

Mesopic LED Light Source for Automotive Luminance and Color Measurements

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Contents

- What led up to our Mesopic Light Source activity?
(brief discussion of the Low Cost ILLUMINANT A Std)
- Photos and Discussion of Automotive Light Sources (Instrument Panels/clusters and Center Consoles) under Light and Dark Conditions
- Measurement Area
- Feature Size
- Measurement Luminous Specs from a number of Auto Mfrs and Suppliers
- Where is the Mesopic luminance region?
- What does this low cost Mesopic Light Source/Transfer Standard look like?



Contents Continued

- How is the LED Mesopic Light Source Constructed?
- What do the measurements look like that we get with these simple Transfer Standards ? – Results from Four units 3 Green and 1 Red
 - a. Tables of Average Luminance and Color Data from each unit
 - b. Luminance Graphs Places on all units
- Issues with current conventions as to the Mesopic Luminance and Color and current practice of just using Photometric Luminance and Color
- Areas where there is a need for a LED Mesopic Transfer Standard for use in Automotive Industry
- Conclusions
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2006 SET UP IN LAB OF LIGHT SOURCE FILTERS,
POWER SUPPLY, CA-2000 2D COLOR ANALYZER
POSITIONING BENCH & COMPUTER



2006 LAB TEST OF LIGHT SOURCE WITH EIGHT
APERTURES HOLDING VARIOUS WRATTEN
GELATIN FILTERS



RGB PICTURE OF THE 8 APERTURES USED IN THE TEST



1. CC10M
2. Two 82B
3. 82B
4. 82C
5. CLEAR
6. CLEAR
7. TWO 82C
8. CC10M

POSITIONS
AND # OF
APERTURES

	1	2		
3	4	5	6	
	7	8		

Our Experimental Light source was near Illuminant “A” using two Wratten Gelatin 82B filters and Nd glass filter Incandescent Lamp at 7V and Opal Glass filter we achieved a light source whose color and LO were $x=0.4539$, $y=0.4026$, $LO=30.08\text{cd/m}^2$.

Note: 2856K (CIE 1964) $x=0.4512$, $y=0.4059$

The reference for this work can be found in the article;

Robert L. Donofrio, Application of a 2D Colorimeter in Constructing an Automotive Laboratory Secondary Light Source Illuminant “A”, SID 2006 Vehicles and Photons Symposium, Oct 12-13, 2006, pp 37-42.



2008 Ford Escape interior showing Instrument Cluster and Center Control Console

and

Night time Driving mode using Blue-White LED



Samples of Instrument Cluster Icons



2004 Chrysler Pacifica Automotive Gauges in light and dark ambient conditions



Dark Ambient illuminated sections of a 1999 Lincoln Continental Instrument Cluster



Artist Concept of Future Automotive Displays from Yazaki



Simulated Measurement of Illuminated Icon region



Feature Size and Light Level

Feature Size:

We have found that the features in the character/icon can be in the range of 0.5mm wide where 0.2 mm is the smallest stroke and 0.3mm is the smallest pixel and

Light Level:

requirements can vary from 100 to 0.2 cd/m².



Luminance Levels involved with lighting of instrument Cluster and or Icon luminance under night conditions for Various Automotive Manufactures and Suppliers

Ford – Night Driving 0.75-3.5 fL in different Zones or about 2.5 cd/m² to 12cd/m² for their (ICE BLUE) blue white LED lighting

GM – 0.1 cd/m² minimum (specs GMW 15118 and GMW15327)

Chrysler (1992) – 1.7cd/m²

TRMI – 1.0 cd/m²

DENSO – non-dimming red - 25cd/m²

VDO – 0.1 cd/m² is minimum

Yazaki – 0.1cd/m² (as required by customers such as GM etc.)



MESOPIC LUMINANCE LIGHT LEVEL INFORMATION

Wyszecki & Stiles –Color Science 1982 - CIE 1978 0.001- 3cd/m²
Page 406 - Johnson 1937 upper limit 5 to 15 cd/m²
1999 Lewin (Lamp Color and Visibility in Outdoor Lighting) –
Roadway/Mesopic region 0.001-3.0 cd/m²

