Photometric and Colorimetric Comparison of OLED, NANOSP, and LCD Television

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Abstract— The LCD - Liquid Crystal Display technology is currently the best known of flat screens TVs. However, two innovative and advanced technologies are emerging to the public: the OLED - Organic Lighting Emission Devices, and the NANOSP - Nano Spectrum, also known as Quantum Dot. The aim of this paper is to present a photometric and colorimetric comparison between LCD, OLED and NANOSP. Radiometric-spectrum measurements in TVs under test allow a direct comparison of their main characteristics and objectives parameters. Our results bring a detailed understanding of these new technologies performance and their outstanding qualities in the market.

Index Terms— TV receivers, HDTV, Photometry

I. INTRODUCTION

TELEVISION sets using flat-screen monitors are becoming increasingly cheap and popular. Since they make use of microelectronics technologies, flat screens are also increasingly thin and advanced. This feature allow a number of variation such as 3D screens, the curved screens, the ultra-high-definition screens, i.e. 4K and 8K, and the screens of large dimensions. The PDP - Plasma Display Panel technology and the LCD - Liquid Crystal Display technology are currently the most popular in flat screens. However, innovative and advanced technologies are emerging, which are the OLED technology [1] and the Nano Spectrum technology, also known as Quantum Dot [2]. The acronym OLED is the designation for Organic Light Emitting Devices, which is a novel and disruptive technology of flat screens with many advantages in color and contrast response [3][4]. Nano Spectrum is a technology where nanocrystals of semiconductor materials, such as silicon, have quantum mechanical properties. One application of the nano spectrum technology is the manufacture of film that can correct color distortions allowing the construction of LCD-LED flat screens with much better color response [5][6][7]. Both the OLED and the technologies were introduced in the TV world market in 2015 [8]. Thus, considering the diversity of options currently available for flat panel technologies, the comprehension of the OLED and NANOSP features, advantages and disadvantages is desirable. The aim of this paper is to show technology features by a photometric and colorimetric comparison between LCD, OLED and NANOSP television. We have carried out radiometric-spectrum measurements in these three types of TV sets, and we present a direct comparison of their main characteristics and objectives parameters. The results bring a detailed understanding of these new technologies performance and their outstanding qualities in the market. The remaining of this paper presents the related work, the measurement methodology, the results, and the conclusion.

II. RELATED WORK

A monitor for computer desktops build with OLED technology was evaluated by Ito *et al*. [9], and their article reports the technical performance of the display model Sony PVM-2541. The measurements approach is similar to ours in which the OLED monitor is driven by a computer connected to the HDMI input port. So, precise image and video are displayed on the screen. Then, the measurements of luminance, color and spectral characteristics of the display were done by a colorimeter and by a spectral radiometer. The authors present an analysis of these parameters: luminance gradation, additivity of RGB luminance values, color space and spectral distribution, luminance/color uniformity, differences between individual displays, difference in luminance between vertical and horizontal gratings, and temporal characteristics. The conclusion highlights for this particular OLED display are: excellent luminance and color uniformity, wide color space, and rapid luminance rise/fall times.

The work by Luo *et al*. [10] has a detailed description of the nano spectrum technology for television display construction and the working principle of color enhancement on the display screen. In the last part, the authors briefly discuss the performance of a NANOSP TVs build with QD-BPLC (Blue Phase Liquid Crystal, one of the most recent quantum dot technology type) in comparison with OLED TVs. The QD-BPLC TV has advantages in lifetime, power consumption, resolution density, color gamut, and cost. On the other hand, OLED has advantages in true black state, thin profile and flexibility.

Since both technologies of OLED and NANOSP are evolving, the performance reported in related work need to state the television set model. Our evaluation was carried out in the year of 2015 with new television sets by that time. The methodology for the performance evaluation is described in the next section.

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III. METHODOLOGY

This section describes the procedure of radiometric-spectrum measurements in the OLED, NANOSP, and LCD types of TV sets.

The measurements were conducted in a room sealed against entry of light, so that the environment remains completely dark during the measurement procedure.

A computer with a graphics card is connected to the HDMI input of the TV under evaluation. A set of specific videos for measurements are displayed on the TV screen, one at a time, as needed for each measurement. The video image occupies the entire screen area.

