Application Note

UV-0006-E

Luminous Color Measurement

Products such as Light Emitting Diodes (LED), Organic Electrical Luminescent (EL) displays, and Plasma Display Panels (PDP) that utilize luminous phenomenon are in widespread use and further developments in this field are proceeding rapidly. Starting with the blue LED developed in 1993, engineers finally succeeded in developing a white LED that is now the mainstream illuminator of the mobile phone backlight, and LED flashlights, etc. In the commercial video display area, next-generation displays with a ‘luminous’ body, such as flat-screen Organic EL displays having superior performance for luminous efficiency and with lower power consumption as well as the PDP for large-sized flat screen TVs are being developed. For these developments, numerical evaluations of display colors, the color rendering of the luminous body itself and of the manufactured display are required. In this paper, methods for evaluating luminous colors and color rendering by a JASCO spectrophotometer are introduced for the cutting edge development of LED, Organic EL, and PDP displays. Moreover, a method for evaluating the colors of liquid crystal displays (LCD) using the same system is also introduced.

System Configuration for Measurement and Analysis

- V-650/660/670 UV-Vis or UV-Vis/NIR spectrophotometers
- Model ELM-742 External Source Fiber Optic Interface
- Calibrated lamp unit
- VWLU-788 Luminous Color Measurement/Analysis Program

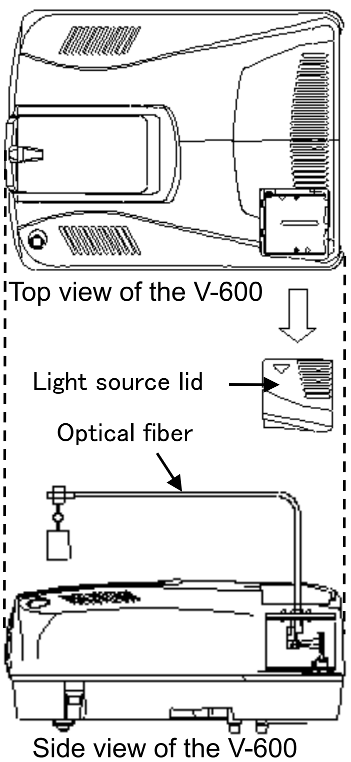


Figure 1: V-600 series spectrophotometer with the external source fiber optic interface

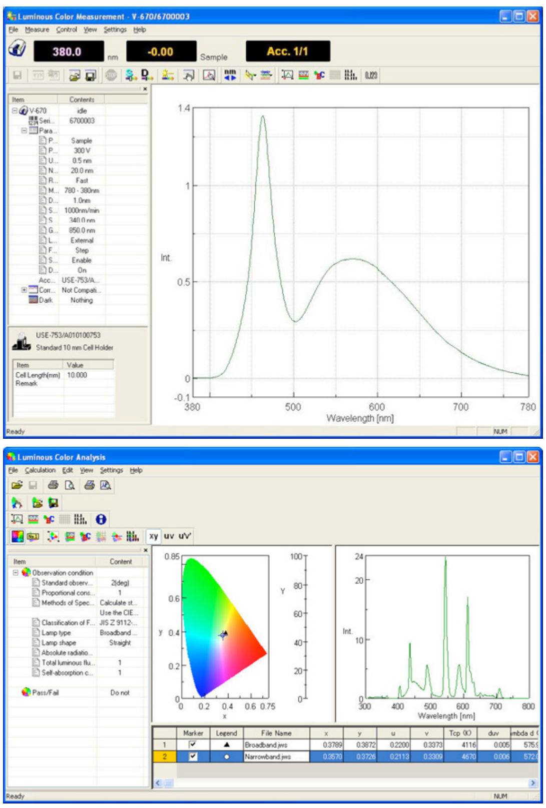


Figure 2: [Luminous Color Measurement] (Top) [Luminous Color Analysis] (Bottom)

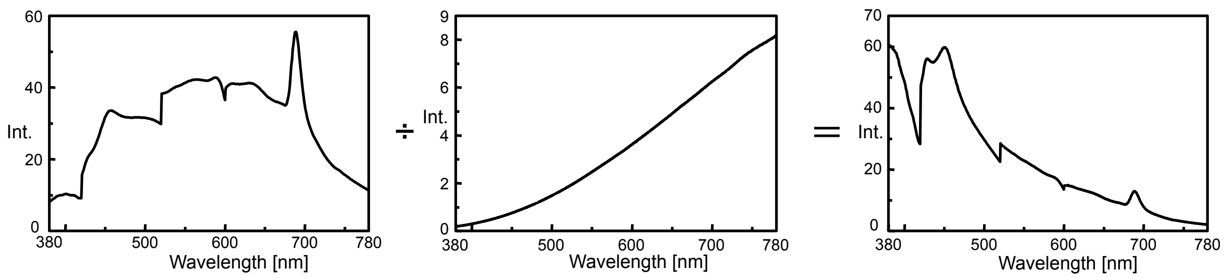
Main Functions of the [Luminous Color Measurement/Analysis]

