Research and design of CSA-510 color analyzer

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Abstract. This paper introduces the measurement principle of color analyzer firstly, and designs a kind detection equipment of color analyzer which can be used for accurate measurement and analysis of color. An experimental comparative study was carried out with foreign mature product CA-310 at last. The results show that When the brightness is greater $\geq 0.1\text{cd/m}^2$, the results of brightness test keep a linear relationship, and the range of error with competitor brightness is less than 2%. The error range of color coordinate accuracy is basically controlled within $\pm 0.0050$. Compared to the high prices of abroad equipment, it has certain competitive advantages.

1. Introduction

With the continuous development of society, the brightness and chroma accuracy of the display screen is higher demanded increasingly by the display equipment industry which is also the key technology of the core competitiveness of manufacturers. Color analyzer is one of the most commonly used detection devices in the field of color detection. The domestic equipment is more poor than mature foreign products with poor accuracy, low range and inability to accurately detect low brightness. The main causes include: 1. inaccurate design of optical path; 2. imperfect filter matching; 3. rough design of circuit; 4. unreasonable designs [1]. Therefore, this paper carries out a detailed experimental to solve the existing problems of the color analyzer, while it puts forward its design scheme, and designs a new kind of detection equipment of color analyzer which has certain reference value in the field of color and brightness detection.

2. The working theory of color analyzer

The color analyzer is a photoelectric integral colorimetric measuring instrument [2]. Which covering the photoelectric detector with a filter to modify the relative spectral sensitivity $S(\lambda)$ of the three $X, Y, Z$ detectors to be the spectral stimulus functions $x(\lambda), y(\lambda), Z(\lambda)$ recommended by the International Lighting Committee for 1931 standard chroma observers, as shown in Figure 1 [3]. Using the three detectors, the tristimulus values $X, Y$ and $Z$ of the target can be measured at one time.

$$X = \begin{cases} \frac{500}{380} \int_{380}^{500} \phi(\lambda) x(\lambda) d\lambda = c_x \int_{380}^{500} \phi(\lambda) S(\lambda) \tau_{ab}(\lambda) d\lambda \\ \frac{780}{500} \int_{500}^{780} \phi(\lambda) x(\lambda) d\lambda = c_x \int_{500}^{780} \phi(\lambda) S(\lambda) \tau_{ab}(\lambda) d\lambda \\ \end{cases}$$

$$Y = \begin{cases} \frac{500}{500} \int_{500}^{500} \phi(\lambda) y(\lambda) d\lambda = c_y \int_{500}^{500} \phi(\lambda) S(\lambda) \tau_{ab}(\lambda) d\lambda \\ \frac{380}{380} \int_{380}^{380} \phi(\lambda) y(\lambda) d\lambda = c_y \int_{380}^{380} \phi(\lambda) S(\lambda) \tau_{ab}(\lambda) d\lambda \\ \end{cases}$$

$$Z = \begin{cases} \frac{780}{780} \int_{780}^{780} \phi(\lambda) Z(\lambda) d\lambda = c_z \int_{780}^{780} \phi(\lambda) S(\lambda) \tau_{ab}(\lambda) d\lambda \\ \end{cases}$$

(1)
Among the k, C_x, C_y and C_z are constant. \( \tau_{xy}(\lambda) \), \( \tau_{xb}(\lambda) \) and \( \tau_{z}(\lambda) \) are the spectral transmittance of each filter, \( S(\lambda) \) is the relative spectral sensitivity of the detector, \( \lambda \) is the wavelength.

\[
\begin{align*}
\tau_{xb}(\lambda) &= \frac{\bar{x}(\lambda)}{S(\lambda)}, (380nm \leq \lambda \leq 500nm) \\
\tau_{xb}(\lambda) &= \frac{\bar{x}(\lambda)}{S(\lambda)}, (500nm \leq \lambda \leq 780nm) \\
\tau_{y}(\lambda) &= \frac{\bar{y}(\lambda)}{S(\lambda)} \\
\tau_{z}(\lambda) &= \frac{\bar{z}(\lambda)}{S(\lambda)}
\end{align*}
\]

![Figure 1. Tristimulus curve of spectrum of CIE-XYZ standard chroma observer.](image)

Through the tristimulus values X, Y and Z of the measured object to measure the color coordinates of the measured object. Because the X_b are similar to Z curve, So X_b=0.151Z are taken as the short wave part of X curve.

