ColorCalculator User Guide

by

OSRAM Sylvania, Inc.

Contents

ColorCalculator User Guide

I. Overview

The ColorCalculator software was developed by Osram Sylvania, Inc to help users design color mixing LED lighting solutions. The software has three main modes of operation along with several other useful features. The main start-up window is shown in Figure 1.

The three main modes of operation are:

1) General photometry.
   - The user either selects the intensity of several LEDs or inputs a spectrum and the program calculates several photometric quantities.
2) Design optimization.
   - A set of desired photometric values are specified by the user and the program calculates the intensity of the LEDs required to obtain the design.
3) Total combinations.
   - The user specifies a set of LEDs and the program calculates all of the designs possible based on this selection.

The photometric quantities are derived from equations given in CIE documents 13.3 and 15.2

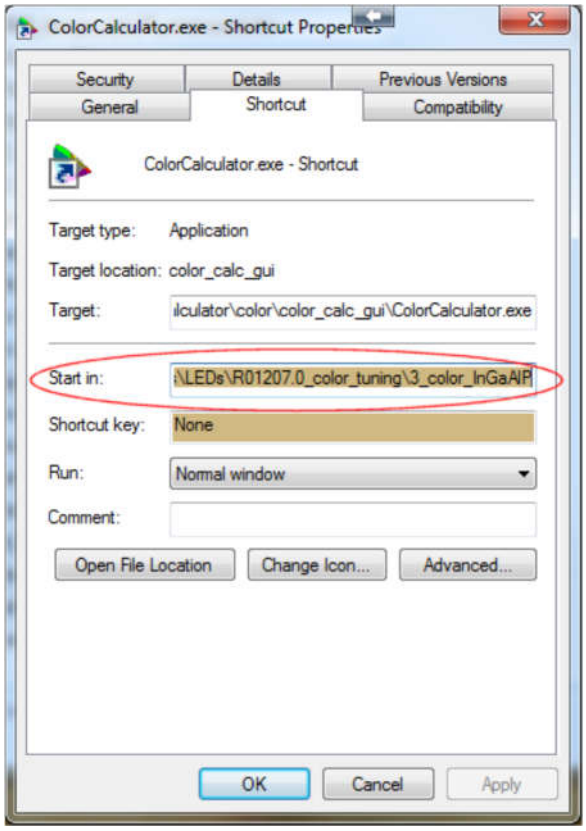
II. Installation and Program Files

The program is completely self-contained in the ColorCalculator.exe file, no other files or dll's are needed. The executable can be moved to any directory or copied to any computer without having to be installed. The program will create several file when run. These files have names such as: ColorCalculator.ini, userSpectra.spec, userFilters.fils, userColors.cols, photometry.txt. All of the files created by this program are in plain text can be viewed in a standard text editor but should not be changed by the user. Other files may be created but with user defined names.

1. Windows Version

The downloaded file is a self-extracting zip file. Save it you your hard drive and double-click. Select the folder you want to save the program in. Two files will be saved: ColorCalculator.exe and ColorCalculator_User_Guide.pdf (a copy of this document).

The files the program writes are written to the directory where the ColorCalculator.exe is located. You may want to put the ColorCalculator.exe in a central location and create Windows shortcuts to this exe in other folders. Then you can edit the “Start in:” directory of the shortcut so that all files will be written to the directory where the shortcut is located. In the example below the shortcut name is ColorCalc. You can put shortcuts in several directories and edit each shortcut so the “Start in” points to the local directory where the shortcut is. This is helpful if you are working on several different projects with different design requirements. See Windows help for more information on working with shortcuts.



2. Mac OS X Version

The Mac version runs in X Windows (X11). If you double-click the program and you only see a terminal window you need to install the X11 libraries. X Windows (X11) can be installed using the XQuartz project files (http://xquartz.macosforge.org/landing/).

The download file is ColorCalculator.dmg.zip, unzip it by double-clicking it. Open the .dmg file and save the two files within, ColorCalculator (the executable) and ColorCalculator_User_Guide.pdf (a copy of this document). You start the program by double-clicking the executable in Finder. The program will try and create a directory called “%HOME%/ColorCalculator_OSI/” where your user files and the ini files will be kept. If this directory cannot be created these files will be stored in your %HOME% directory.

III. Main Modes of Operation

Not all of the available menu commands will be discussed in details here. Most of them should be fairly obvious to the experienced designer or may be best understood by trying them. Also, if you let your mouse pointer hover over an input box many of the input boxes have a small pop-up help description.

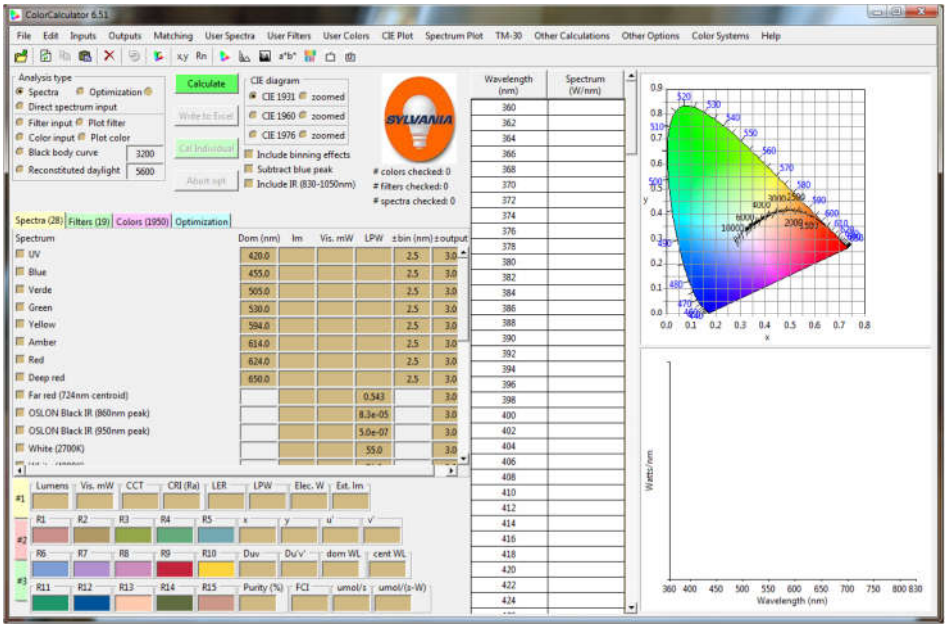


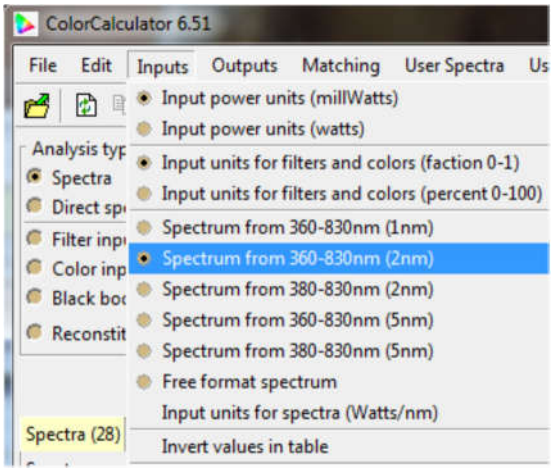
Figure 1. Main window at start-up.

1. General Photometry

The user selects the LEDs to include in the design (by checking them), enters the dominate wavelengths and the intensities. The intensity can be entered as watts or lumens and these can be mixed. Once the design is entered the “Calculate” button is clicked and the results are displayed in the window and the resultant spectrum is displayed in the table. The spectra from the individual LEDs are combined together additively to give the spectrum of the mix. By default, the photometry results are also written to a text file called “photometry.txt” in the directory where the ColorCalculator.exe is located.

