Novel Technology for View Angle Performance Measurement

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Abstract

Several different techniques currently exist for measuring display view angle performance. These include conoscopes, goniometric systems, and, most recently introduced to the market, instruments based on Imaging Sphere technology. This paper will compare measurement accuracy and speed of these various methodologies with different FPD types and even 3-D displays.

1. Objectives and Background

View angle performance is an important metric of display quality that is measured of a variety of display types. Currently, several different technologies are available for measuring view angle performance. Specifically, these include conoscopes, and goniometric systems employing both spot spectroradiometers and imaging colorimeters. Recently, new instrumentation for view angle performance measurement based on imaging sphere technology was introduced to the market.

No comprehensive survey of view angle performance measurement devices has been conducted before this. This work provides a clear comparison of the available instrumentation in terms of accuracy as well as practical factors, such as speed and ease of use. The results presented here will give display developers and manufacturers clear guidance on how current metrology solutions can best be implemented in their own application.

2. Measuring Equipment

The traditional method for measuring view angle performance of a FPD incorporates a dual axis **goniometer** and a spot **spectroradiometer**. This methodology is still considered the most accurate method of measurement due to the superior accuracy of a spectroradiometer as compared to a colorimeter and because it does not suffer from stray light issues. It should also be noted however that tilting the panel relative the spot meter distorts the area on the display being sampled into an ellipse, which can adversely affect the accuracy of the measurement, especially if the display has some spatial non-uniformity. The Goniometer used for our measurements was a custom built 2-axis machine outfitted with a Topcon SR-3 spectroradiometer with a 1 degree field-of-view and located at 50cm from the device under test.

The **conoscope**[1] is based on a imaging colorimeter and Fourier Optics that transforms the angular distribution of light emitted from a small spot on the display surface onto a CCD such that each pixel corresponds to a different emission angle. This enables brightness and color at multiple angles to be measured simultaneously. Specialized software converts the spatial information on the CCD back into angular information in the FPD frame of reference. The conoscope used for the measurements was an Eldim EZ contrast L80 that has a 2mm spot size and measures up to 80 degrees from normal.

The **Imaging Sphere**[2] is an optical system that can acquire the entire output distribution (over all view angles) from one region of interest on a display in a single measurement. The optical path of the Imaging Sphere includes a coated, diffuse, low reflectance hemisphere, a curved secondary mirror and an imaging colorimeter. In operation, the display under test is positioned at the aperture of the hemispherical chamber. Light from the display strikes the inner surface of the coated hemisphere, which is essentially a curved screen. The convex mirror at the base of the chamber acts as a "fish-eye lens" enabling the camera to image the entire inner surface of the hemisphere in a single exposure. This image contains all the information necessary to reconstruct the angular intensity profile of the illumination over nearly 2π steradians. The angular resolution of the instrument is determined by the camera's image sensor, and is typically <0.5°. The Imaging Sphere was a Radiant Imaging IS-SA, outfitted with a 1024x1024 resolution CCD camera. It measures up to 85 degrees from normal.