CIE TC1 -58 Mesopic region 0.001cd/m² – 10cd/m²

2003 article by Schanda etal 0.001 cd/m² – 3 cd/m²

2005 MOVE (Mesopic Optimization of Visual Efficiency) HUT
- 0.01cd/m² – 10/cd/m²

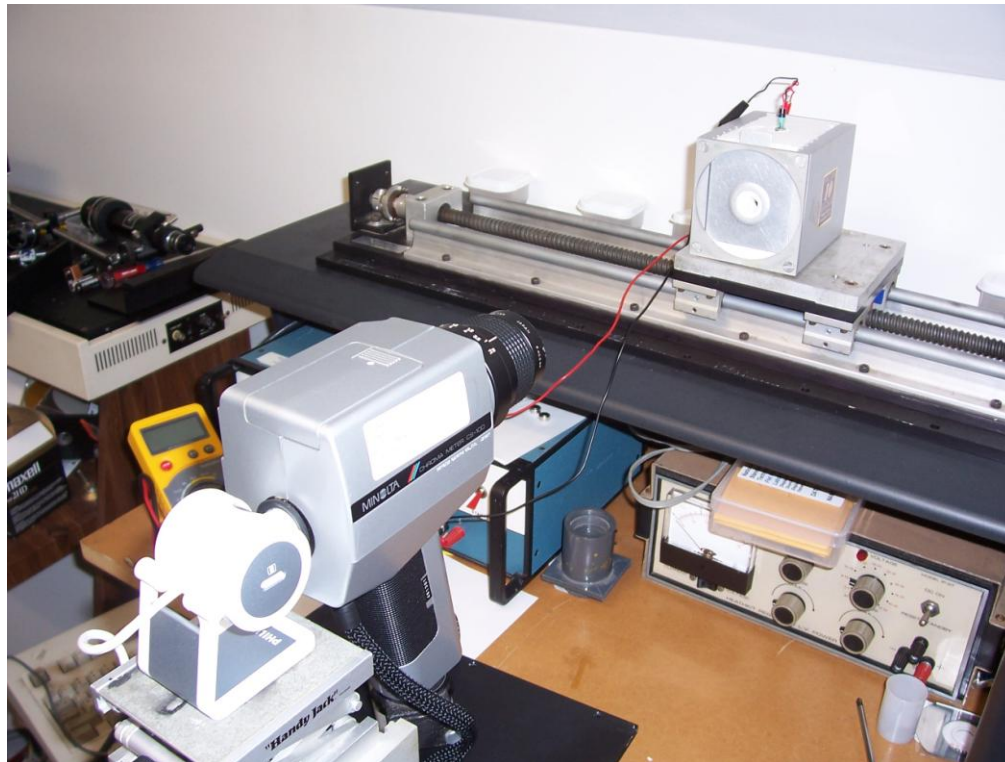
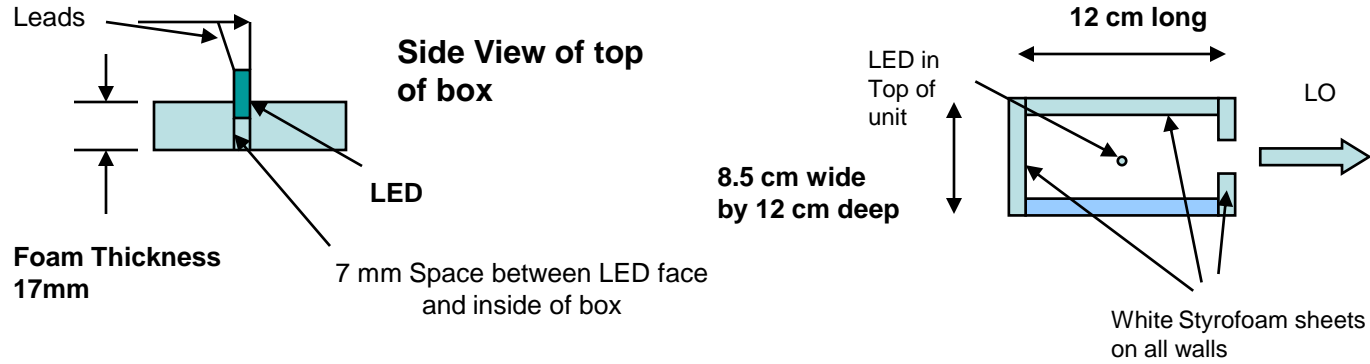
2006 Eloholma presentation Analysis of Performance based Mesopic Models on
New Data Sets - Adaptation levels 0.003 -10cd/m²