- The spectroradiometer - CS-1000A device, is placed at approximately 80 cm apart, in a line perpendicular to the TV screen, as illustrated in Figure 1. This distance is not relevant to the test, but rather the direction to the screen is important to the measurements. Thus, the CS-1000A lens was perpendicularly aimed to one positioning mark on the image used for the ANSI contrast measurement of Fig. 1.

Fig. 1. Position of CS-1000A, perpendicular to an OLED television set.

Initially, just after turning on the TV, a video is continuously played for at least 30 minutes before starting the measurements. After this period, measurements are performed within the totally dark environment.

The luminance measurements are carried out with eleven gray images ranging from 100% to 0% of the pixel scale in steps of 10%. The image of 100% grayscale corresponds to the maximum luminance, i.e., totally white. The image of 0% grayscale corresponds to the minimum luminance, i.e., the black image. The other images are in grayscale.

The TV color emission measurements are performed with images of the three primary colors RGB (Red, Green, and Blue) and the images of the three secondary colors CMY (Cyan, Magenta, and Yellow).

Measurements of the ANSI contrast are conducted with images containing white and black rectangles in a 4x4 arrangement. With the CS-1000A equipment always in the same position, we measure the emission from white area in the first image, followed by the emission from black area in the second image. In this second measurement, in the black area, the screen does not turn off because there are white areas in the image. The ANSI contrast is the ratio of the luminance of these two measurements.

Additionally, the same ANSI contrast calculation procedure was performed with measurements obtained from the spectrophotometer i1Pro 2. The difference from the above procedure is the position of the equipment. The i1Pro 2 is placed onto the TV screen surface, as illustrated in Fig. 2.
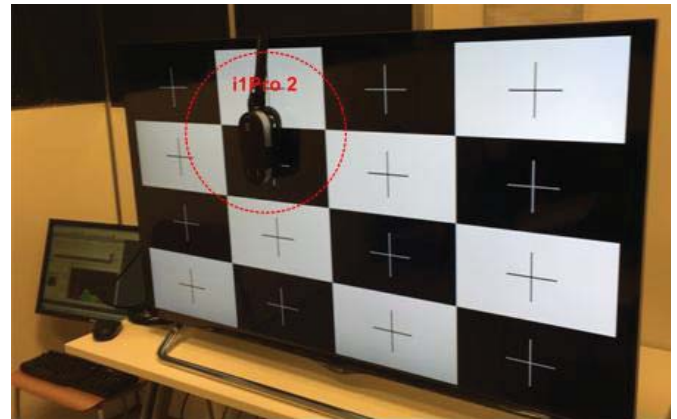

Fig. 2. Position of i1Pro 2 on the TV screen surface, of a NANOSP television set.

In the next step, all the same luminance measurements are performed with room light environment.

The viewing angle measurements were carried out in a dark environment, repositioning the CS-1000A equipment, moving it angularly at a 15 degree angle radius from the previous position, and keeping the lens pointed at the same point of the screen. Thus, it measures the luminance emitted at angles of 15, 30, 45, 60, and 75, in relation to the starting position perpendicular to the screen.

Measurements of horizontal luminance uniformity were performed in dark environment, repositioning the CS-1000A equipment, moving it horizontally, but keeping it perpendicular to the TV screen test. The measured screen points are indicated as marks 1, 2, 3, and 4 in Fig. 3 (a). The 100% white pattern shown in Fig. 3 (b) was used in this measurement. The white area of this image was moved in the TV screen accordingly to the point marks, so that it lies in the center of each measurement position.

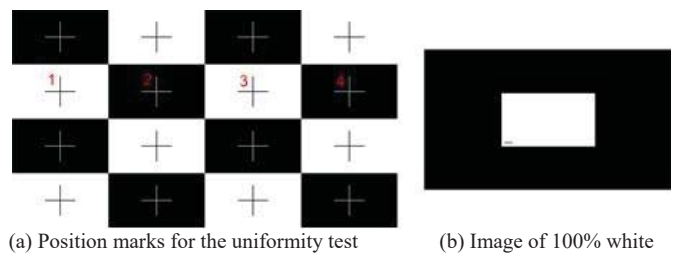(a) Position marks for the uniformity test   (b) Image of 100% white

Fig. 3. Points of luminance measures and the image used to perform measurement.

