Chromaticity coordinates and luminance measurements

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This report presents the results of chromaticity and luminance measurements using three different meters (used at IPO). The source is a "LeuchtdichteNormal LN2", having a reference luminance of L_n = 2927 cd/m^2 and chromaticity coordinates of x = 0.450, y = 0.413, with correlated color temperature T_n = 2870 K. Color temperature is the temperature of a blackbody radiator, that would emit light of the same chromaticity as the test source. A set of reference filters (MEL) is used, in combination with the source, to obtain different chromaticity coordinates and luminance values. A list of those values is presented in table I. One of the meters used is a luminance meter (LMT-L1003), and thus measuring only luminance values. The two other ones are color meters (SPECTRASCAN PR 650 and THOMA). These meters measure the tristimulus values X, Y, and Z, from which the color coordinates x and y are derived.

1. MEASUREMENTS

All measurements were performed for the source and then, for each filter placed in front of the source. Two meters (LMT and SpectraScan) have objective lenses and were placed almost 1 m from the source. The field of measurement is 1° and focused on the middle of the source, so the corresponding area was 2.4 cm^2. The other meter (Thoma) has a measuring head which should be placed directly on the source.

- **The SPECTRASCAN PR 650 meter**
  The SPECTRASCAN PR 650 meter measures the radiation with a 128 element photodiode array, in a spectral range of 380-780 nm with a spectral bandwidth of 8 nm (fwhm). It provides both the chromaticity coordinates (x,y) and the luminance values. We have to note that, for this meter, the total uncertainty (RMS) is 4.1%. The minimum luminance which provides accurate measurements is 3.5 cd/m^2 (i.e., L_{min} = 3.5 cd/m^2). The correlated color temperature of the source, as measured by the meter, is T = 2761 K. The chromaticity coordinates and luminance values are

shown in Table II. The table, also, presents the luminous transmittance values (LT) expressed as in equation 0.1. The source luminance (using no filter) measured by this meter is $L_{max} = 2725$ cd/m^2.

- **The THOMA meter**
  This meter measures the tristimulus values with passive bandpass filters. The results of the measurements are shown in Table III. The empty cells in the table are due to meter overflow. Because of the meter overflow, the luminance of the source, L_{max}, could not be measured using this meter (see Table III). For this reason, the transmittance values are calculated with respect to the reference luminance L_n, i.e. as shown in Eq. (0.1) with $L_{max} = L_n = 2927$ cd/m^2.
- **The LMT-L1003 (IPO 4006) meter**
  This meter only measures the luminance values. The luminance of the source was measured to be $L_{max} = 2910$ cd/m^2. Both the (measured) luminance and the (calculated) transmittance values are presented in Table IV.

2. EVALUATION

All meters provide luminance values, so that the relative transmittance can be calculated as:

$$LT = \frac{L}{L_{max}} 100\%, \tag{0.1}$$

where L_{max} is the source luminance (using no filter) measured by the meter. The chromaticity and luminance values, measured by the three different meters, are compared to the corresponding values in Table I, which are offered by the manufacture as reference. The values Δx and Δy in Tables II and III are calculated as follows:

$$\Delta v = v_{meas} - v_{ref}, \tag{0.2}$$

where v_{ref} is the reference value (of x or y) as given by the manufacture, and v_{meas} is the measured one.

The values R1, R2, and R3 shown in Tables II, III, and IV, respectively, are calculated as the ratio of the measured LT, by each meter, to the reference value (LT_{ref}) presented in Table I. The average relative accuracy (A.R.A.) value, in Table IV, is calculated as the sum of the R3 values, at each filter specification, divided by the total number of filters. In tables II and III, the average values of R1 and R2, respectively, are calculated in a similar way, except that the transmittance ratio at the filter B-3 is disregarded. In this case, the values of R1 = 3.00 and of R2 = 0.50 may be due to a measuring failure, since the accuracy of both SPECTRASCAN and THOMA meters decreases at low luminance level.