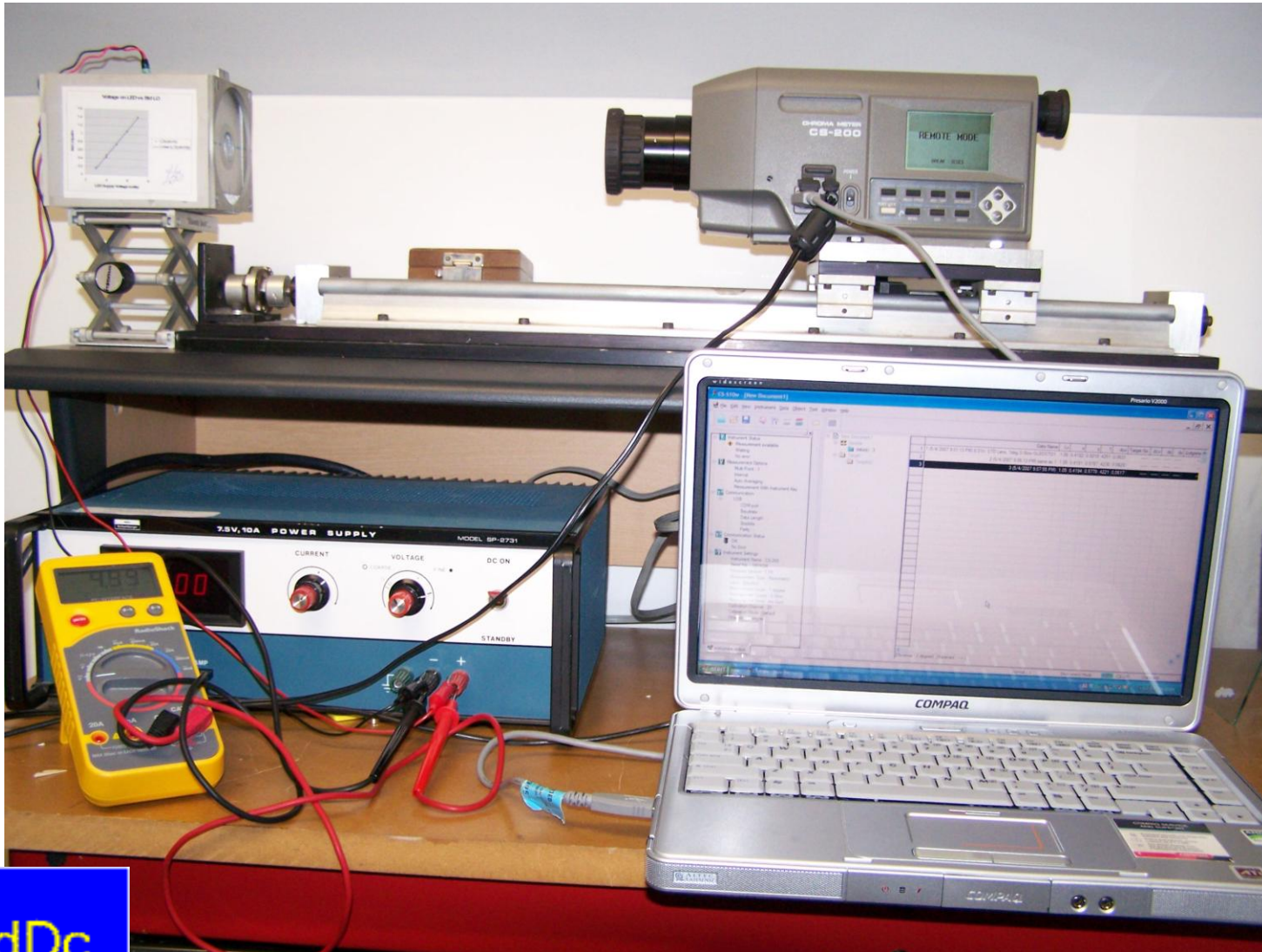
2006 Bullough (RPI) Light for Health and Vision, Mesopic Vision - Looks at 0.1-
1.0 cd/m² in his study