The user can also enter a spectrum directly into the table. This is done by first selecting the “Direct spectrum input” as the “Analysis type” and pasting the spectrum into the table. You can enter the spectrum at predefined wavelength intervals or in a free format. The wavelength intervals can be selected from the menu item “Inputs->Spectrum from….”. If the “Inputs ->Free format spectrum” is used then the program will resample the entered data to the calculation points. The free format spectrum is

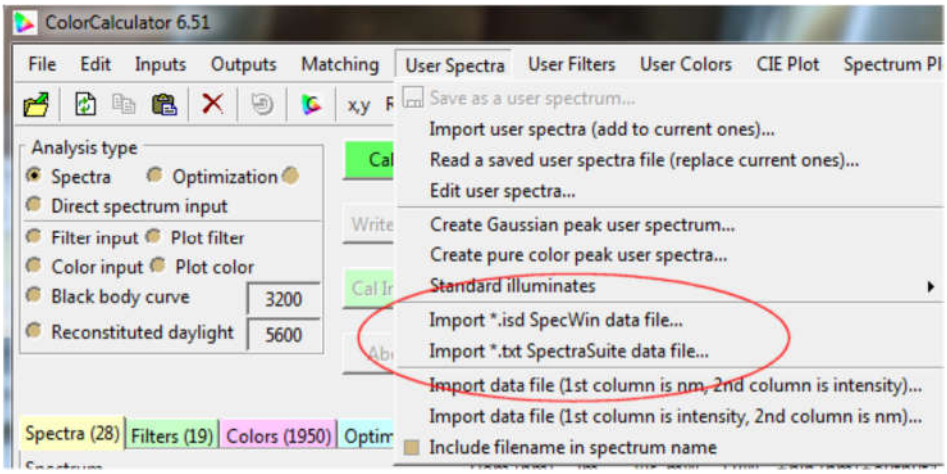
useful when importing data from photometric sphere measurements where the data is not measured at regular intervals.



Once a design has been entered it can be saved for later use. To save a spectrum first perform a calculation then click the menu item “User Spectra->Save as user spectrum”. You will be prompted to enter a name and a LPW. Entering the LPW is optional, you may leave this blank. All of the user spectra you save are written to a file called “userSpectra.spec” in the directory where the ColorCalculator.exe file is located. The “userSpectra.spec” file is in plain text and can be viewed in any standard text editor. Under the “User Spectra” menu item are several other functions useful in maintaining and manipulating your saved spectra.

The program can read certain file formats directly without the user having to cut-and-paste the data by hand. The program can read data files from the SpecWin and SpectraSuite software packages.The “SpectraSuite” format will also read-in an asc file with two columns of wavelength and intensity. You can encode the drive current and forward voltage in the filename and the program will parse these out and calculate the LPW and include this information in the photometry.xls file. Example files names are “test_led_3.1V_50mA.isd”, “test led 3.1V 50mA.isd” and “test led 50mA 3.1V.isd”. The important feature is that you must use ”V” to indicate the forward voltage and “mA” to indicate the drive current, with no space between the number and the symbol. Both must be surrounded by ether underscores or spaces or be at the beginning or end of the file name for this feature to work. You can also use “W” for readings from a watt meter.

Spectra for current LEDs from OSRAM Opto Semiconductors can be downloaded from our web site at https://apps.osram-os.com/Characteristic



2. Design Optimization

The user selects several LEDs to include in a design, specifies a set of photometric targets and the program adjusts the intensity of the LEDs to reach the target design. It is best to first find a design that is reasonably close to your target, as described in the previous section. In Figure 2 the optimization method is "Target a CRI". The target CRI is defined as 80 with a CCT within 50K of 3000K and a Delta(uv) of 0.002. Also, a minimum R9 of 40 is specified. Only some of these parameters need to be specified. If an input box is left blank it will not be constrained. Once you click the "Calculate" button the program will prompt you to enter any required values that you left blank. In order to optimize for the LPW, the LPW of all of the LEDs included in the design must be specified. You will be prompted if any are missing.

The TM-30 optimization method can work in 2 ways. You can enter targets for the R_f, R_g and/or $R_{f,skin}$ and the program will try to hit these targets. Only one of these need be entered. Another way this method works is if you enter a '+' sin in either the R_f or R_g fields the metric with the '+' symbol will be maximized. Any other parameters entered will be used a minimum values.

If your optimization is successful the new intensity values will be copied to the correct input boxes for you to run a complete calculation. If you do not like the design you may return to the original intensity values by clicking the "Reset values" button. If the optimization is not successful you may need to relax some of the optimization constraints, begin with a better design or add more LEDs to the design.

While design optimization is a very powerful tool it may not be the best approach to find a desirable design. One of the drawbacks is that it gives you only one "best" design. There may be a design that is very close to the "best" but has some advantages that would lead you to select it over the "best" design if you were aware of it.

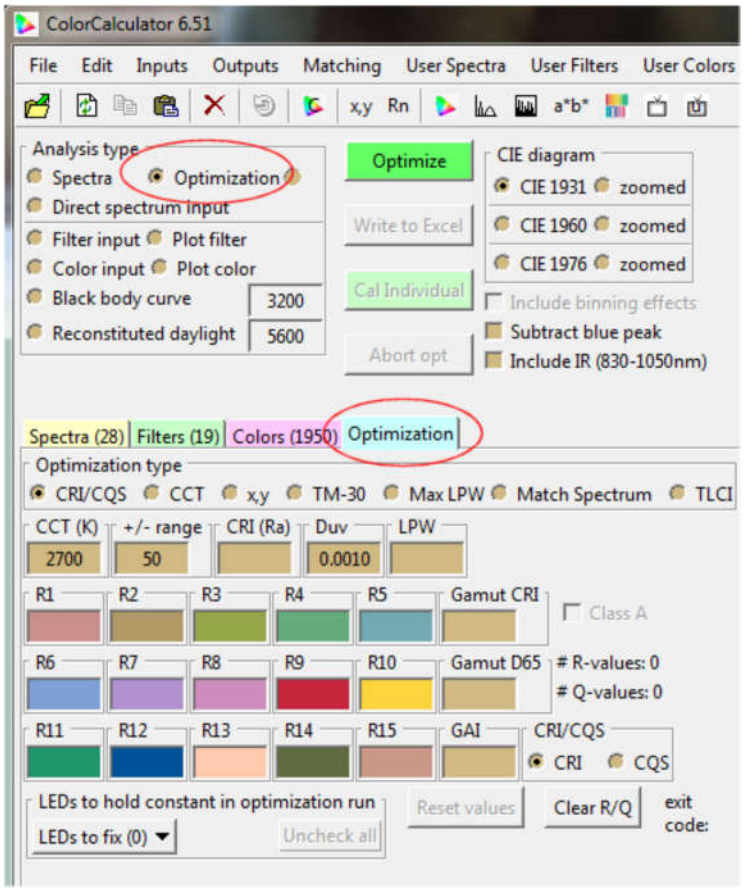


Figure 2. Portion of the main window used to define the optimization targets.

IV. Other Functionality

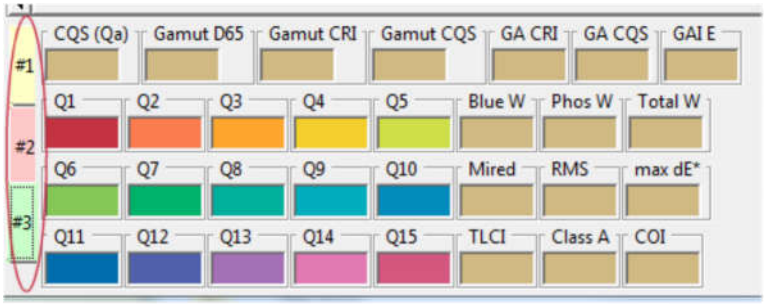
1. Filters

A filter is used in some applications to control some aspect of the light. You can enter and save a filter much in the same way as a spectrum can be saved. To enter a filter select the “Filter input” “Analysis type” and paste your transmission data directly into the table, click the “Calculate” button to have the program check the data. You can then use the “User Filters” menu item to save or manipulate your user filters as you would your user spectra. The transmission is defined as between 0 and 1 or as a percent from 0 to 100. The units can be changed in the “Data” menu item. The saved filters are saved to a plain text file called “userFilters.fils”.

If you use filters it is helpful to create a user spectrum that has a value of 1 for the intensity at all wavelengths. This can be used to check your filters by selecting the constant spectrum and a filter. The resultant plot will be a plot of the transmission of the filter.

2. Color Quality Scale (CQS)

The Color Quality Scale is being developed by NIST (National Institute of Science and Technology) as a possible replacement for the Color Rendering Index (CRI) for use with LED light sources. A full description of the CQS is given in W. Davis, Y. Ohno, Optical Engineering, v49(3), 033602 (March 2010). The user can switch back-and-forth between the CRI and CQS using the tabs at bottom left of the main window as highlighted below.