The three evaluated television sets have 55-inch screen and 4K (3840x2160) pixel resolution. The evaluated models are:
(i) OLED model: 55EG9600-SA,
(ii) NANOSP model: 55UF9500-SA, and
(iii) LCD model: 55UB8500-SA,
All these TV sets are made by LG Electronics.
The radiometric-spectrum measurements with the equipment Konica Minolta CS-1000A, all photometric and

colorimetric values are based on spectral measurements of radiance in W / (m2.sr.nm) in the range of 380nm to 780nm.

Table I presents the television adjustment of parameters settings used on the TVs under test.

TABLE I
TELEVISION ADJUSTMENT PARAMETERS

Parameter	OLED	NANOSP	LCD
IMAGE Menu			
- Image Mode	Photo (User)	Photo (User)	Photo (User)
- Energy Saving	OFF	OFF	OFF
IMAGE MODE Menu			
- LED Light	100	----	----
- Backlight	----	100	100
- Contrast	100	100	100
- Brightness	50	50	50
- Sharpness	10	10	10
- Color	50	50	50
- Tone	0	0	0
ADVANCED CONTROL Menu			
- Dynamic Contrast	OFF	OFF	OFF
- Super Resolution	OFF	OFF	OFF
- Color Range	Wide	Wide	Wide
- Contour Enhance	OFF	OFF	OFF
- Color Filter	OFF	OFF	OFF
- Advanced Pattern	OFF	OFF	OFF
- Gamma	2.2	2.2	2.2
WHITE BALANCE Menu			
- Color Temperature	Medium	Medium	Medium
GENERAL Menu			
- Timer	OFF	OFF	OFF
- Wait Light	OFF	OFF	OFF
- HD ECO Mode	OFF	OFF	OFF
- Software Version	03.00.06	03.00.13	04.65.05

IV. RESULTS

From the measurements of parameters obtained in the previous sections, a comparative analysis was made considering the following parameters shown below:

Luminance: luminance is a measure of the brightness of the white color, in this regard the NANOSP TV showed performance near the OLED TV and far superior to LCD TV;

Angular Luminance: angular luminance is the brightness of the white color seen from a certain angle, in this study we decided to adopt the extent of 45 degree tilt angle. In this case it is observed that NANOSP TV performance is almost equal to the LCD TV, however OLED TV has much higher performance;

Gamma 2.2: the Gamma 2.2 curve is the standard measure of grayscale brightness in flat panel TVs; and the higher adherence to Gamma 2.2 curve the better the contrast of images in grayscale. In these measurements, the OLED TV has almost total adherence to the Gamma 2.2 curve. The LCD TV has median performance and NANOSP TV has lower performance;

Uniformity: this measure evaluates the brightness distribution along the panel. The three TVs have a very great uniformity, and the outstanding uniformity of OLED TV is less than 3%.

Room Light Reflection: the flat screen reflection index at room light is an important parameter to measure the influence of ambient room light on the image. In this aspect the OLED TV showed a superior performance than the LCD TV and NANOSP TV.

Contrast: Contrast measures the difference between white and black levels. The contrast of the OLED TV is far superior to the LCD and the NANOSP TVs.

RGB Interference: the RGB interference measures the degree of spectral overlapping between colors, the smaller the interference of R color on the G color, and the interference of G color on B color, the greater is the separability and fidelity of colors in the screen image. In this aspect the OLED TV showed far superior performance than LCD and NANOSP TVs.

Color Gamut: the color gamut represented in the form of a triangle in the CIE diagram represents all the possible space of colors that can be displayed by a Flat screen. In this aspect the TV OLED presented the color gamut with the largest area, followed by NANOSP TV and the LCD TV.