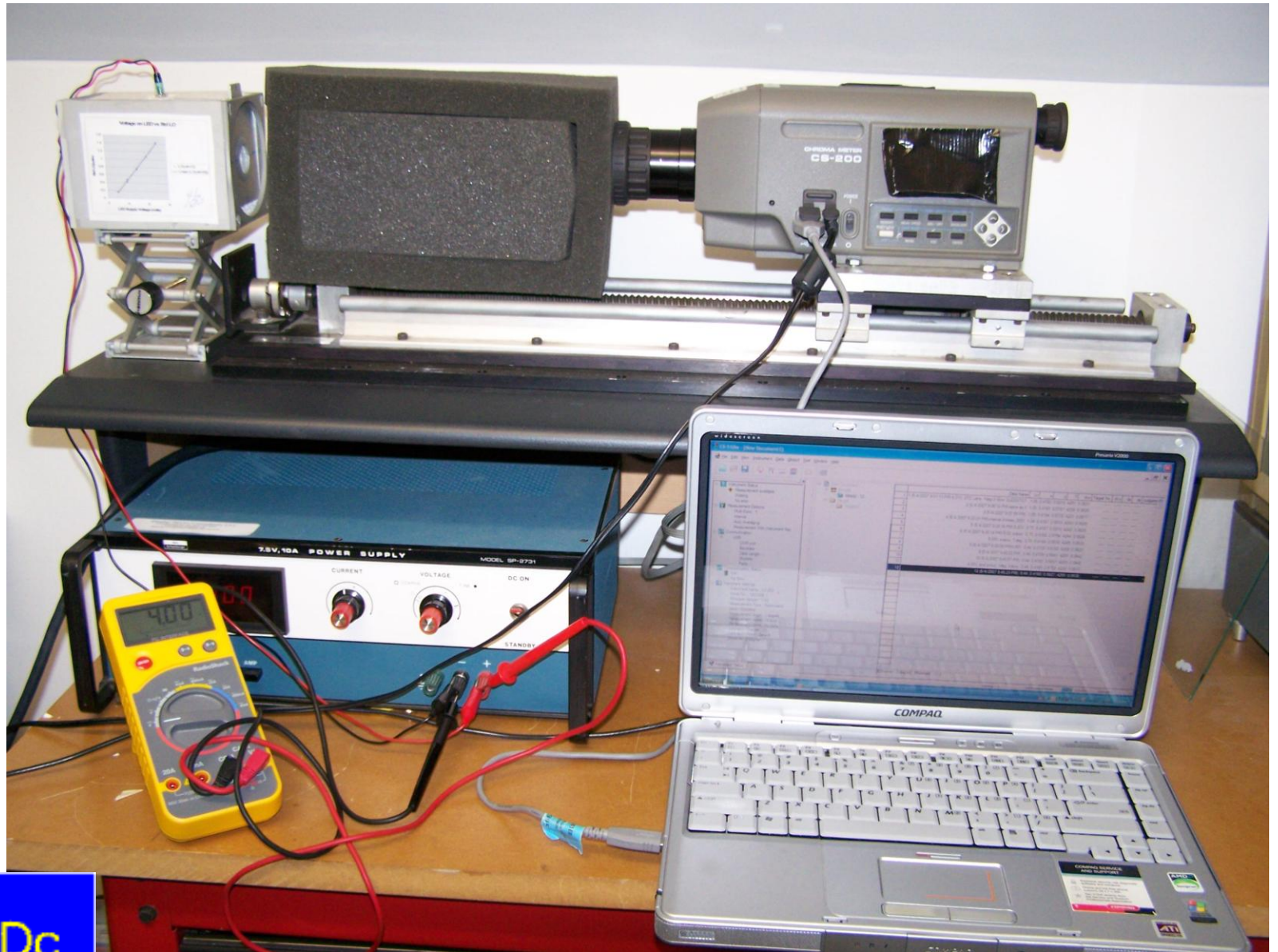
IESNA TM-12-06 Spectral Effects of Lighting on Visual Performance at Mesopic
Light Levels – luminance below 1.0 cd/m²



Design and Testing of the Mesopic LED Light Source/ Transfer Standard







Luminance and Color Measurements (CIE 1931) on LED Transfer Standard

Lamp V	LO(cd/m ²)	x	y	Lamp V	LO(cd/m ²)	x	y
7.00V	1.36	0.4178	0.5794	4.00V	0.41	0.4122	0.5826
+/-0.01	1.34	0.4175	0.5825	+/- 0.01	0.41	0.4135	0.5826
	1.34	0.4161	0.5811		0.41	0.4129	0.5888
	1.34	0.4167	0.5801		0.41	0.4121	0.5827
6.00V	1.02	0.4166	0.5818	3.000V	0.16	0.4167	0.5833
+/- 0.01	1.03	0.4158	0.5822	+/-0.001	0.16	0.4075	0.5822
	1.03	0.418	0.5892		0.16	0.4161	0.5839
5.00V	0.71	0.4145	0.5892	2.500V	0.06	0.4109	0.5897
+/-0.01	0.71	0.4145	0.5840	+/-0.001	0.06	0.4107	0.5833
	0.71	0.4143	0.5842		0.06	0.4060	0.6000
					0.06	0.3917	0.5617