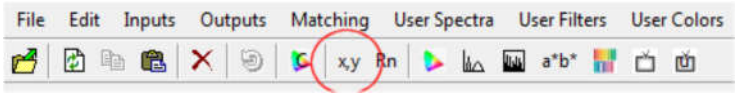
3. Colors

The individual values in the CRI and CQS scales (R1-R14 and Q1-Q15) give a measure as to how well the test source will render a color as compared to the reference source (a black body at the same CCT). The individual colors in the CRI and CQS scales were chosen for their general applicability. However, in some cases, you may want to see how a different color will be rendered. To do this you can define a “user color”. A user color is defined by entering the spectral reflectance representing the color. The measure of how well this color will be rendered compared to the reference source will be calculated using the CQS formulation and written to the “photometry.txt” file for each user color checked. The user colors can be managed in the same manner as the user filters. The reflectance is defined as 0 and 1 or as a percent from 0 to 100. The saved colors are saved to a plain text file called “userColors.cols”.

4. Custom CIE Plots and Delta(uv)

The delta(uv) is a measure of the distance a point is from the black body locus in u-v space. The delta(u'v') is a measure of the distance a point is from the black body locus in u'-v' space. For "white" light you generally want delta(uv) to be below 0.0020. If you have x,y data and want to plot it on a CIE diagram or calculate the CCT or delta(uv) values you can click the button with the CIE icon with the "C" near the top of the main window. A new window will open where you can enter your data and have the program plot your points and calculate the desired values. This can also be used to plot more than one point on the CIE diagram.

If you have several spectra you want to plot at the same time you can take the following steps. After a calculation click the "x,y" button near the top of the main window. This will save the x,y data for the spectrum that was just calculated. Repeat this for as many spectra as you wish, click the button, and in the new window that opens click the "x,y" button. The saved x,y pairs will be written into the table. Then click the "calculate" button to plot the data.



You can clear the saved x,y pairs by clicking the "Data->Clear all saved x,y values" menu item on the main window or by restarting the program. You can also check several spectra and press the "Cal Individual" button. This will calculate each checked spectra individually and automatically save the x,y point. These can then be pasted into the Duv table using the method described above.

From this window you have several features such as; change plot symbols, show/hide the MacAdams ellipses and/or u'v' circles for the individual points. You can also display one MacAdams ellipse centered on all of your points. You can also enter only the CCT and the program will calculate the x,y for a point on the black body at this CCT. This is useful for adding reference points to a plot.

If you left-click on a plot symbol you will see the pop-up as shown in Figure 5. You can select the symbol for each individual point. You can apply the same symbol to several points at once if the points are in adjacent rows. To do this you click on the first row, then press "cancel" at the bottom, then hold down the shift key and press the plot symbol in the last row and pick your symbol. You can save your selected plot symbols and point labels to a file to use later using the "Save as…" menu item. The information will be written to a text file. If you have a lot of points with complicated symbol and text selections you can create this file yourself. The symbol shapes go left-to-right from 0 to 9, the colors go top-to-bottom from 0 to 19. The data must be separated by either spaces or tabs and the labels (if present) must be enclosed in double quotes. You should first save a file using the program so see the exact format.

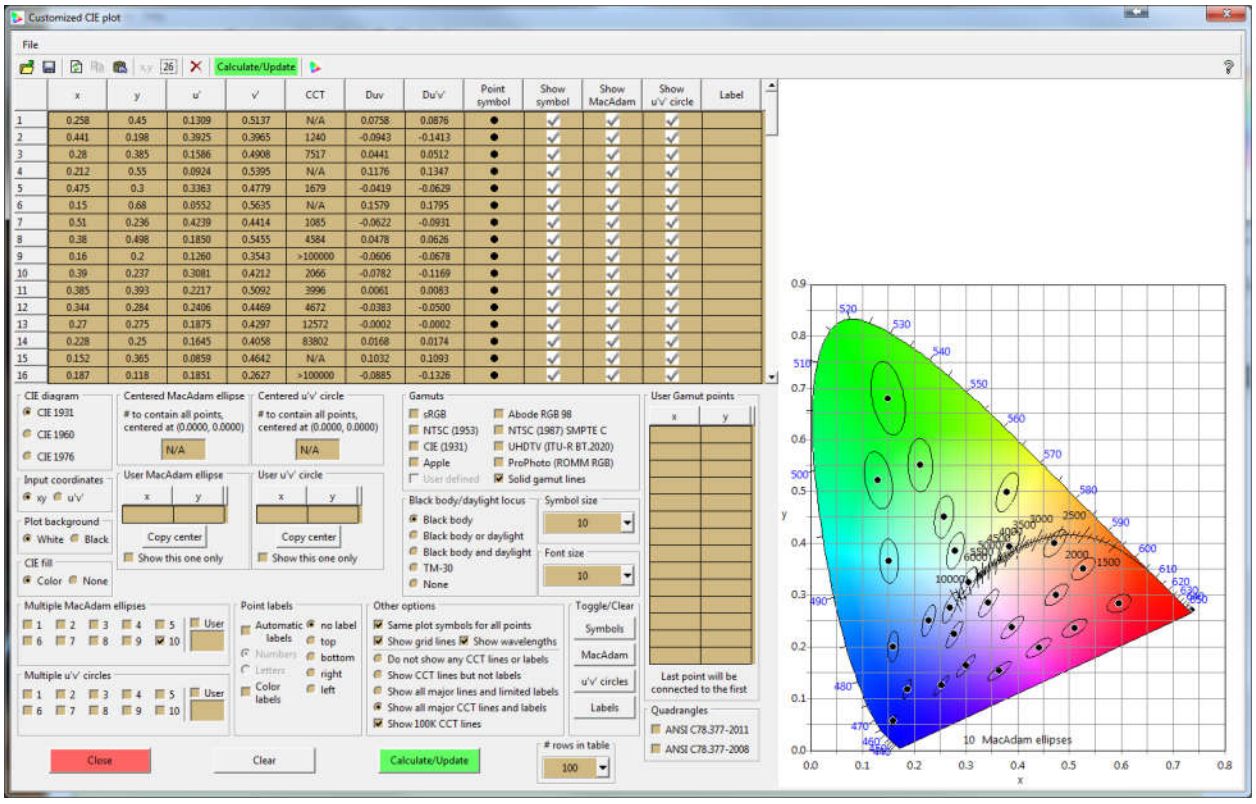


Figure 4. Input form for the Delta(uv) calculations.

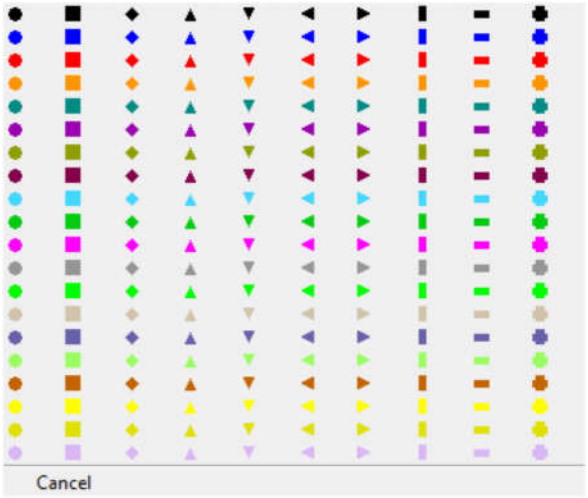
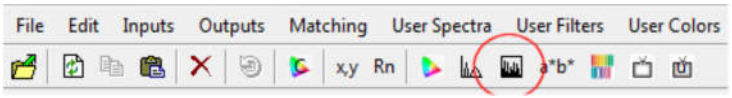


Figure 5. Plot symbols and colors.

5. R-Values Plots

You can make a plot of the R-values or Q-values, depending on which metric is selected. After a calculation click the button circled in red below.



You will see a plot similar to the one below (Figure 6).

