5. Conclusions

The influence of the measurement spot diameter MSD on viewing angle measurements has been examined in details both experimentally and theoretically using a conoscopic instrument. We have shown that a measurement spot diameter of almost 6mm is needed to fulfill all the requirements for FPD measurements up to 80 inches diagonal.

The main characteristics of the last generation of viewing angle systems from ELDIM are summarized in Table I. The maximum angle of view is 88° and a MSR up to 6mm is proposed with the EZContrast XL88W system. The working distance is 1mm. If a 80° angular aperture is sufficient, the MSR can also be 6mm with a larger working distance of 2.5mm.

ELDIM System	Maximum angle (deg)	Spot diameter (mm)	Working distance (mm)
EZContrast LI80	80°	2	1.2
EZContrast L80W	80°	6	2.5
EZContrast XL88	88°	2	1
EZContrast XL88W	88°	6	1

Table I: Specifications of the last generation of ELDIM viewing angle systems

6. References

[1] “Flat panel display measurement standard”, version 2.0, p.197, June 1, 2001.

[2] “Fast contrast vs. viewing angle measurements for LCDs”, T. Leroux, Eurodisplay’93 Proceedings, 447, 1993

[3] “Dispositif pour determiner le contraste d’un écran d’affichage en fonction de la direction d’observation», Patent FR2613830, April 8th 1987

[4] «Device for determining the contrast of a display screen as a function of the observation direction”, Patent US270863, September 26th 1989