3. Design of color analyzer
The color analyzer system is mainly divided into two parts: probe and control panel. The probe part includes the design of optical path, mechanical structure and signal acquisition and processing circuit board. The core of the control panel is circuit board. The composition flow chart of system is shown in Figure. 2.
The optical system of the probe mainly includes objective lens, optical fiber module, filter lens and sensor. Its working principle: the light of source to be measured gathers on the receiving window surface of the optical fiber module through the objective lens, and guides to the sensor through the optical fiber module and the filter lens. Especially to obtain accurate actual values in time of testing low brightness, the most important thing is that reduces the light loss to transmitted to the sensor, and prevents the light from focusing on the outside area of the receiving window of the optical fiber module. In such a case to reduce the light loss and could obtain accurate measurement. The following Figs are respectively the appearance of prototype and the test interface.

**Figure 2.** The flow chart of system.

**Figure 3.** The appearance of prototype.

**Figure 4.** The test interface.
Experimental results and analysis: The CA-310 color analyzer is a mature product. As a competitive product, it will be tested and compared under the same conditions to verify the accuracy and reliability of the product. Experimental conditions: standard lamp, CA-310, self-made CSA-510 and other auxiliary equipment, etc. Brightness and color coordinates were measured. The test results are as follows.

| lv    | x    | y    | lv    | x    | y    |
|-------|------|------|-------|------|------|
| 458.00| 0.4715| 0.4156| 452.10| 0.4741| 0.4109|
| 299.10| 0.4717| 0.4154| 294.30| 0.4740| 0.4109|
| 199.50| 0.4716| 0.4154| 197.30| 0.4731| 0.4147|
| 100.60| 0.4710| 0.4154| 99.70 | 0.4724| 0.4130|
| 50.40 | 0.4708| 0.4156| 51.40 | 0.4730| 0.4126|
| 29.50 | 0.4713| 0.4154| 30.10 | 0.4729| 0.4141|
| 15.00 | 0.4709| 0.4154| 15.20 | 0.4730| 0.4140|
| 10.07 | 0.4712| 0.4156| 10.10 | 0.4722| 0.4177|
| 5.00  | 0.4714| 0.4162| 5.10  | 0.4748| 0.4167|
| 4.00  | 0.4713| 0.4164| 4.00  | 0.4743| 0.4177|
| 3.20  | 0.4713| 0.4164| 3.20  | 0.4766| 0.4131|
| 2.50  | 0.4819| 0.4239| 2.45  | 0.4857| 0.4228|
| 2.07  | 0.4829| 0.4243| 2.00  | 0.4859| 0.4255|
| 1.50  | 0.4822| 0.4258| 1.48  | 0.4823| 0.4277|
| 1.00  | 0.4837| 0.4263| 1.02  | 0.4847| 0.4254|
| 0.50  | 0.4829| 0.4272| 0.50  | 0.4836| 0.4265|
| 0.10  | 0.4850| 0.4284| 0.10  | 0.4871| 0.4281|

According to the data in the table: Under the same test conditions, the brightness of test results basically maintain the same linear relationship with the calibration results. The error is less than 2%. The color coordinates keeps good consistency. The error is within ±0.050. At the same time, the same result can be maintained with CA-310 for low brightness measurement.

4. Conclusion

In this paper, according to the principle of color measurement, The CSA-510 color analyzer is designed. Proved by experiment: the brightness of test results basically maintain the same linear relationship with the calibration results. The error is less than 2%. The color coordinates keeps good consistency. The error is within ±0.0050. At the same time, the same result can be maintained with CA-310 for low brightness measurement. It can meet the requirement of color measurement. It has certain reference significance for the design of color testing products.

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