

Low Luminance Display Testing



01 \\ LumiTop – The reference for production display testing

Instrument Systems engineered the LumiTop imaging colorimeters for display production testing. As the industry's fastest, most reliable and most accurate imaging colorimeter, LumiTop has become the reference for high performance display production testing.

The unique combination of a high-resolution camera, a fast photometer and an extremely accurate spectroradiometer of our CAS series renders LumiTop an exceptionally powerful tool for display quality assurance and solves even the most demanding optical testing challenges, also under low luminance conditions.



LumiTop test system comprises an imaging colorimeter, a high-end spectroradiometer and a photodiode.

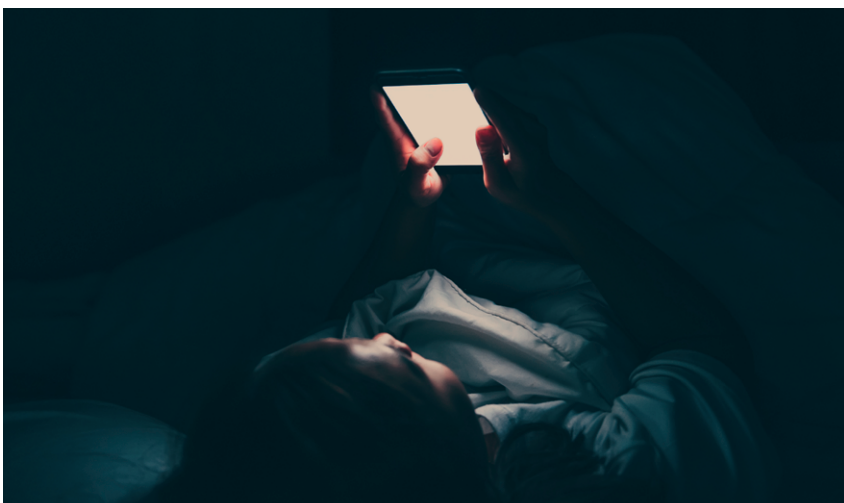
02 \\ Low luminance – important for comfortable display viewing

The human eye can easily adapt to low and bright light conditions by two different “sensors” with different spectral sensitivities on the retina:

rod cells for low light (green-blue peak sensitivity) and cone cells for high brightness (broad sensitivity).

Therefore, for comfortable viewing, modern displays can adapt luminance and color according to the different lighting conditions. OLED and other LED based displays can dim the luminance to zero and enable low luminance levels to relieve the spectator's eyes under low light conditions. Smartphone manufacturers for example use specific luminance and color modes in the dark to avoid dazzling and to maintain a pleasant viewing experience.

Consequently, display luminance and color have to be accurately tested under low luminance conditions to assure an excellent user experience.



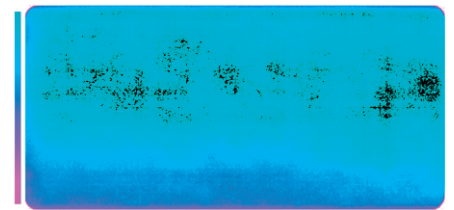
03 \\ Accurate display testing down to 1 mcd/m²

Studies¹⁾ show that a display in dark environments must emit at least luminance levels of ~20 cd/m² to be comfortable to read, and higher luminance (~40 cd/m²) if displayed content, such as maps, requires distinguishing between several brightness levels.

In order to guarantee sufficient contrast for display content at low light conditions and uniformity, low luminance tests are typically performed at much lower luminance in the range from 0.001 cd/m² to 0.1 cd/m².

Often displays are not very uniform at low luminances. Therefore, it is important to have measurement devices that maintain a high level accuracy and instrumental precision to produce meaningful test results. LumiTop is a device which is able to measure at these conditions with good signal to noise ratios and proves its precision calibration by low luminance standard light sources, which are traceable to national metrological standards.

The figure shows a typical low luminance measurement of a display at 0.1 cd/m². Accuracy and repeatability of the measurement is a critical requirement for subsequent uniformity analysis of luminance and color.



A typical low luminance measurement of a smartphone display. Luminance levels vary by an order of magnitude from 0.01 cd/m² to 0.1 cd/m².

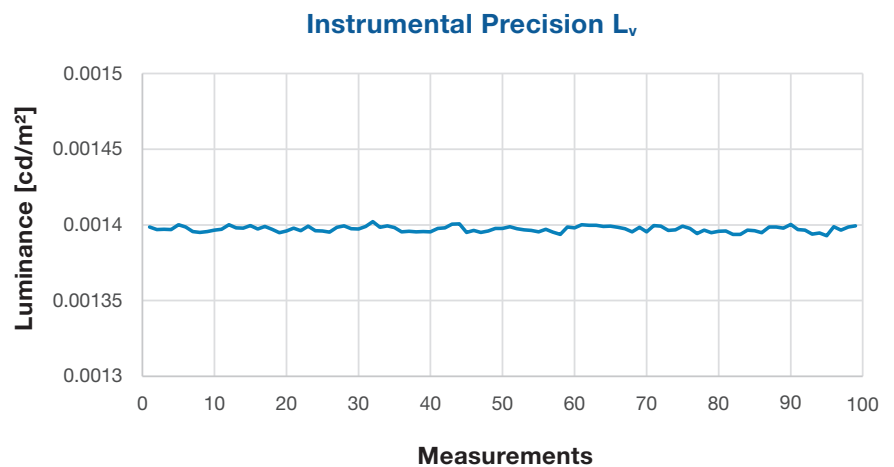
04 \\ Production takt times & precision

The fastest way to measure a display is a camera. The most accurate way is a spectroradiometer. LumiTop systems use both devices simultaneously and meet production takt times even at low luminance. For example, LumiTop 4000 measures a display at 0.1 cd/m² in just 1 s, featuring the spectral accuracy of a spectroradiometer and the speed of a spectrally enhanced CMOS camera. LumiTop X30 will only need 3 s for measuring a 0.002 cd/m² display at a signal-to-noise ratio of 10:1.