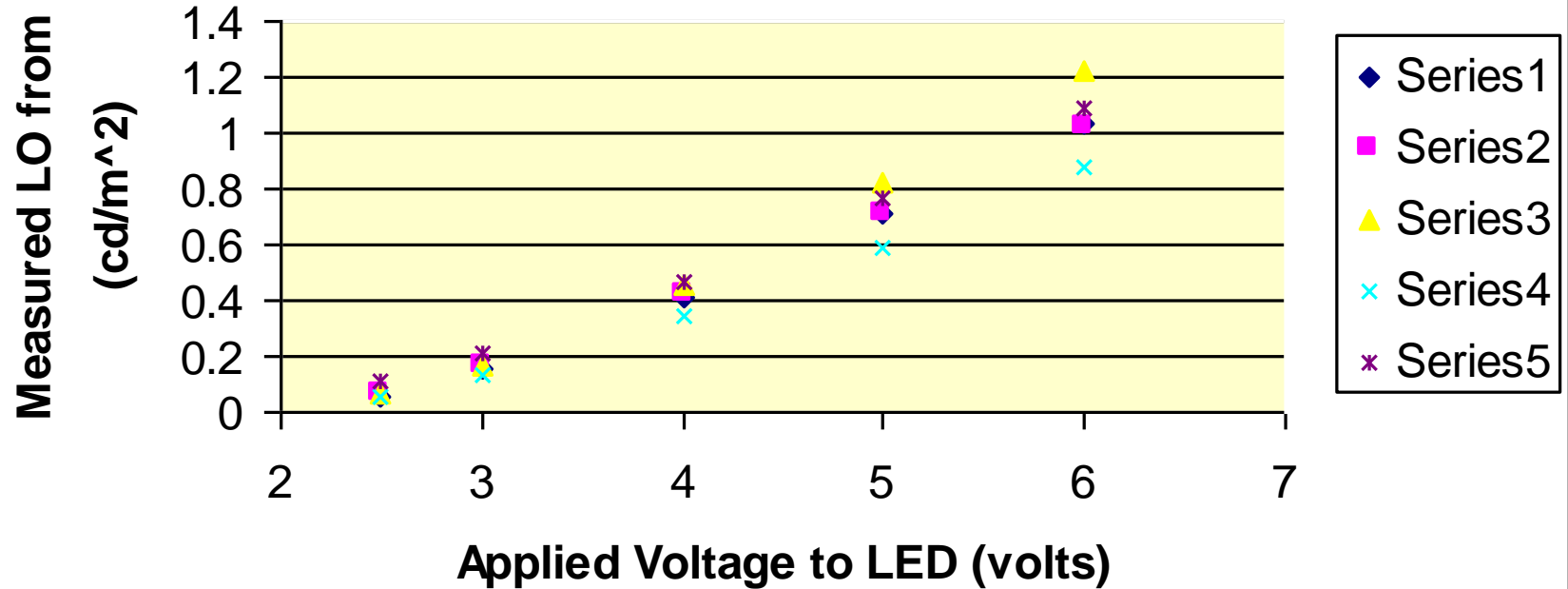
Showing results of reducing LED Lamp Voltage using CS-200

Table of CIE (1931 color coordinates) and Applied Voltage for the 3 Green LED and 1 Red LED Mesopic Stds.

V	G STD #1 11/1/06		G STD #1 5/2/07		G STD #2		G STD #3		R STD	
	x	y	x	y	x	y	x	y	x	y
6.00	0.42	0.58	0.42	0.58	0.42	0.58	0.42	0.58	0.7	0.3
5.00	0.41	0.59	0.42	0.58	0.42	0.58	0.42	0.58	0.7	0.3
4.00	0.41	0.58	0.41	0.58	0.42	0.57	0.42	0.58	0.7	0.3
3.000	0.41	0.58	0.41	0.57	0.42	0.57	0.41	0.58	0.7	0.3
2.500	0.40	0.58	0.41	0.58	0.42	0.57	0.41	0.56	0.7	0.3



LO vs Voltage for 4 LED Mesopic Light Sources / Transfer Stds.

