Laser Projection Television Color Measurement System

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Abstract. Color measurement is important for TV color display performance evaluation indicators. Photochromic basic parameters of laser projection TV measurement are introduced, including color temperature, contrast ratio, color gamut, uniformity of illuminance luminous and so on. At last, a laser projection TV color measurement system is given out.

1. Introduction
Television display equipment has experienced four generations of technological changes including cathode ray tube display (CRT), liquid crystal display (LCD), light emitting diode display (LED) and laser projection display (LPD). The laser projection display is the representative of the fourth generation display technology. By using laser as light source and making full use of its advantages such as high saturation, low power consumption and long life, the display image has a larger color domain space, and the image color is richer and more lifelike. The display performance is superior to the traditional halogen lamp, ultra-high-pressure mercury lamp, LED and other light sources.

With the technological change of TV display equipment, the color performance evaluation methods and indicators of the display are changing and refined. At present, the color measurement index of the display mainly includes color temperature, contrast, color range, irradiance uniformity, and output luminous flux.

2. Basic color parameters measurement of laser projection TV

2.1. Color temperature measurement
If the color of the emitted light from a light source is the same as that of the black body at a certain temperature, the absolute temperature of the black body is called the color temperature of the light source (referred to as color temperature)[1]. When the color of the light source is different from the black body, the concept of "correlation color temperature" is often used to describe the color of the light source. In a certain uniform chromaticity diagram, if a light source has the closest light color to the black body at a certain temperature, the absolute temperature value of the black body is called the relevant color temperature of the light source[2].

Suppose the color stimulus of the light source the detector receives is \( \varphi(\lambda) \), the tristimulus value of sample color is:
\[
X = k \int_{380}^{780} \phi(\lambda) x(\lambda) d\lambda = c_x \sum \phi(\lambda) S(\lambda) \tau_x(\lambda) \Delta \lambda \\
Y = k \int_{380}^{780} \phi(\lambda) y(\lambda) d\lambda = c_y \sum \phi(\lambda) S(\lambda) \tau_y(\lambda) \Delta \lambda \\
Z = k \int_{380}^{780} \phi(\lambda) z(\lambda) d\lambda = c_z \sum \phi(\lambda) S(\lambda) \tau_z(\lambda) \Delta \lambda
\]

(1)

Here \( k, c_x, c_y \text{ and } c_z \) is constant, \( \tau_x(\lambda), \tau_y(\lambda), \tau_z(\lambda) \) are the spectral transmission ratios of three matched filters. \( S(\lambda) \) is the spectral sensitivity of the detector. Generally \( \Delta \lambda = 5 \text{nm} \) or \( 10 \text{nm} \).

The relative spectral power distribution of black body emitted light is given by Planck's law,

\[
P(\lambda, T) = c_1 \lambda^{-5} (e^{c_2 / \lambda T} - 1)^{-1}
\]

(2)

Here \( T \) is the absolute temperature of the black body \((K)\), \( \lambda \) is the wave length \((\text{nm})\), \( c_1 \) is the first radiation constant, \( c_1 = 3.7417749 \times 10^{-16} \text{Wm}^2 \), \( c_2 \) is the second radiation constant, \( c_2 = 1.4388 \times 10^{-2} \text{mK} \).

The color coordinates \( u \) and \( v \) of the light source in the CIE 1960 UCS uniform chrominance coordinate system are:

\[
\frac{4X}{X + 15Y + 3Z} = u \\
\frac{6Y}{X + 15Y + 3Z} = v
\]

(3)

Change \( \phi(\lambda) \) in equation (1) to \( P(\lambda, T) \) in equation (2) and substitute it into equation (3). Black body color coordinates \( u \) and \( v \) can be obtained.

The black body \( u-v \) color coordinate track of various temperatures is shown in figure 1. Iso correlative color temperature line is a series of linear clusters perpendicular to the black body color temperature trajectory.

![Figure 1. Iso correlated color temperature lines of uniform standard color chart](image)

The commonly used methods for calculating color temperature include direct interpolation, triangular pedicles and successive approximation of color temperature.

The projection shows different color temperatures, different light colors and different visual feelings. People feel bleak and cold under high color temperature (>5000K). Low color temperature (<3000K)
gives a warm and stable feeling; Intermediate color temperature (3000–5000K) gives a feeling of cheerfulness. Now some high-grade display color temperature adjustment function, can adjust color temperature according to individual preference.