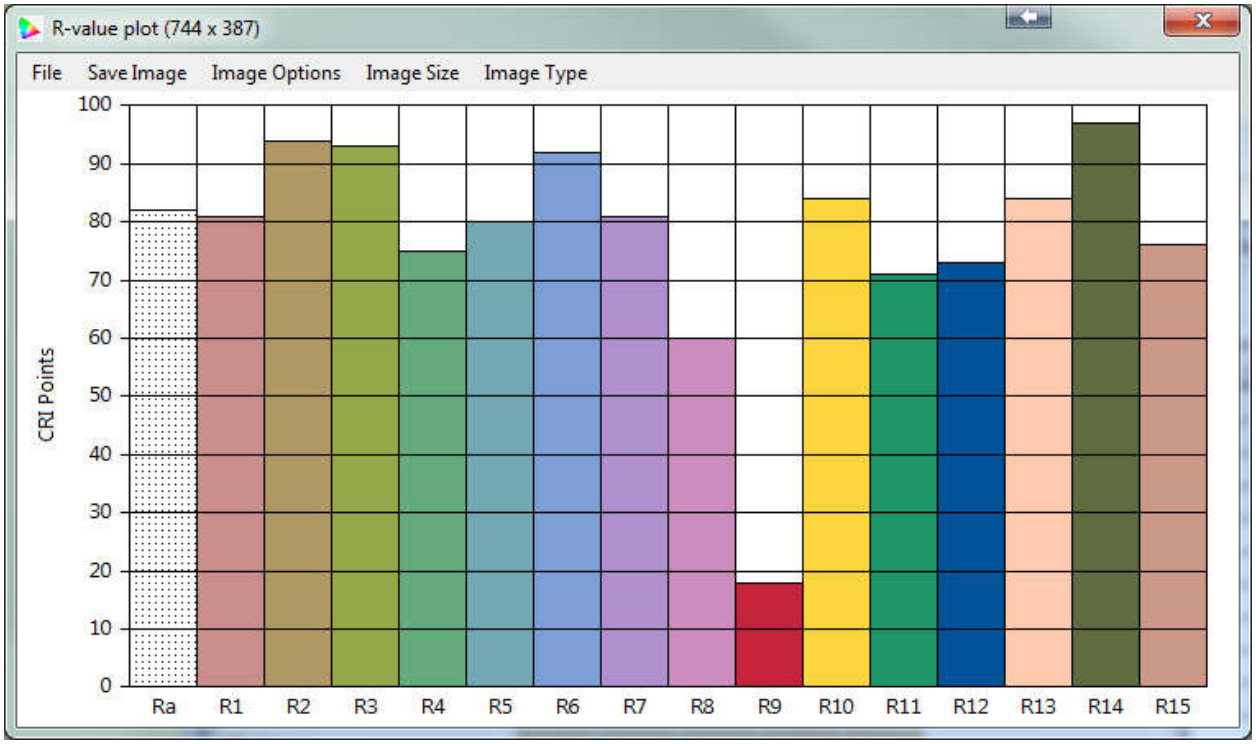
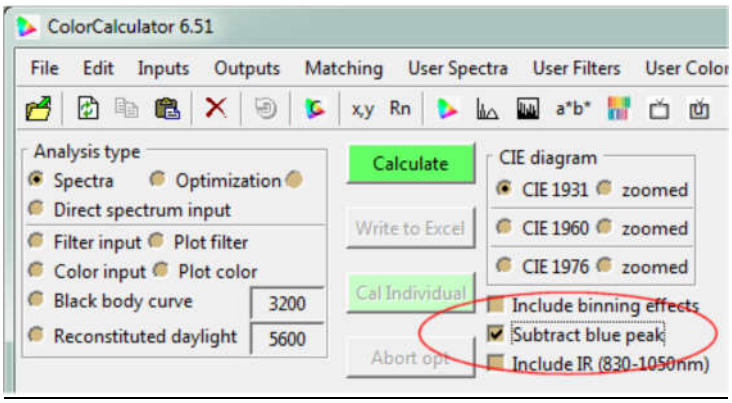


Figure 6. R-value plot.

You can plot the R-values from several spectra on the same plot by saving the R-values by clicking the button circled in red below. You can clear the saved R-values by clicking the "Data->Clear all saved R-values" menu item on the main window or by restarting the program.

6. Subtract Blue Peak

The "Subtract blue peak" option will automatically fit the blue peak and subtract it from the spectrum. The amount of watts in the fitted blue peak and the remaining peak (called the phosphor peak) will be reported in the output. The spectrum without the blue peak will be plotted as a solid black line so the user can see the fit and evaluate if it is reasonable. The calculated watts in each peak are usually good to within 10%. These values only are meaningful for LED sources.



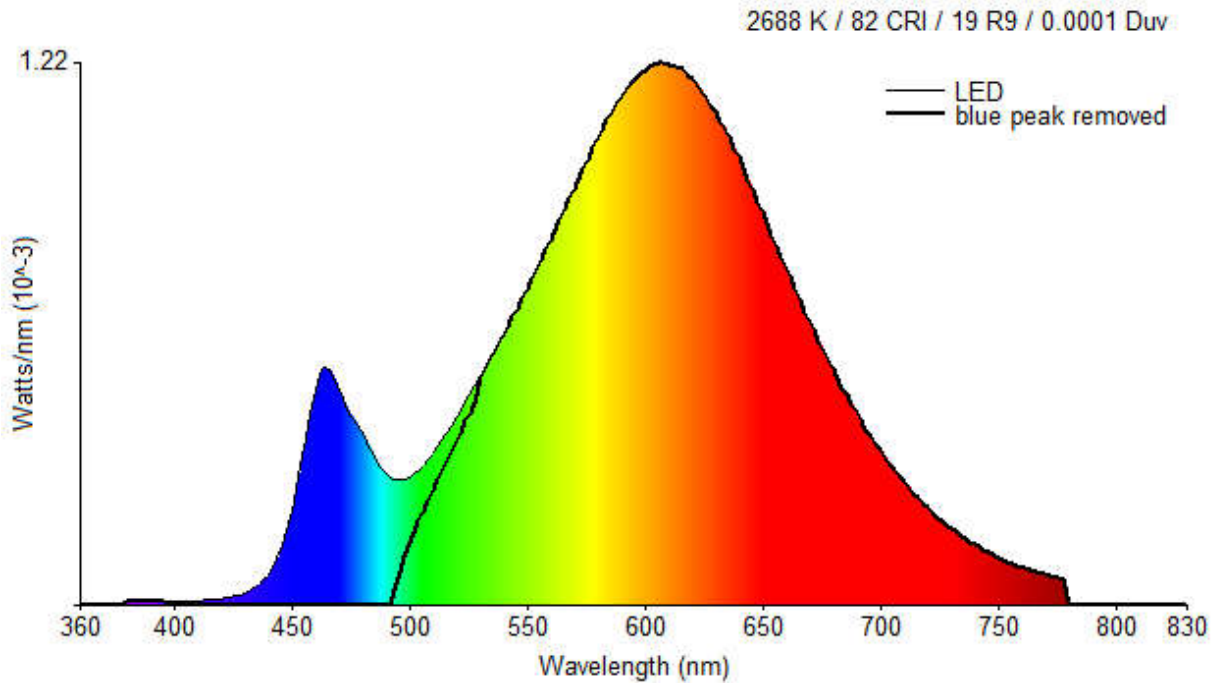
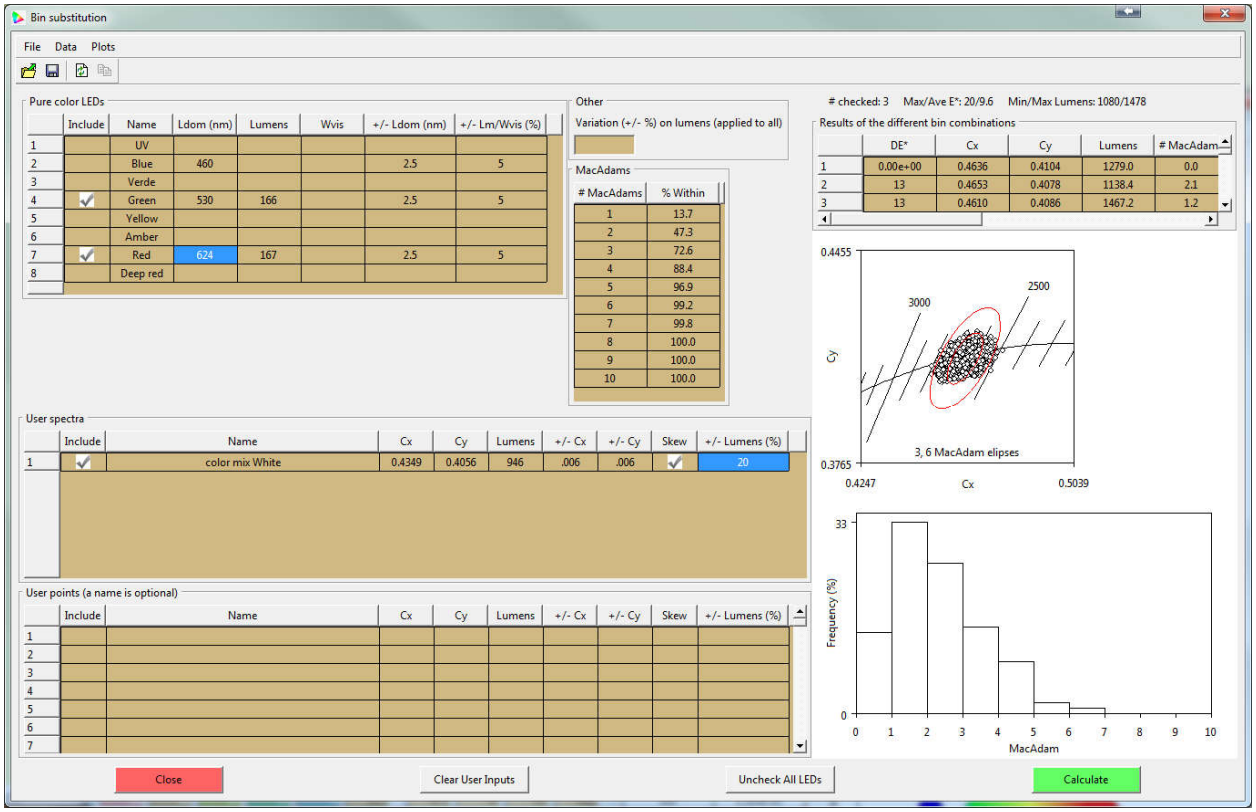
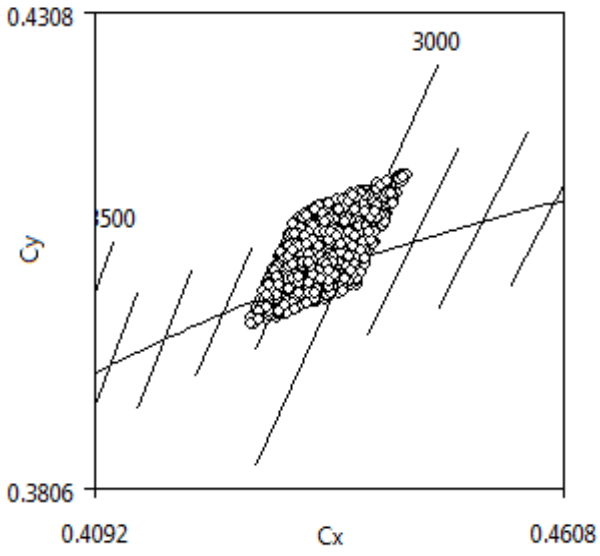