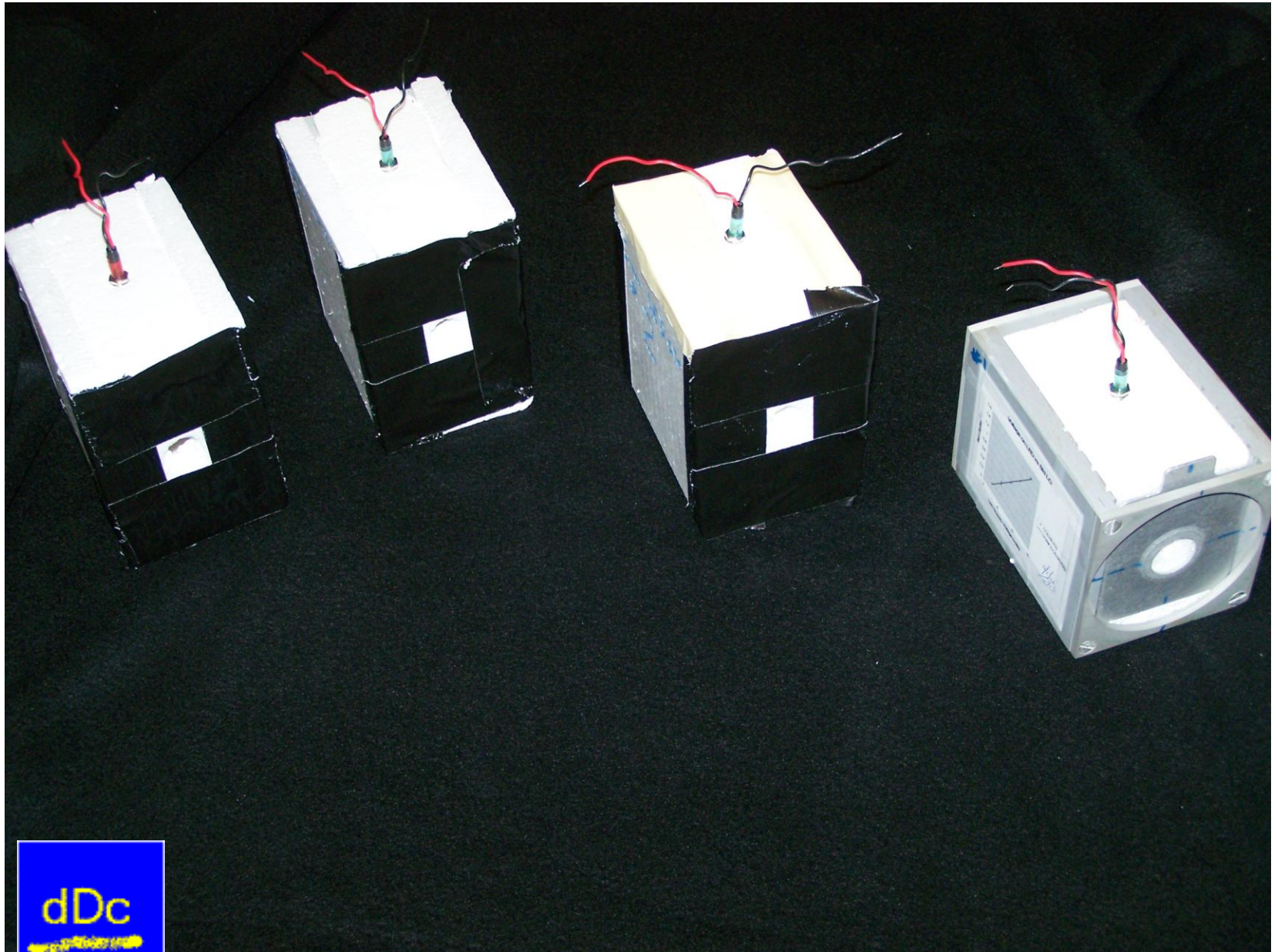


Series 1=G LED Std #1 11/1/06, Series 2=G LED Std #1 5/07

Series 3 = G LED #2, Series 4 = G LED #3 and Series 5= Red LED

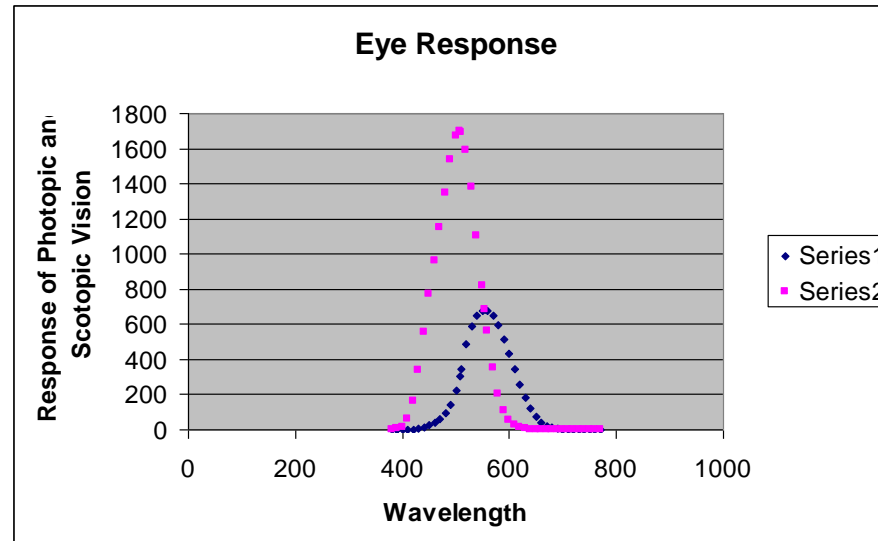






Issues with Mesopic LO and Color Measurement

1. Generally we use (by Convention) Photopic Eye Response and not Mesopic.
2. It is known that both the Eye Response and Color observed varies with Luminance – What corrections do we have other than the eye response curves between the Photopic and Scotopic as seen below?



Continuation of Mesopic Issues

3. We know that the Photopic range is above 3.4 cd/m^2 and the Scotopic is below 0.034 cd/m^2 (in some of the literature this is below 0.001 cd/m^2). Note Judd and Wyszecki (ref 3) claim the region to be from 0.001 cd/m^2 to 125 cd/m^2 .
4. Recommended Practice for the minimum luminance of Roadway Lighting to be 0.3 cd/m^2 .
5. Thus the whole range of the data we measured with our Light Sorce/Std. is in the Mesopic region. However, in this region we should not use the CIE 1931 values of Luminance and Color as they are clearly in error here. It has been stated the Sylvania reference (ref 7) that they use the Photopic response here as “a convention”.
6. Slightly off the topic is the contrast measurements by VESA on LCDs with black level of 0.18 cd/m^2 which is clearly in the Mesopic Region



Areas Where There Is Need for the Mesopic Light Source/ Transfer Standard

Optical Measurement Sales Reps – Test equipment before going to customer

Lab Techs - in Automotive (both auto manufacturer and first and second tier parts manufacturer) – To periodically Check out Instrumentation for major parameter changes

Engineers to test out their light level Designs and insert various Icons in front of Transfer Std.