The figure shows the superior instrumental precision of the LumiTop X30 at very low luminance with a mean value of ~0.0014 cd/m² measured with a stabilized standard white light source.

The measurement values fluctuate only by ±0.0004 mcd/m² which results in an instrumental precision of 0.3 %.

This is far below human perception and enables accurate display testing and hence a pleasant low light display experience.

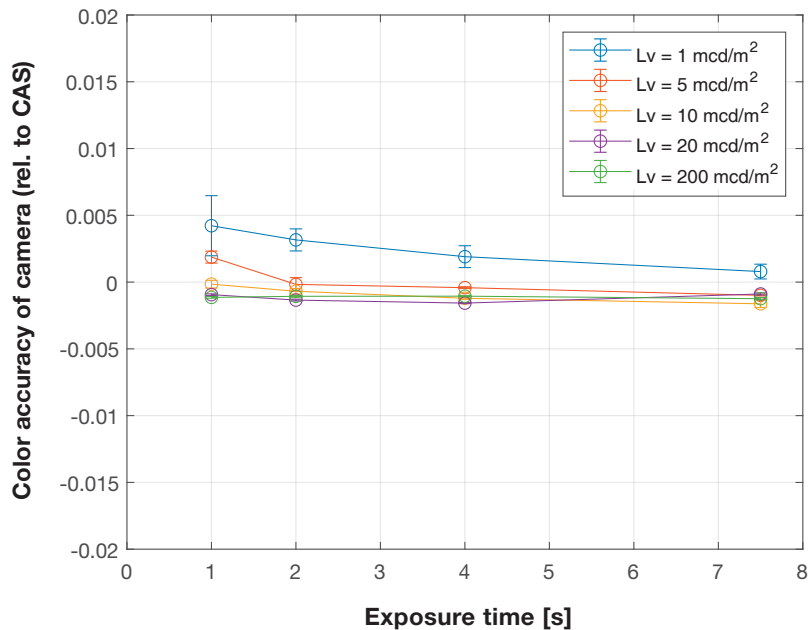


The figure shows data of the LumiTop X30 instrumental precision at very low luminance.

¹⁾ R. Mantiuk, A. G. Rempel, and W. Heidrich, "Display considerations for night and low-illumination viewing" in Proceedings of the 6th Symposium on Applied Perception in Graphics and Visualization (ACM, 2009), pp. 53–58.

05 \\ High pass/fail certainty with live calibration

At low luminances displays can have relatively large luminance and color fluctuations that result in large DUT-to-DUT variations, which can make “golden sample” calibrations fail. This can lead to rejection of good displays or acceptance of bad displays in the production line. Both is undesirable and costs money. LumiTop provides a hybrid measurement mode, where calibration is checked and if necessary adapted for every DUT in the production line. This is possible since the LumiTop system uses a highly accurate spectroradiometer to measure absolute and traceable luminance and chromaticity for every DUT. This way calibration is always up to date and highly accurate for each tested DUT. This improves certainty of pass/fail decisions and increases production yield.



The figure shows the color accuracy of the LumiTop X30 camera relative to the measured values of the CAS at different low luminance conditions.

06 \\ LumiTop specifications

All LumiTop devices with CAS 140D offer remarkable instrumental precision of 0.03% in luminance and ± 0.0001 in color (Table 1). The shown lower luminance limits are specified at 10 s exposure time and a signal-to-noise ratio of 10. The next generation LumiTop X series offer an improved dynamic range and enable precise low luminance measurements down to 0.001 cd/m² while keeping the good instrumental precision and signal-to-noise ratio.

Camera specification at low luminance conditions

LumiTop model	LumiTop 4000	LumiTop X20	LumiTop X30
Minimum luminance for a signal-to-noise ratio of 10:1 at 10 s exposure time			
Minimum luminance	0.02 cd/m ²	0.002 cd/m ²	0.001 cd/m ²
Instrumental precision at low luminance (2σ of repeated measurements)			
Luminance @ 100 cd/m ²	0.03 %	0.03 %	0.03 %
Color @ 100 cd/m ²	± 0.0001	± 0.0001	± 0.0001
Luminance @ 0.02 cd/m ²	0.08 %	0.07 %	0.03 %
Color @ 0.02 cd/m ²	± 0.0003	± 0.0003	± 0.0001
Luminance @ 0.005 cd/m ²	-	0.22 %	0.07 %
Color @ 0.005 cd/m ²	-	± 0.0007	± 0.0003
Luminance @ 0.001 cd/m ²	-	-	0.20 %
Color @ 0.001 cd/m ²	-	-	± 0.0006