Color Calculation Functions:
Tristimulus Values: X, Y, Z (based on JIS standard Z 8701-1999)
Chromaticity coordinate (x, y), (u, v), (u', v') (based on JIS standard Z 8701-1999)
Dominant Wavelength (λ_d), (Complementary Wavelength (λ_c)), Excitation purity (p_e) (based on JIS standard Z 8701-1999)
Correlated Color Temperature T_{cp} and Deviation d_{uv} (based on JIS standard Z 8725-1999)
Color Rendering Index R_a, R_1 to R_{15} (based on JIS standard Z 8726-1990)
Classification of Fluorescent lamps (based on JIS standard Z 9112-1990, 2004)
Pass/Fail Criteria established by user

Spectral Measurement Methods

1. Instrument Correction Coefficient Spectrum Measurement

A spectrophotometer has a differing grating efficiency and detector sensitivity based on wavelength, so any collected spectrum reflects the instrument characteristics. To remove the instrument characteristics, a standard light source having a known emission must be measured in order to obtain the instrument characteristics (Instrument Correction Coefficient Spectrum). Here, the emission spectrum of the standard light source is referred to as the "standard light source data", and a spectrum of the standard light source measured by the spectrophotometer is "standard light source spectrum". The "Instrument Correction Coefficient Spectrum" can be calculated by dividing the "standard light source spectrum" by the "standard light source data" (Fig.3). Subsequent spectra collected using the instrument can then be 'corrected' using the stored Instrument Correction Coefficient spectrum.

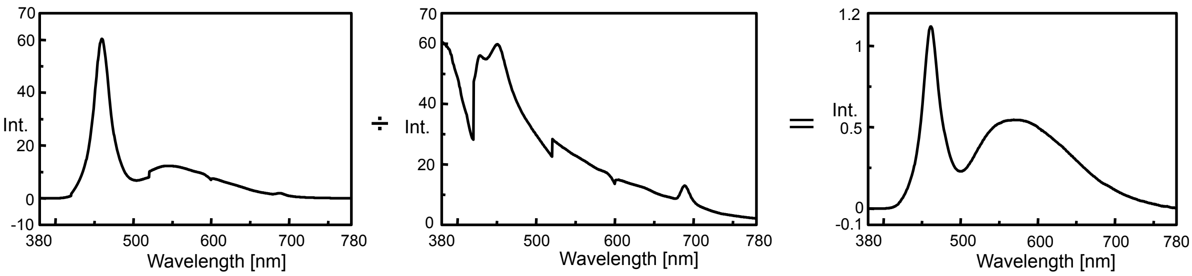


Standard light source spectrum | Standard light source data | Correction Coefficient Spectrum

Figure 3: Calculation of the Instrument Correction Coefficient Spectrum

2. Sample Measurement

Samples are measured after obtaining the Instrument Correction Coefficient Spectrum. A spectrum measured by the spectrophotometer is referred to as the "raw spectrum of sample", and "Spectrum Correction" means removing the instrument characteristics from the spectrum. The "Spectrum Correction" is executed by dividing the "raw spectrum of sample" by the "Instrument Correction Coefficient Spectrum".



Raw spectrum of sample   Correction Coefficient Spectrum   Corrected Sample Spectrum

Figure 4: Method for Spectrum Correction

Example 1: Color Rendering and Correlated Color Temperature of Illumination Sources (Illuminants)

Three 'white' LED's, a fluorescent lamp, and sunlight were measured to calculate the Color Rendering Index and the Correlated Color Temperature. The white LED's show a relatively favorable Color Rendering Index (R_a) with a high Correlated Color Temperature (T_{cp}). The color of the white LEDs differ according to their types, some of which demonstrate a deeper blue color. Sunlight provides a R_a of almost 100 and the fluorescent lamp demonstrates a smaller R_a than sunlight.

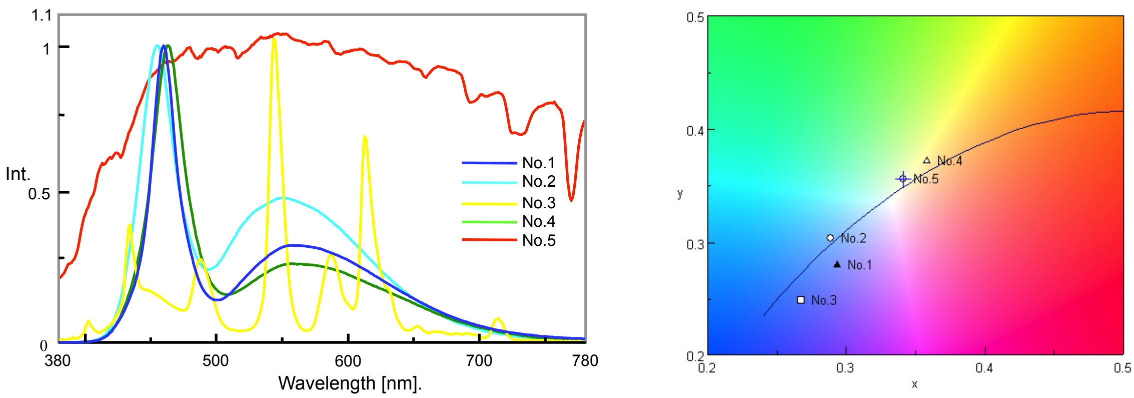


Figure 5: Emitting spectra of the illuminants (left) and data plotted on the chromaticity diagram (right)