A comparative radar diagram is shown in Fig. 4, which was constructed by normalization of numerical measurements results. The next subsections discuss the performance results for each of these parameters.
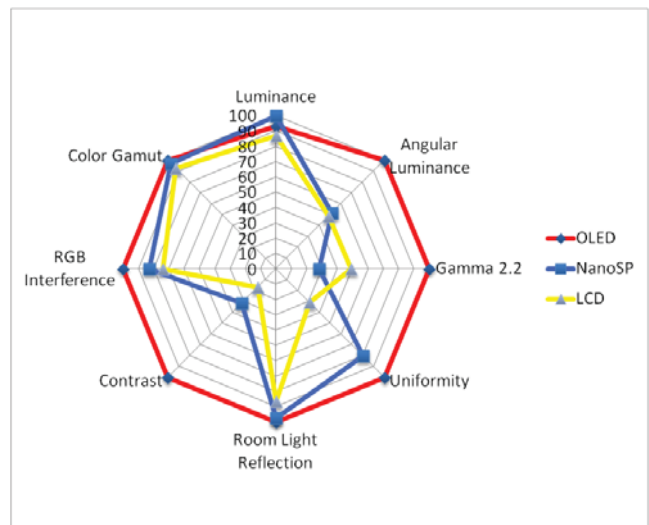

Fig. 4. Radar Diagram of Analyzed Parameters.

A. Maximum luminance

The maximum luminance measurement was made for the 100% white image. Fig. 5 presents the absolute measurements.
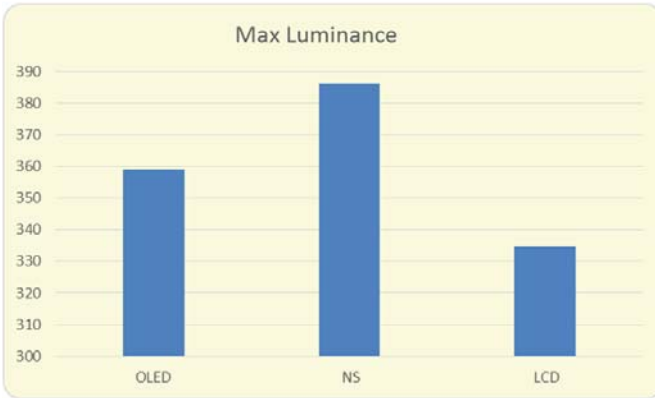
Fig. 5. Maximum luminance results graph.

Fig. 8. Results of the horizontal luminance uniformity test.

B. Luminance angular dependence

The OLED TV showed a significantly lower angle dependence of the luminance with the change in viewing angle, as shown in Fig. 6.
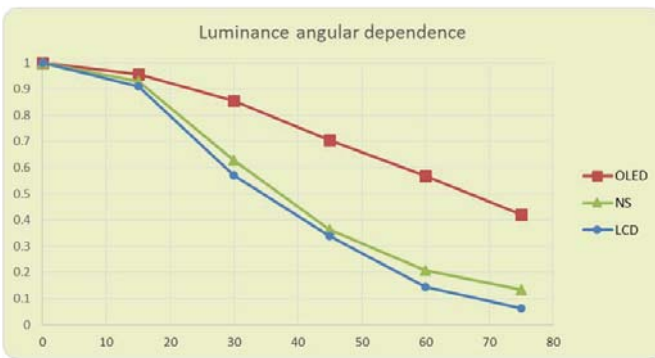

Fig. 6. Luminance angular dependence measures.

C. Gamma correction: Luminance tracking versus grayscale

The luminance tracking curve in relation to Grayscale adopted by the industry is the 2.2 Gamma correction curve. The better the TV the closer to Gamma 2.2 function curve. The OLED TV presented the best approximation to the Gamma 2.2 curve, as shown in Fig. 7.
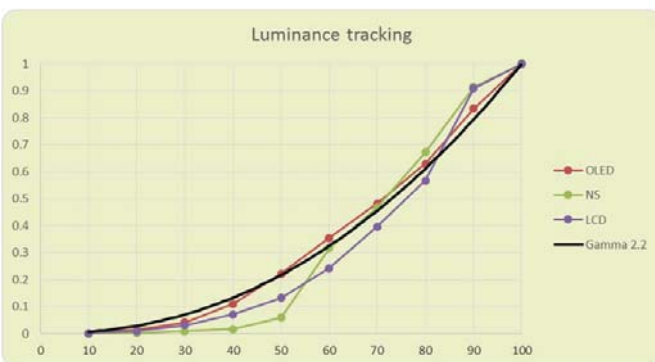

Fig. 7. Luminance tracking graphs.

D. Horizontal luminance uniformity

The results of the horizontal luminance uniformity test have few significant differences for all the tested televisions, as shown in Fig. 8.