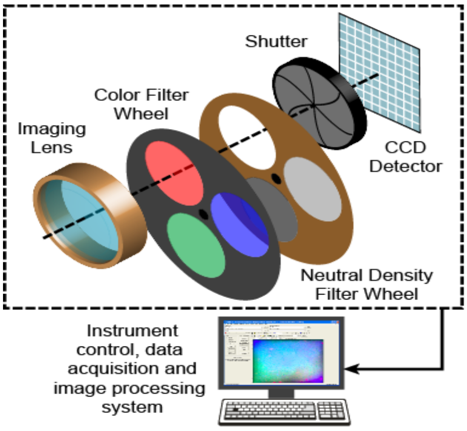

Fig.1. Main elements of an imaging colorimeter

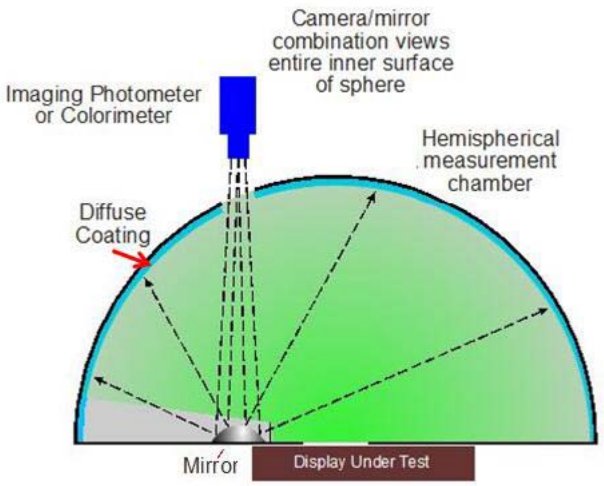

Fig. 2. Schematic of Imaging Sphere

3. Description of Displays Tested

View angle measurements of several display types, including a plasma monitor, a 17" TN LCD Monitor, and a 32" wide viewing angle LCD TV, and 3-D displays were performed using each of the instrument types just described. Parameters such as total measurement speed, luminance and color accuracy, and contrast ratio were obtained for each instrument and display type combination. This paper presents the detailed results of all these measurements.

4. Results

Measurement time:

The goniometer setup measured red, green, blue, and white at each view angle, so the times given below are for the complete run only. The measurement times recorded for 32" VA Mode TV were very similar and so not included here.

<u>17 TN Monitor, 270 cd/m^2 white, 0.28 cd/m^2 black</u>

	Goniometer	**Conoscope**	**Imaging Sphere**
Red		55 sec	20 sec
Green		45 sec	20 sec
Blue		50 sec	20 sec
White		50 sec	20 sec
Total (RGBW)	**60 min**	**3.3 min**	**1.3 min**
Black	n/a	3 min	10 min

Notes: The Conoscope adjusts exposure automatically for each measurement and so this time was included in the above table. The Imaging Sphere exposure time was set in advance, and therefore was not included in the measurement time.

Measurement resolution:

The goniometer measurements were done at 5 degree steps from -80 to +80 degree along the horizontal and vertical axis only. Higher resolution (smaller step size) is possible and additional off axis measurements were possible, but would have taken much longer to complete.

The Conoscope has a resolution of .5 degrees, and the Imaging Sphere had a resolution of .5 degrees, but because 4x4 binning was used, the resolution was reduced to .7 degrees.