Table 1: Correlated Color Temperature and Color Rendering for each Illuminant

No.	Illumination (Spectrum Color)	T_{cp} (K)	d_{uv}	λ_d (nm)	P_e (%)	Reference Illuminants	R_a	Classification of FL
1	White LED1 (Blue)	9055	-0.013	469.37	19.28	D9055	86	-----
2	White LED2 (Light Blue)	8563	0.003	482.54	17.62	D8563	80	-----
3	White LED3 (Yellow)	19359	-0.014	470.37	31.23	D19358	80	-----
4	Fluorescent lamp (Green)	4632	0.005	572.78	19.05	P4632	82	N
5	Sunlight (Red)	5158	0.003	566.74	9.1	D5158	98	N

Example 2 : Color Calculation of a Liquid Crystal Display (LCD)

The screen of a liquid crystal display were measured when it was programmed to illuminate as white, red, blue, green, yellow, light blue, and deep red only. The spectra were calculated by the color calculation program.

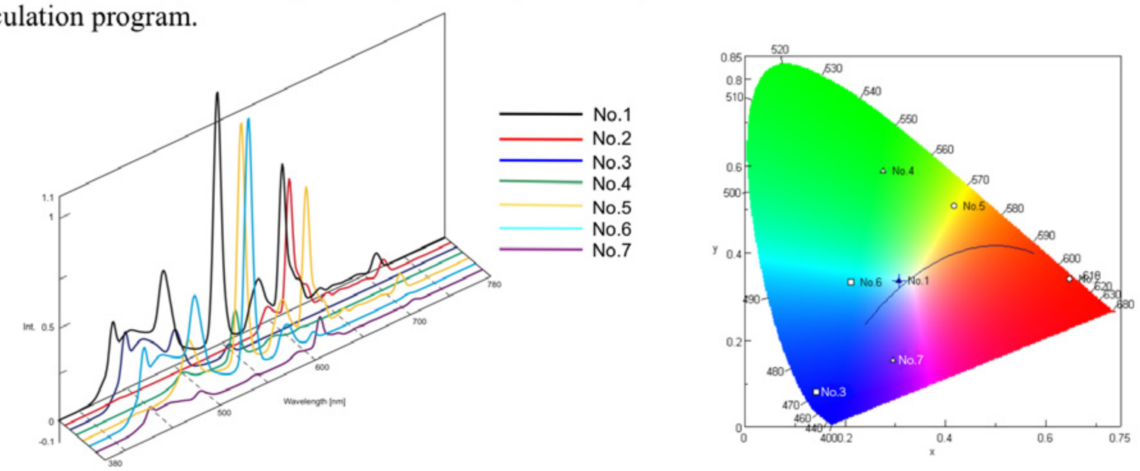


Figure 6: Spectra for each screen color (left) and data plotted on the chromaticity diagram (right)

Table 2:Color Calculation Result for each color

No.	Color	X	Y	Z	x	y	T_{cp} (K)
1	White	18.95	20.56	22.01	0.308	0.3342	6714
2	Red	8.66	4.51	0.19	0.648	0.3376	-----
3	Blue	3.56	1.95	19.37	0.1431	0.0784	-----
4	Green	1.37	2.9	0.67	0.277	0.5868	-----
5	Yellow	15.3	18.54	2.82	0.4173	0.5057	-----
6	Light blue	10.2	15.96	22.06	0.2115	0.331	-----
7	Deep Red	2.74	1.4	5.1	0.2963	0.1518	-----

(Two-degree standard observation is used for the calculations)

The XYZ values were converted into the RGB values and compared with the values of the display settings. Although the calculated RGB values demonstrated relatively different values than those set for the display, we considered that the results were a reasonable match, based on the predominant values for the RGB calculations vs. the display settings.

Table 3: Comparison of RGB values for display settings and converted XYZ values

Color	Display RGB settings			RGB converted from XYZ		
	R	G	B	R	G	B
White	255	255	255	247	262	256
Red	255	0	0	269	0	0
Blue	0	0	255	0	57	256
Green	0	128	0	0	127	32
Yellow	255	255	0	254	257	30
Light Blue	0	255	255	0	263	259
Deep Red	128	0	128	128	11	139

The conversion of the XYZ values into RGB values is executed according to the method outlined by the Colors & Dyeing Club in Nagoya/Osaka (http://www005.upp.so-net.ne.jp/fumoto/index.htm).