3. CONCLUSIONS

If we look at the transmittance ratios R1, R2, and R3 (and their averages) in Tables II, III, and IV, respectively, we notice that the transmittance values, calculated for both the SPECTRASCAN and LMT-L1003 meters, are similar and comparable to the reference values. However, the LMT-L1003 meter provides a source luminance of $L_{max} = 2910$ cd/m^2 (as compared to $L_{max} = 2725$ cd/m^2, read by the SPECTRASCAN meter), which is closer to the reference L_n. The THOMA meter readings result in transmittance values that are further away from the reference values in the low luminance range, i.e. the R- and B-filters luminances. Another problem with the THOMA meter is that it overflows at Luminance values ≥ 1000 cd/m^2 for a white source. When we compare the measured values to the reference values, we end up with the following results:

- **Readings of the SPECTRASCAN PR 650 meter**
  On average the relative luminance measurements are reasonable accurate (3%). The accuracy at the highest luminance (no filter) is somewhat less $\frac{L_n - L_{max}}{L_n} = 6.9\%$.
  Red (R-) filters: $|\Delta x| \leq 0.006$, $|\Delta y| \leq 0.001$.
  Yellow (Y-) filters: $|\Delta x| \leq 0.004$, $|\Delta y| \leq 0.004$.
  Green (G-) filters: $|\Delta x| \leq 0.009$, $|\Delta y| \leq 0.012$.
  White (W-) filters: $|\Delta x| \leq 0.010$, $|\Delta y| \leq 0.006$.
  Blue (B-) filters (except B-3): $|\Delta x| \leq 0.012$, $|\Delta y| \leq 0.030$.
- **Readings of the THOMA meter**
  On average the relative luminance measurements are fairly accurate (6%). The absolute accuracy cannot be calculated.
  Red (R-) filters: $|\Delta x| \leq 0.023$, $|\Delta y| \leq 0.051$.
  Yellow (Y-3) filter: $|\Delta x| \leq 0.019$, $|\Delta y| \leq 0.023$.
  Green (G-) filters: $|\Delta x| \leq 0.011$, $|\Delta y| \leq 0.022$.
  White (W-) filters: meter overflow.
  Blue (B-) filters (except B-3): $|\Delta x| \leq 0.023$, $|\Delta y| \leq 0.010$.
- **Reading of the LMT L1003 luminance meter**
  On average the relative luminance measurements are reasonable accurate (2%). The accuracy at the highest level is even better $\frac{L_n - L_{max}}{L_n} = 0.6\%$.

REFERENCES

[1] SpectraColorimeter Operating Manual (Release Number 9903-0006-05 Rev.B), Chastworth, California, 1992.

[2] Martens, J.B., Image Technology (Class Notes), 1993-1994.

Table I: M.E.L. Chromaticity Reference filters

Chromaticity coordinates and Luminous Transmittance values (LT_{ref}) obtained in combination with Luminous Normal LN2.

- $L_n = 2927\ cd/m^2$.
- Color coordinates at 2856 K.

Filter	x	y	z	LT_{ref} (%)
R-1	.7190	.2809	.0000	4.30
R-2	.6641	.3291	.0067	24.71
R-3	.6979	.3017	.0004	12.86
Y-1	.5991	.3974	.0035	50.17
Y-2	.5469	.4443	.0088	73.43
Y-3	.4999	.4884	.0117	18.86
G-1	.2461	.5572	.1967	34.33
G-2	.1971	.6548	.1481	18.36
G-3	.3027	.6026	.0947	37.89
G-4	.3430	.5010	.1560	54.49
G-5	.2424	.6096	.1480	29.24
W-1	.4482	.4184	.1334	88.18
W-2	.4986	.4286	.0728	80.44
W-3	.4962	.3938	.1100	71.99
W-4	.4500	.3836	.1665	66.80
B-1	.1491	.2049	.6460	4.73
B-2	.2066	.2056	.5878	4.66
B-3	.1706	.0604	.7689	0.02
B-4	.1108	.1483	.7410	0.22
B-5	.1711	.1341	.6948	1.76
None	.4475	.4074	.1450	

Table II: SPECTRASCAN PR 650

Chromaticity and luminance measurements (1/6/94)

- A.R.A.: Average Relative Accuracy.
- T = 2761 K.
- Field of measurement = 1 deg., distance source-meter ~ 1 m.
- R1 = LT/LT_{ref}.
- $[(L_n - L_{max})/L_n]x100\ (\%) = 6.9\%$.