Figure 7. Spectrum with the blue peak fit.

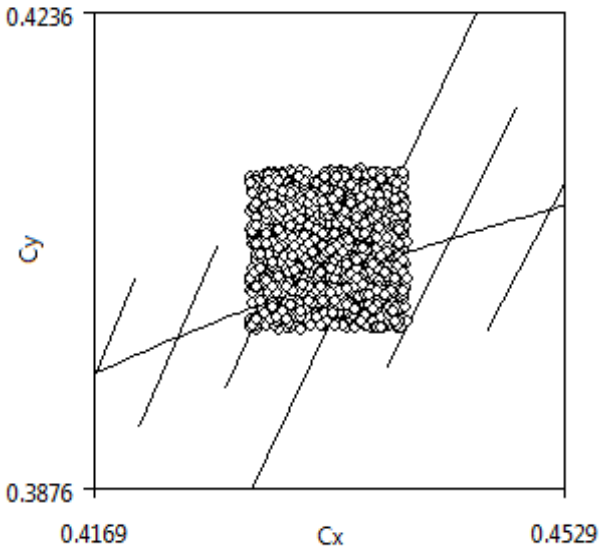
7. Evaluation of Binning

The effects of bin selection can be simulated using the "Other Calculations->Calculate binning from x, y and lumens…" menu item. You enter the information for your design in terms of the LEDs used and their lumen levels. Enter the color and lumen bin information and a Monte Carlo simulation is used to generate several thousand data points which are then used to show the expected color spread on the CIE diagram and in terms of MacAdam ellipses. The only option available in this simulation is whether or not to skew the bins of the non-pure color LEDs. The figure below shows a typical skewed bin. You can see the effect by only checking the bin to be skewed and see if you like the effect.





With skew effect

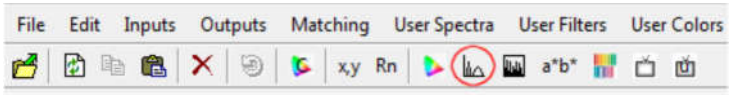


Without skew effect

Other Plot Types

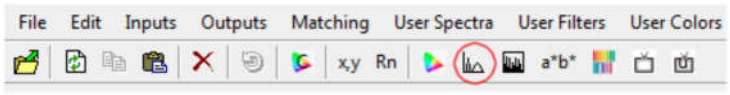
a. Spectrum Plots

You can save the plot of a spectrum to a file as a bitmap image. To save the spectrum click the button circled in red below. A window will open with only the spectrum plot in it. You can resize the plot and save it to a file.



b. CIE Plots

You can save the plots of the CIE diagram to a file as a bitmap image. To save the CIE diagram click the button circled in red below. A window will open with only the CIE diagram plot in it. You can resize the plot and save it to a file. There are several options in the menu of this window that allow you to tailor the plot in many ways. The display of the MacAdam ellipses can also be controlled in this window.



c. Matching Plots

If you check the “Matching->Matching mode” menu item a new column will be added to the table. You can paste a spectrum into the column labeled “Matching”. When you calculate the spectrum this “matching” plot will also be plotted. You can also select to use the photopic curve as the matching spectrum by checking the appropriate box in the “Matching” menu item.

d. CIEL*a*b* Plots

You can make and save CIEL*a*b*plots of either the CRI, CQS or user colors to a file as a bitmap image. To display the CIEL*a*b*plot click the button circled in red below. A window will open with the CIEL*a*b*plot in it. You can resize the plot and save it to a file. The CMCCAT2000 chromatic adaptation

is used to correct the CQS and user colors and the von Kries chromatic adaptation is used to correct the colors. The plot can display the results as individual points of as vectors connecting the test and reference points, color rendering vectors (CRV). You can also make these types of plots using any user colors you have any defined and checked.

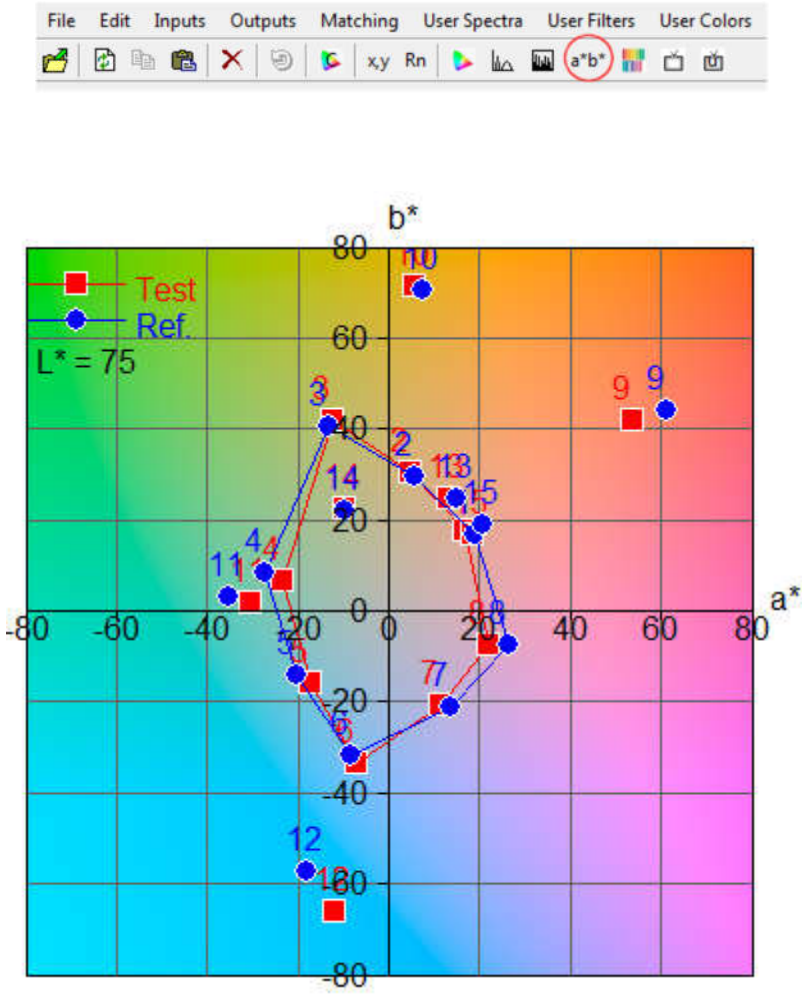


Figure 8. CIEL*a*b* plot of the 14 R-values for the reference and test light source.