E. Room lighting reflection effect

When tested in typical room lighting environment, with the screen turned off, the screen reflection was significantly lower in the case of OLED TV, as shown in Fig. 9.
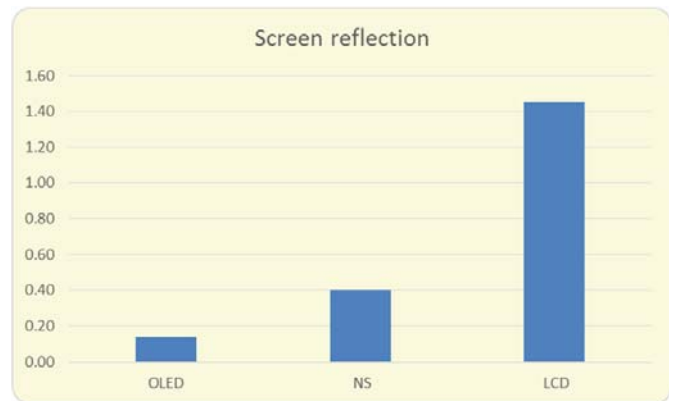

Fig. 9. Screen Reflection with room lighting.

F. ANSI Contrast

The contrast values, calculated as the ratio between white and black luminance of ANSI standard in the same measuring point were greater on the TV screen OLED as shown in the graph of Fig. 10, with the i1Pro 2.
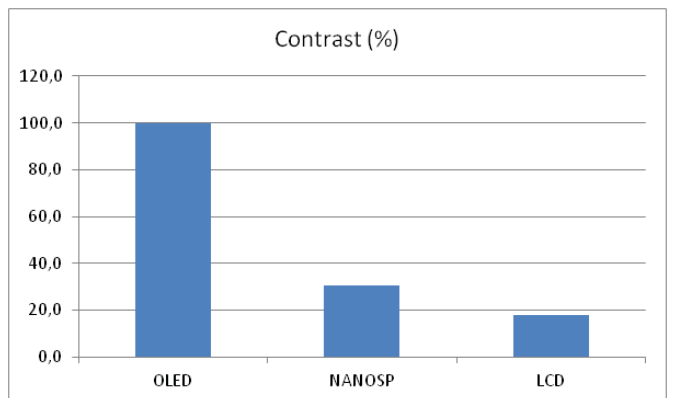

Fig. 10. Contrast ratio of ANSI standard, measured by i1Pro 2..

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G. RGB Spectral crosstalk

This study shows a calculation of the power interference ratio of each individual channel and the other two channels within each color band. This value is called the signal-to-interference ratio (SIR), and it is calculated in decibels (dB). The higher the value of SIR, the smaller is the spectral interference.