Probably others



Conclusions

1. We have developed a low cost method of generating an LED Mesopic Transfer std for Automotive applications.
2. Showed that the minimum light level for Automotive night lighting is usually in the Mesopic light level region.
3. Measurements on Green STD #1 show that data is reasonably reproducible after 6 months.
4. We recommend that these low light level measurements are to be made with light shield such as a “Snout used in this study”.
5. Improved units can be made with Intensity corrections (for example via a change in aperture near LED) and should be put in more durable housings
6. Units can also be used for visual testing at Mesopic light levels to see how the Mesopic LO and color varies for Automotive Applications



References:

1. Robert .Donofrio “An Illuminant “A” Secondary Standard for Automotive Applications”, 2006 SID Symposium on Vehicle Displays and Photons, Oct 2006.
2. Robert Donofrio “The Evolution of Automotive Displays”, Photonics Spectra. Feb 2007. (to be published)
- 3a. Judd and Wyszecki “Color Science in Business, and Technology, “The region between 10^{-3} and 125 cd/m^2 is called the Mesopic region in which both the rods and cones are active
- 3b Flat Panel Display Measurements Standard Version 1.0 (VESA – Video Electronics Standards Associaton) may 15th, 1998 page 43. also in Version 2.0 June 1, 2001 page 43.
4. Dr. E. Kelley. 2006 NIST Course on Display Metrology. Lecture & Lab notes.
5. Konica Minolta Technical Note
KMSE -TI-06002
6. [hyperphysics.phy- astr.gsu.edu/
hbase/vision/bright.html](http://hyperphysics.phy-astr.gsu.edu/hbase/vision/bright.html)
7. Sylvania article “ Lumens and Mesopic Vision, FAQ 16-0297