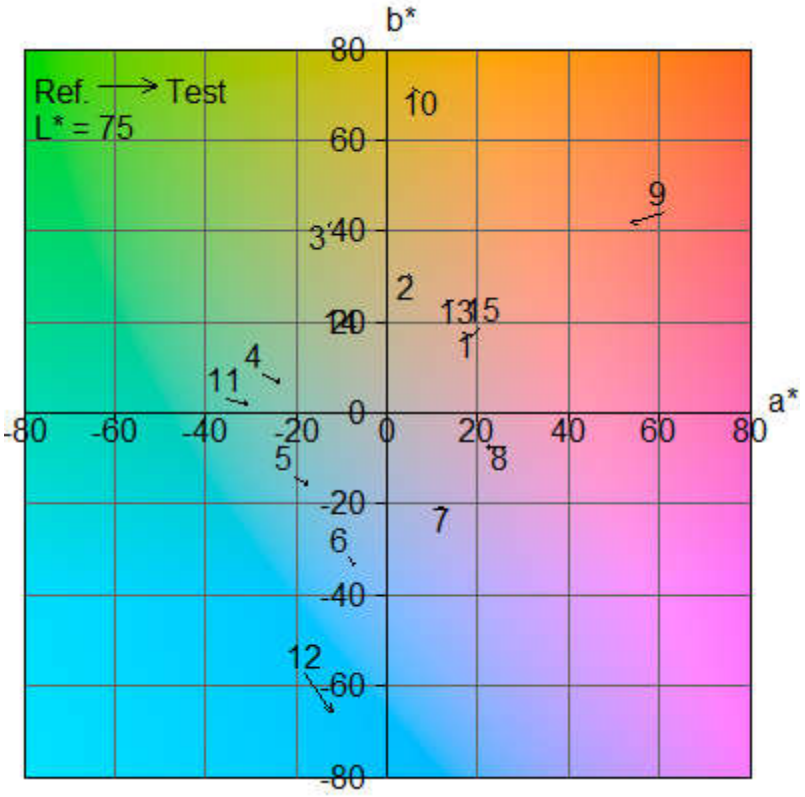
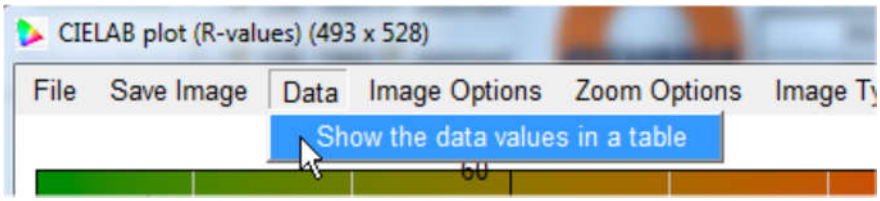


Figure 9. CIEL*a*b* plot of the 14 R-values for the reference and test light source showing color rendering vectors (CRV). A vector pointing toward the center indicates that a particular color is under saturated, a vector pointing away from the center indicates that the color is oversaturated. Vectors pointing in a rotational direction indicate that there is a shift in hue for a color. Longer vectors indicate larger shifts in color and/or saturation.

Once the plot is displayed you can list the L*, a* and b* values (and related metrics) in a table by clicking the “Data->Show the data values in a table” menu item.



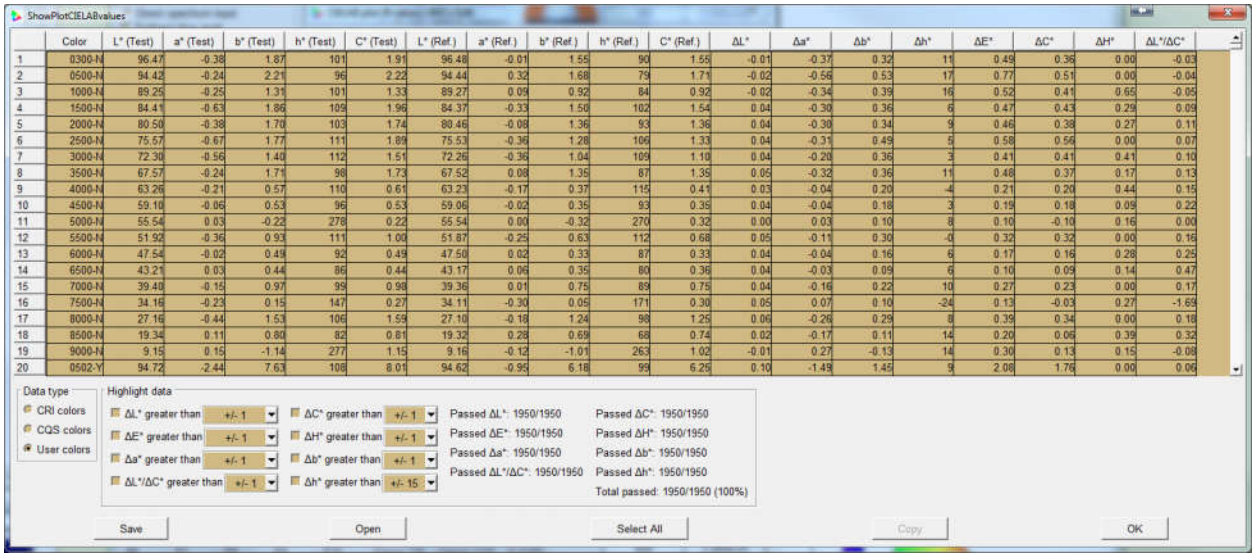
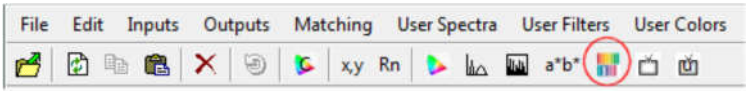


Figure 10. Values used to make the CIEL*a*b* plot.

e. Color Rendering Plots

How well each color is rendered can be seen using the “color patch” plot, Figure 11. The plot can be seen using the “Other plots->Show color patches of R, Q or user colors” menu item. You can also show user colors, if you have any defined and checked, using the “Plot type” menu item. Note, the colors are only approximate and are rendered as sRBG assuming a gamma of 2.2 and normalized to 100 lumens. The CMCCAT2000 chromatic adaptation is used to correct the colors and the source illumination is D65.



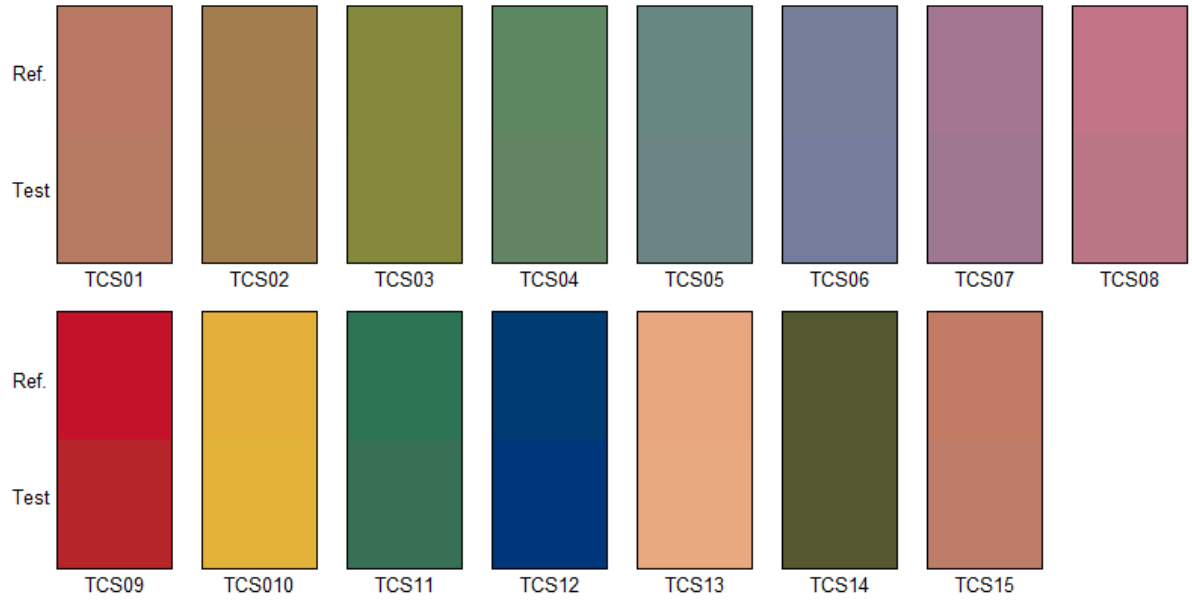
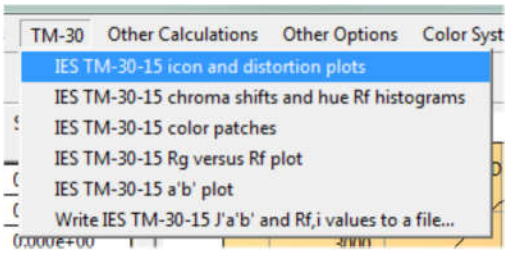


Figure 11. Color patch plot of the 15 R-values for the reference and test light source.

f. IES TM-30-15

After a calculation is performed, plots according to the IES TM-30-15 standard can be made. There are 6 different types of plot available in TM-30-15. You have to use the "Image Type" menu command on some of the plot windows to switch between image types. The numeric results are displayed on tab #2.