Fig. 11 shows the interference on the G channel for OLED TV set, and the calculated SIR is 12.2dB. Fig. 12 shows the interference on the G channel for NANOSP TV set, and the calculated SIR is 10.1dB. Fig. 13 shows the interference on the G channel for LCD TV set, and the calculated SIR is 8.9dB. Thus, we conclude that OLED TV presents a better performance regarding RGB spectral interference than other two TVs.
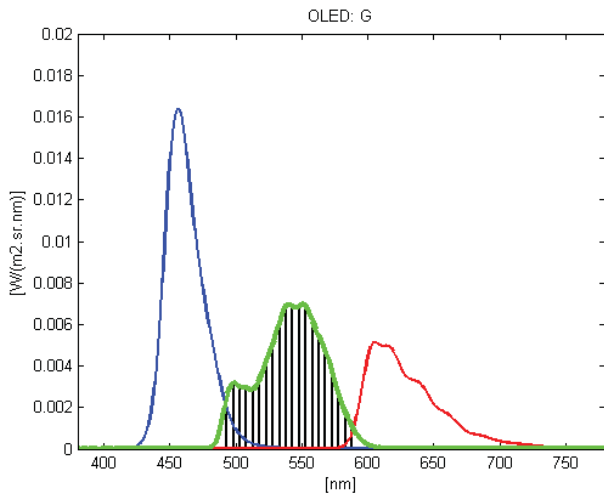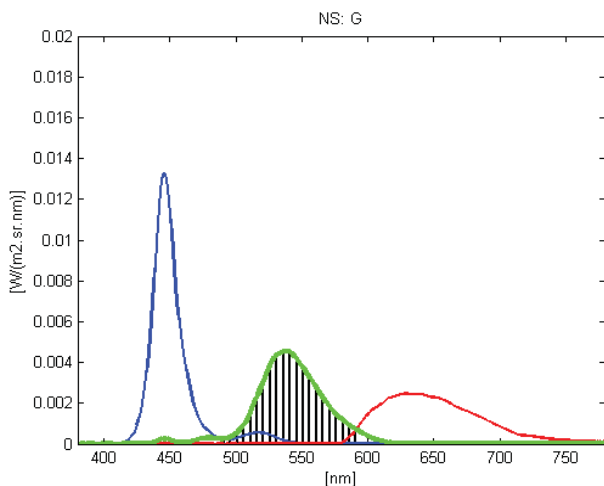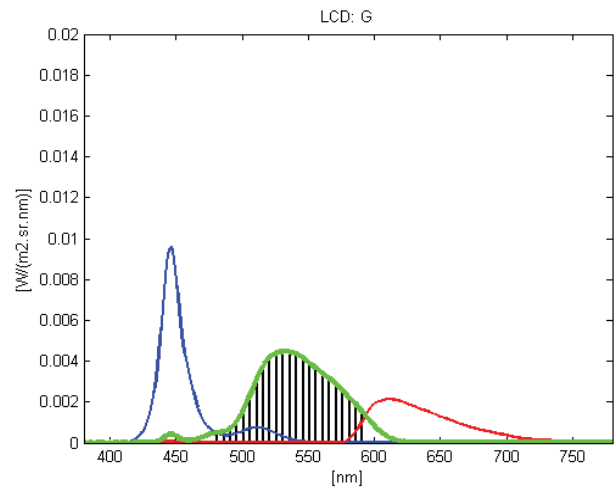

Fig. 13: Interference on G channel for LCD TV.

We also calculated the interference on R channel and on B channel, and both had similar comparative results. However, the interference on G channel is stronger in all TVs.

H. Color Gamut

The OLED TV gamut is larger towards the R-G and G-B axes while the NANOSP TV gamut is larger towards the R-B axis, as shown in Fig. 14.
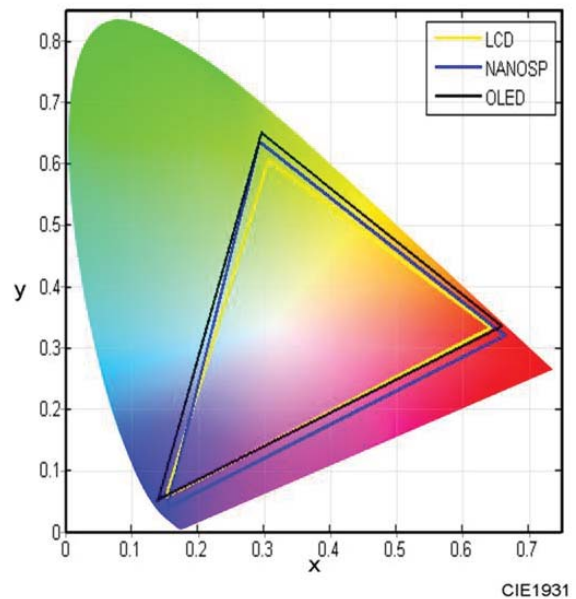

Fig. 11: Interference on G channel for OLED TV.

Fig. 12: Interference on G channel for NANOSP TV.

Fig. 14. Comparison of color gamut in the CIE xy diagram.

V. CONCLUSIONS

This paper presents a photometric and colorimetric comparison of OLED, NANOSP, and LCD television sets. We have carried out radiometric-spectrum measurements in these three types of TV sets, and we presented a comparison of their main characteristics and objectives parameters. We conclude that the OLED TV showed an overall better photometric and colorimetric performance in all parameters. We also noticed that either OLED and NANOSP

technologies offer a superior perceived image quality than LCD TVs. In future work we plan to extend the measurements to more parameters, and also we plan to evaluate newer models of television receivers in the market. In regard to television receivers' lifetime estimation, we also plan to carry out measurements in the same models by checking colorimetric and photometric changes after excessive usage time.

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