2.2. Measurement of contrast

Contrast has a great influence on the effect of projection display. Generally, the larger the contrast is, the clearer and the more striking the image will be, and the brighter the color will show. It will make the whole picture look dark and unclear with smaller contrast. High contrast can obviously enhance the image clarity, detail and gray level.

The contrast measurement generally uses the contrast test image shown in figure 2 to measure the ratio of the average illumination between eight white areas and eight black areas. The brighter the white is and the darker the black is, the higher the contrast will be.

![Contrast test image](image)

\[ C = \frac{\sum_{i=1}^{8} E_{iW}}{\sum_{j=1}^{8} E_{iB}} \]  

(4)

2.3. Gamut

Each color image output device or medium presents different color performance range due to its different color structure and mechanism. Gamut describes the range of colour spectra that the device can reproduce[3]. The colors of the visible spectrum in nature constitute the largest gamut space, which contains all the colors that human eyes can see. As shown in figure 3, the horseshoe region is a color-domain space recognized by human eyes.

First, measure the CIE\((u', v')\) in the full-field signal of three-color RGB, The coordinates of \(u\) and \(v\) were measured respectively. For red (R), the value was \(u_r\) and \(v_r\); For green (G), the value is \(u_g\) and \(v_g\); For blue (B) is \(u_b\), \(v_b\), and the area of R, G, B triangles can be calculated.

\[ S_{rgb} = \frac{1}{2} \left[ (u'_{r} - u'_{b})(v'_{g} - v'_{b}) - (u'_{g} - u'_{b})(v'_{r} - v'_{b}) \right] \]  

(5)

If the measurement is CIE1931 \((x, y)\), the \((u', v')\) value can be calculated by the following formula.
\[ u' = \frac{4x}{3 - 2x + 12y} \]
\[ v' = \frac{9y}{3 - 2x + 12y} \]

Gamut coverage \( C_p = \frac{S_{rgb}}{0.1952} \times 100\% \).

Taking CRT TV as an example, the color coordinate of CIE1931 was measured as (0.61,0.34), (0.28,0.61) (0.15,0.065) respectively, and the color gamut coverage was 18.5% and about 74.7%NTSC.

![Figure 3. Gamut coverage](image)

In the figure 3, the black triangle is the coverage area of CRT TV color gamut, and the white triangle is the coverage area of NTSC color gamut.

2.4. Measurement of illumination uniformity

The more uniform the light distribution shows, the better the illumination, the more comfortable the visual experience, and the poor illumination uniformity will increase visual fatigue. Therefore, uniformity is an important index to evaluate projection display performance.

According to ANSI's definition of projection uniformity, thirteen points measurement method was used. The method of selecting thirteen test points is shown in figure 4. The whole display area is divided into nine small squares. The center of each square is taken as nine points. Take 10% of the distance from the four vertices of the larger grid to the central point as the other four points. The measurement of the display uniformity is to take the ratio of the minimum value to the maximum value of thirteen points under the all-white image output. The higher the ratio, the higher the uniformity of the output light will be.

![Figure 4. ANSI thirteen test points distribution](image)
2.5. Measurement of luminous flux

Luminous flux refers to the energy that the light source radiates into the surrounding space in unit time and causes vision. Because human eyes have different sensitivity to different wavelengths of light, the luminous flux is not only related to the radiation intensity of the light source, but also to the light efficiency function of the light source spectrum [4].

According to ANSI's definition of luminous flux, the display plane is divided into nine squares of the same size. Under the all-white image output, the illumination value of each center point is measured, and the average value is obtained, multiplied by the whole display area, which is luminous flux.

\[
\phi = S \sum_{i=1}^{9} \frac{E_i}{9}
\]  

(8)

3. Laser projection television color measurement system

The color measurement system of laser projection television shall include the above basic evaluation parameters, such as color temperature, contrast, color range, irradiance uniformity and luminous flux.

As shown in figure 5, the measurement system is mainly composed of data measurement system, data processing system and three-dimensional motion measurement platform.

![Schematic diagram of color measurement system of laser projection TV](image)

**Figure 5.** Schematic diagram of color measurement system of laser projection TV

The data measurement system mainly consists of a spectrophotometer and its clamping tool. The spectrophotometer can measure irradiance, color temperature and relative spectrum power distribution accurately. And the other parameters can be tested and calculated by the above formulas.

References

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