8. Other Features

a. Generic Pure Color LEDs

You can also display what are called "generic pure color LEDs" in addition to the standard packaged LEDs shown by default. You can control what types of LEDs are displayed with the "Other options" menu item. The "generic pure color LEDs" are mainly of interest to designers using the "Total combinations"

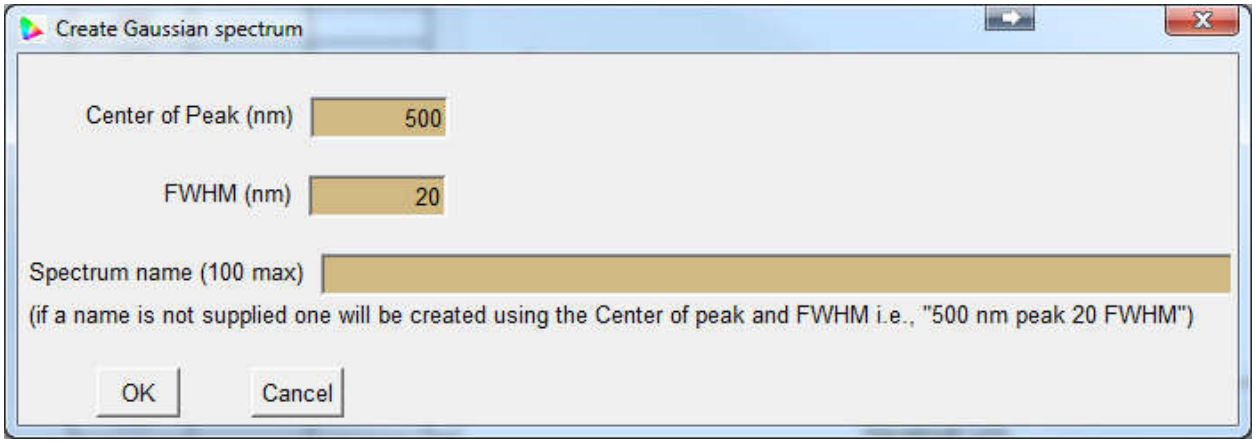
method previously described. These LEDs have their peak shapes defined by Gaussian fits. Each peak is represented by a fit of three individual Gaussians which were derived by fitting to experimental data. The peak shapes change with the dominate wavelength. When these LEDs are shown the "Total combinations" window looks as shown below. In addition to the standard LEDs you can chose these generic LEDs and include the wavelength variation in a combinations run.

b. Black Body and Daylight Spectra

You can display the spectrum of a black body or reconstituted daylight at any CCT. This can then be saved as a user spectrum or used as a matching plot.

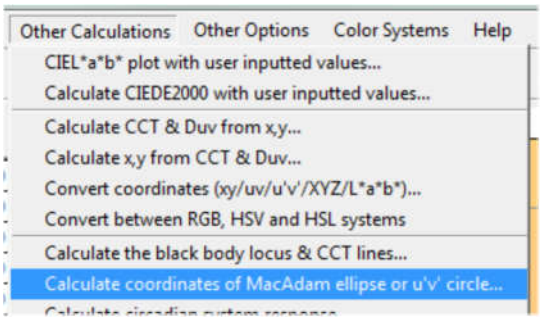
c. Gaussian Peak

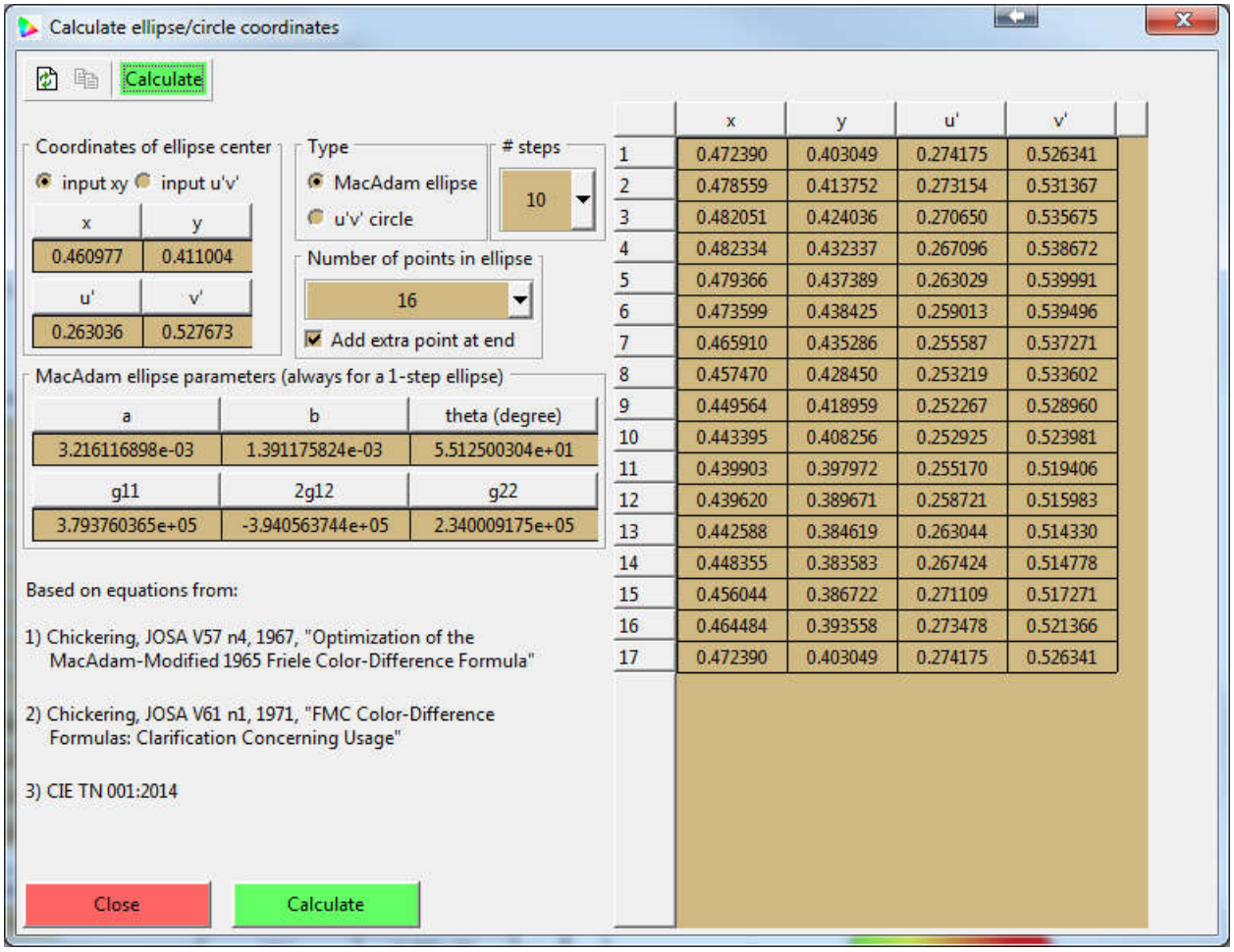
You can have the program generate a simple Gaussian peak to represent an LED. Click the "User Spectra->Generate Gaussian based user spectrum" menu item. You can then enter the peak center, the peak width (FWHM) and a name and the program will generate the spectrum and add it to your user spectra.



d. MacAdam Ellipses

The program will calculate the points for a MacAdam ellipse for use in other plotting software. Use the "Other Options->Calculate coordinates of MacAdam ellipse…" to display this window:

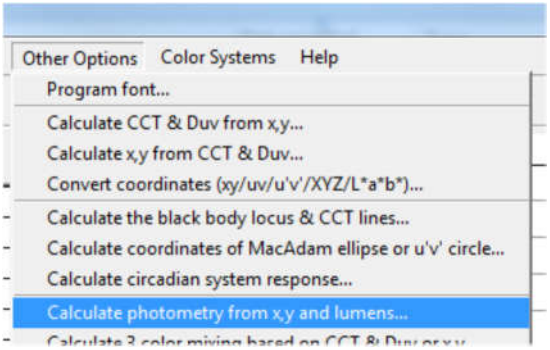




You can enter the ellipse center and the other parameters and the points describing the ellipse will be written to the table. These parameters are always for a 1-step ellipse. Note that the ellipse is based on equations from: Chickering, JOSA V57 n4, "Optimization of the MacAdam-Modified 1965 Friele Color-Difference Formula" and Chickering, JOSA V61 n1, "FMC Color-Difference Formulas: Clarification Concerning Usage".

e. Adding Color Points

You can add a series of x,y and lumen value to see the resultant color point.