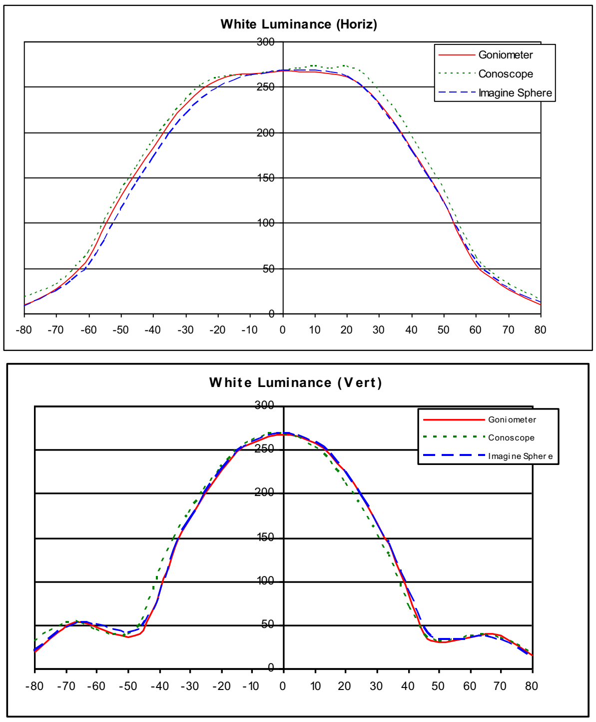

Fig.3. 17" TN Monitor horizontal and vertical luminance cross sections

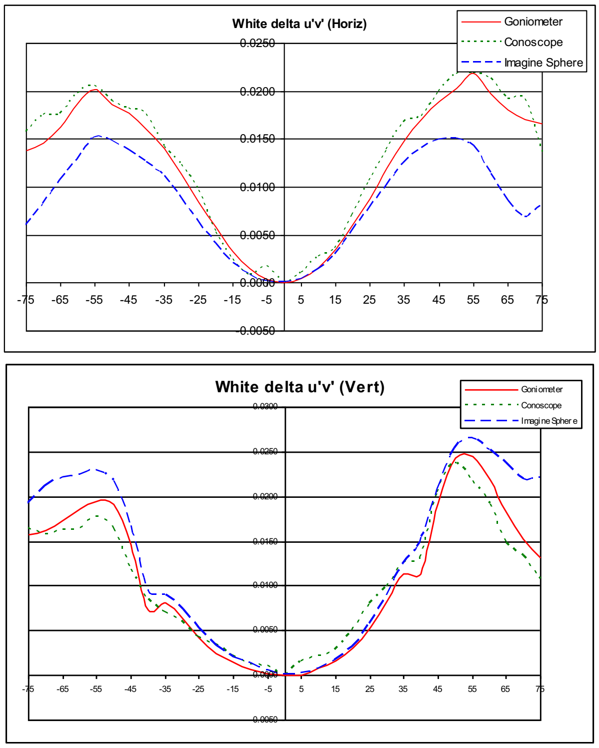

Fig.4. Comparisons of color shift (delta u'v') for17" TN Monitor

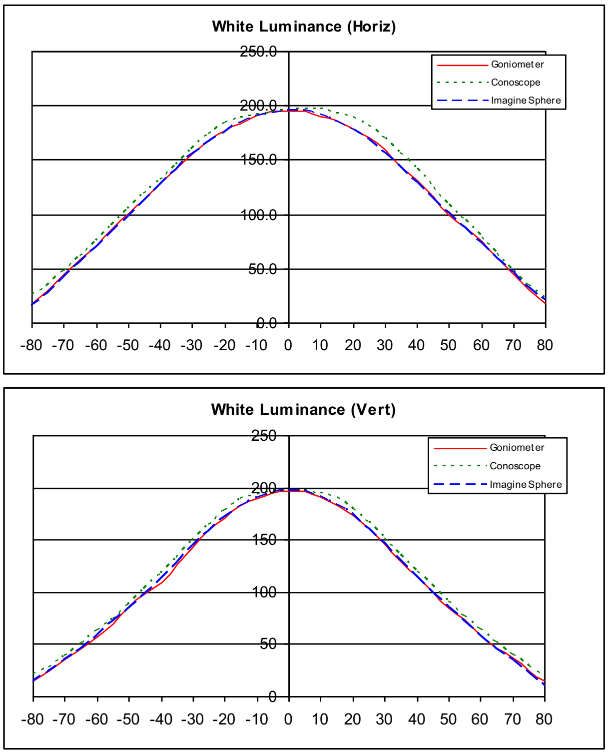

Fig.3. 32 inch SPVA TV horizontal and vertical luminance cross sections

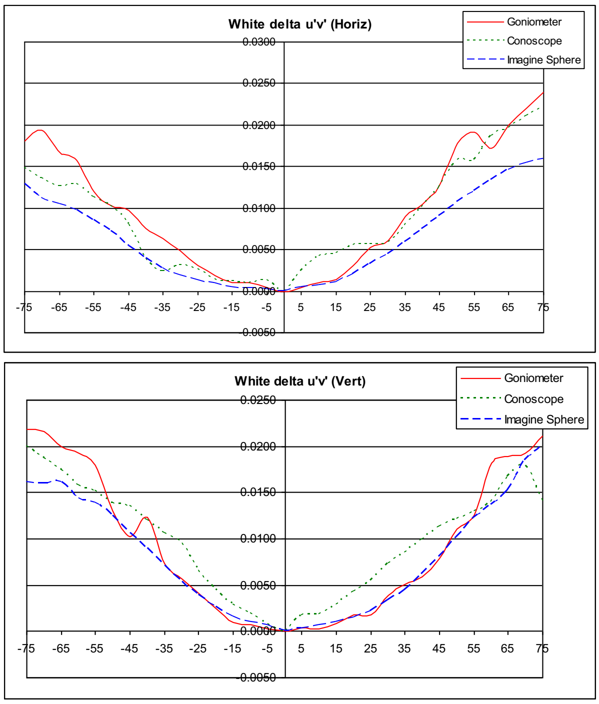

Fig.5. Comparisons of color shift (delta u'v') for 32 inch VA mode TV

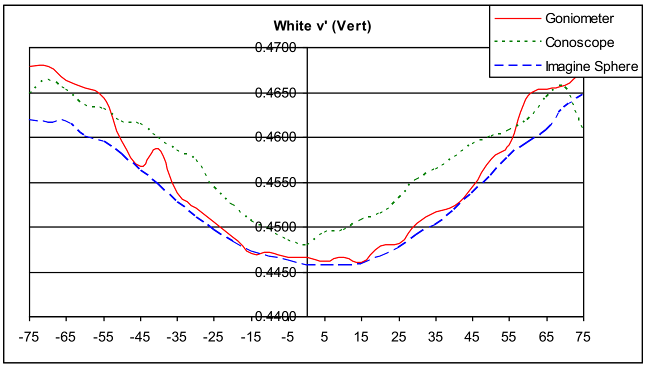

Fig. 6. Comparison of color vs. angle

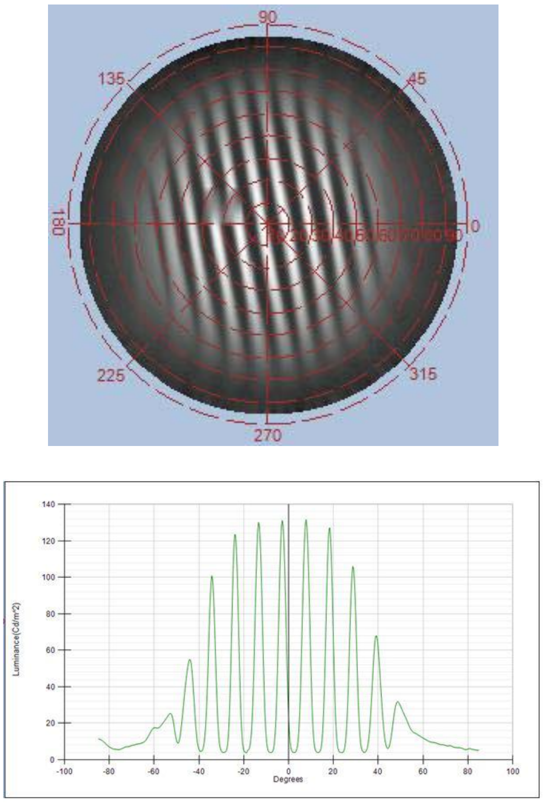

Fig. 7. Measurement of 42" 3D display with Imaging Sphere – View 5 of 9

5. 3D Display measurement

We had hoped to do a comparison of 3D display measurements, however because the working distance requirement of the conoscope was too short to enable focusing on the display surface, we were only able to perform measurements with the Imaging Sphere. A typical result is illustrated in Fig. 7.

6. Conclusions

Using a goniometric measurement with a spectro-radiometer as a reference for measuring view angle performance, we compared the performance of Imaging Spheres and Conoscopes. The Imaging Sphere clearly correlates with the goniometric measurements in luminance more closely than the conoscope. For absolute color accuracy and color shift, both methods exhibited similar variations, with no clear advantage. The following table summarizes the comparison