Appendix 1 – Complete data on Green LED Std #1 Voltage Measurements for 11/06 & 5/07

V	G STD #1 11/1/06			G STD #1 5/2/07		
	LO	x	y	LO	x	y
6.00v	1.02	0.4166	0.5818	1.02	0.4192	0.5774
	1.03	0.4158	0.5822	1.01	0.4162	0.5781
	1.03	0.418	0.5892	1.02	0.417	0.579
5.00v	0.71	0.4145	0.5892	0.71	0.415	0.5769
	0.71	0.4145	0.584	0.71	0.418	0.582
	0.71	0.4143	0.5842	0.71	0.4156	0.5778
				0.72	0.4183	0.5777
4.00v	0.41	0.4122	0.5826	0.43	0.4141	0.5778
	0.41	0.4135	0.5826	0.43	0.4149	0.5784
	0.41	0.4129	0.5888	0.43	0.4151	0.5768
	0.41	0.4121	0.5827	0.41	0.4148	0.574
3.000v	0.16	0.4167	0.5833	0.17	0.4184	0.5816
	0.16	0.4075	0.5822	0.17	0.4201	0.5799
	0.16	0.4161	0.5839	0.17	0.4187	0.5813
2.500v	0.06	0.4109	0.5897	0.07	0.4146	0.5772
	0.06	0.4107	0.5833	0.07	0.4083	0.5917
	0.06	0.406	0.6	0.07	0.4065	0.5935
	0.06	0.3917	0.5617	0.07	0.4094	0.5748



Appendix 2 . Comparison of Green LED Stds. #1, #2 & #3 for 6.00V and 5.00V

G STD #1 5/2/07			G STD #2			G STD #3		
LO	x	y	LO	x	y	LO	x	y
1.02	0.4192	0.5774	1.22	0.4218	0.5758	0.88	0.4202	0.5798
1.01	0.4162	0.5781	1.22	0.4213	0.5726	0.88	0.4181	0.5766
1.02	0.417	0.579	1.22	0.4213	0.5736	0.87	0.4179	0.5742
1.02	0.4194	0.5806	1.22	0.4228	0.5772	0.88	0.4202	0.5772
			1.22	0.4227	0.5773	0.88	0.4192	0.5762
0.71	0.415	0.5769	0.82	0.4213	0.5787	0.58	0.418	0.5751
0.71	0.418	0.582	0.83	0.4206	0.5752	0.59	0.4195	0.5805
0.71	0.4156	0.5778	0.82	0.4219	0.5746	0.59	0.4193	0.5797
0.72	0.4183	0.5777	0.82	0.4194	0.5729	0.59	0.4186	0.5775
			0.82	0.4219	0.5781	0.59	0.4205	0.5795



Appendix 3 Continued Comparison of Green LED Stds. #1, #2 & # 3 for 4.00V, 3.000V and 2.500V

G STD #1 5/2/07			G STD #2			G STD #3		
LO (cd/m ²)	x	y	LO (cd/m ²)	x	y	LO (cd/m ²)	x	y
0.43	0.4149	0.5784	0.46	0.4159	0.5716	0.33	0.4159	0.5789
0.43	0.4151	0.5768	0.46	0.4209	0.5766	0.34	0.4136	0.5864
0.41	0.4148	0.574	0.47	0.4227	0.5748	0.34	0.416	0.5739
0.41	0.4157	0.5787	0.46	0.4191	0.5734	0.33	0.4139	0.5791
0.17	0.4184	0.5816	0.17	0.4189	0.5811	0.13	0.4115	0.5531
0.17	0.4201	0.5799	0.17	0.4197	0.5639	0.13	0.4057	0.5943
0.17	0.4187	0.5813	0.17	0.4175	0.5657	0.12	0.4151	0.5802
0.17	0.4045	0.5502	0.17	0.4149	0.5851	0.13	0.4091	0.5909
0.17	0.4054	0.5743	0.16	0.422	0.578	0.13	0.4204	0.5796
0.07	0.4146	0.5772	0.07	0.4298	0.5702	0.05	0.4043	0.5638
0.07	0.4083	0.5917	0.07	0.4	0.5667	0.05	0.4	0.5263
0.07	0.4065	0.5935	0.06	0.4059	0.5941	0.06	0.4271	0.5729
0.07	0.4094	0.5748	0.07	0.4224	0.569	0.06	0.3981	0.5825