Filter	x	Δx	y	Δy	L(cd/m^2)	LT(%)	R1
R-1	.713	-.006	.282	.001	130	4.77	1.11
R-2	.663	-.001	.329	.000	705	25.87	1.05
R-3	.695	-.003	.302	.000	373	13.69	1.06
Y-1	.601	.002	.395	-.002	1411	51.78	1.03
Y-2	.551	.004	.440	-.004	2043	74.97	1.02
Y-3	.504	.004	.484	-.004	525	19.27	1.02
G-1	.255	.009	.569	.012	954	35.01	1.02
G-2	.206	.009	.660	.005	505	18.53	1.01
G-3	.311	.008	.604	.001	1049	38.49	1.02
G-4	.352	.009	.509	.008	1520	55.78	1.02
G-5	.251	.009	.616	.006	812	29.80	1.02
W-1	.458	.010	.424	.006	2459	90.24	1.02
W-2	.507	.008	.430	.001	2249	82.53	1.03
W-3	.505	.009	.397	.003	2008	73.69	1.02
W-4	.460	.010	.390	.006	1872	68.70	1.03
B-1	.154	.005	.228	.023	132	4.84	1.02
B-2	.215	.008	.224	.018	128	4.70	1.01
B-3*	.268	.097	.155	.095	1.72	0.06	3.00
B-4	.123	.012	.178	.030	6.61	0.24	1.09
B-5	.182	.011	.154	.020	50.7	1.86	1.06
None	.457	.010	.413	.006	2725	100	
A.R.A.							1.03

Table III: THOMA meter

Chromaticity and luminance measurements (3/6/94)

- A.R.A.: Average Relative Accuracy.
- Meter placed on the source.
- Empty cells ==> overflow.
- R2 = LT/LT_{ref}.

Filter	x	Δx	y	Δy	L(cd/m^2)	LT(%)	R2
R-1	.735	.016	.230	-.051	106	3.62	0.84
R-2							
R-3	.721	.023	.263	-.039	327	11.17	0.87
Y-1							
Y-2							
Y-3	.519	.019	.465	-.023	530	18.11	0.96
G-1	.251	.005	.570	.013	1026	35.05	1.02
G-2	.199	.002	.677	.022	537	18.35	1.00
G-3	.314	.011	.606	.003	1123	38.37	1.01
G-4							
G-5	.247	.005	.623	.013	854	29.18	1.00
W-1							
W-2							
W-3							
W-4							
B-1	.132	-.017	.215	.010	132	4.51	0.95
B-2	.196	-.011	.205	-.001	121	4.13	0.89
B-3*	.142	-.029	.048	-.012	0.39	0.01	0.50
B-4	.088	-.023	.155	.007	5.88	0.20	0.91
B-5	.161	-.010	.135	.001	46.0	1.57	0.89
None							
A.R.A.							0.94

Table IV: LMT-L1003 (IPO 4006)

luminance measurements (1/6/94)

- A.R.A.: Average Relative Accuracy.
- Field of measurement = 1 deg., distance source-meter ~ 1m.
- $R3 = LT/LT_{ref}$.
- $[(L_n - L_{max})/L_n]x100\ (\%) = 0.6\%$.

Filter	L(cd/m^2)	LT(%)	R3
R-1	134.5	4.62	1.07
R-2	744	25.57	1.03
R-3	389	13.37	1.04
Y-1	1508	51.82	1.03
Y-2	2180	74.91	1.02
Y-3	566	19.45	1.03
G-1	1021	35.09	1.02
G-2	538	18.49	1.01
G-3	1125	38.66	1.02
G-4	1629	55.98	1.03
G-5	869	29.86	1.02
W-1	2625	90.21	1.02
W-2	2400	82.47	1.03
W-3	2140	73.54	1.02
W-4	1990	68.38	1.02
B-1	135.9	4.67	0.99
B-2	132.4	4.55	0.98
B-3	0.640	0.02	1.00
B-4	6.20	0.21	0.95
B-5	50.8	1.75	0.99
None*	2910	100	
A.R.A.			1.02