RMSE Analysis - White Measurements (17" TN)

Cross-section	Horizontal		Vertical	
	Cono-scope	Imaging Sphere	Cono-scope	Imaging Sphere
L(normalized)	7.96	6.85	7.68	2.64
u'	0.003	0.003	0.002	0.002
v'	0.003	0.004	0.002	0.002

RMSE Analysis - White Measurements (32" VA)

Cross-section	Horizontal		Vertical	
	Cono-scope	Imaging Sphere	Cono-scope	Imaging Sphere
L(normalized)	5.92	2.33	4.44	1.65
u'	0.003	0.002	0.002	0.003
v'	0.002	0.004	0.004	0.003

Both the Conoscope and Imaging Sphere were much faster than the goniometric method. The Imaging Sphere was a faster in measuring RGB and White, while the Conoscope was faster when measuring black.

We were unable to adequately compare 3D measurements because the working distance requirement of the conoscope was too short to enable focusing on the display surface.

7. References

1. T. Leroux, C. Rossignol, "*Fast analysis of LCD contrast and color coordinates versus viewing angle*", SID Proceedings, 73, 1995
2. Rykowski, Kreysar, and Wadman, "*The Use of an Imaging Sphere for High-Throughput Measurements of Display Performance – Technical Challenges and Mathematical Solutions*", SID Symposium Digest of Technical Papers, June 2006, pp. 101-104.