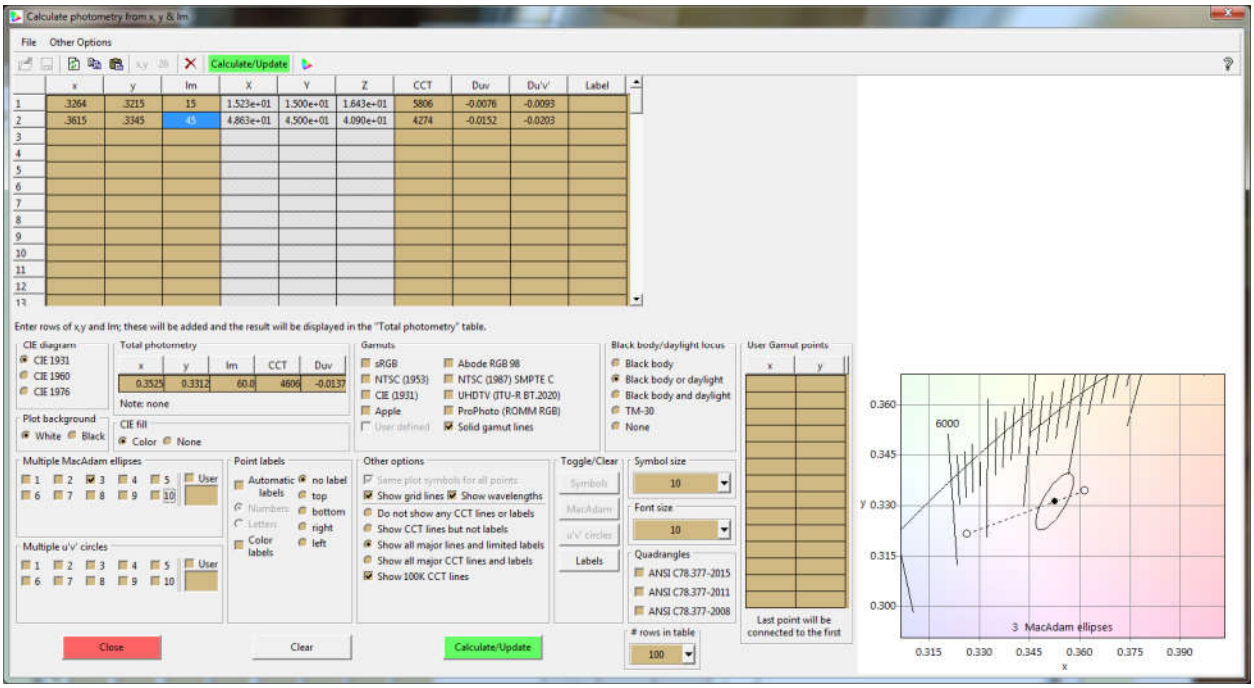
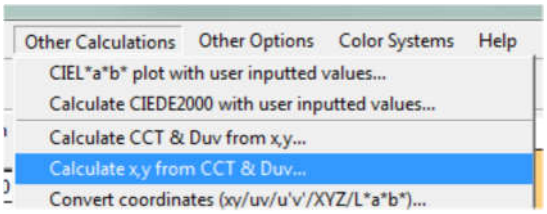
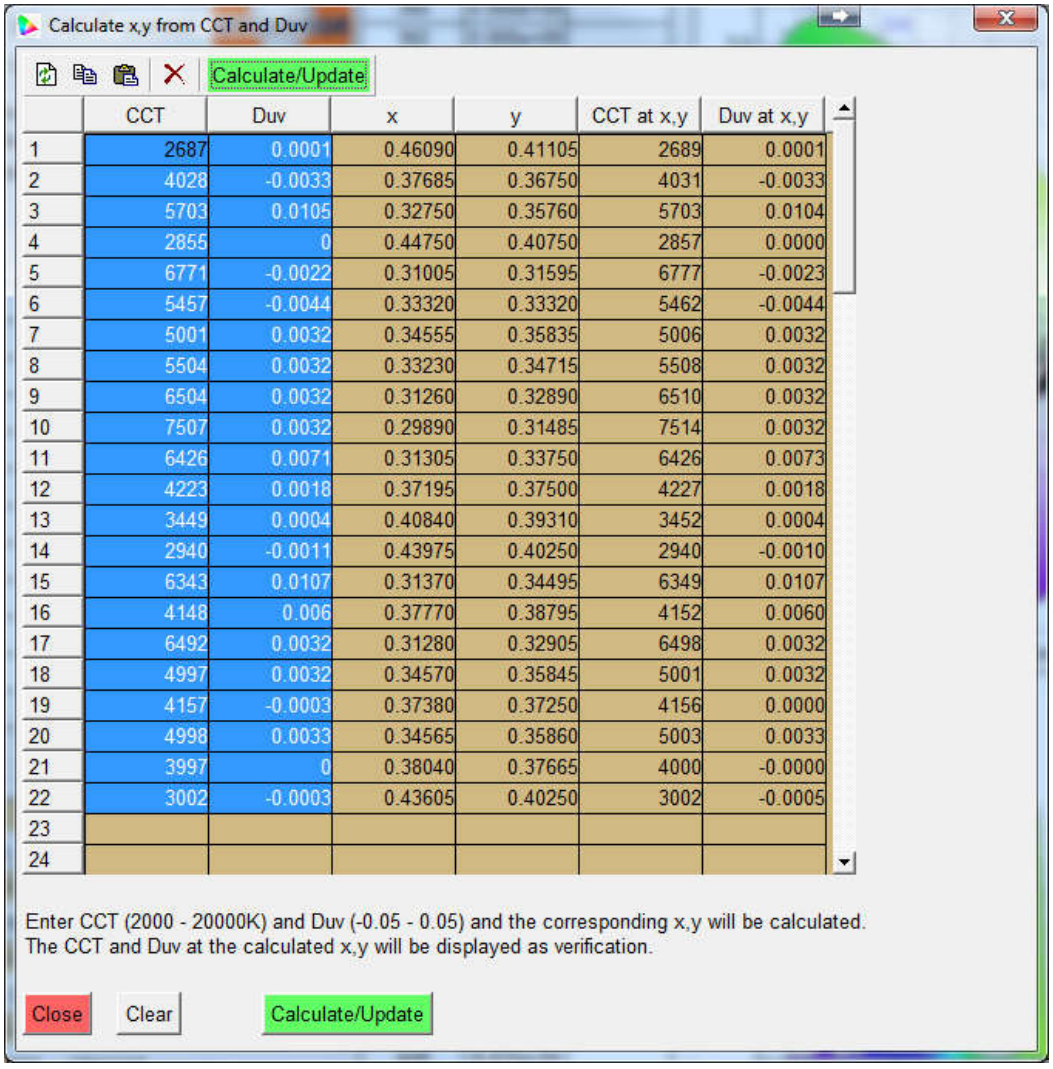


Figure 12. Input form for the additive x,y and lumen calculations.

f. Calculating x,y from CCT and Duv

You can enter values for the CCT and Duv and have the program calculate the corresponding x,y color points. The program solves for the x,y and then uses these to redo the forward calculation to calculate the CCT and Duv so you can compare the calculated to inputted values as a check on the solution.

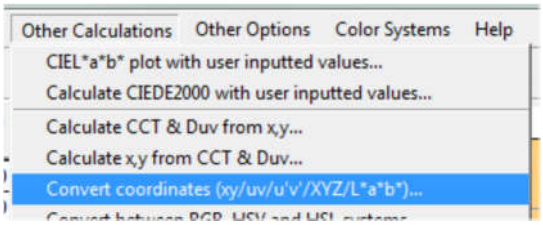


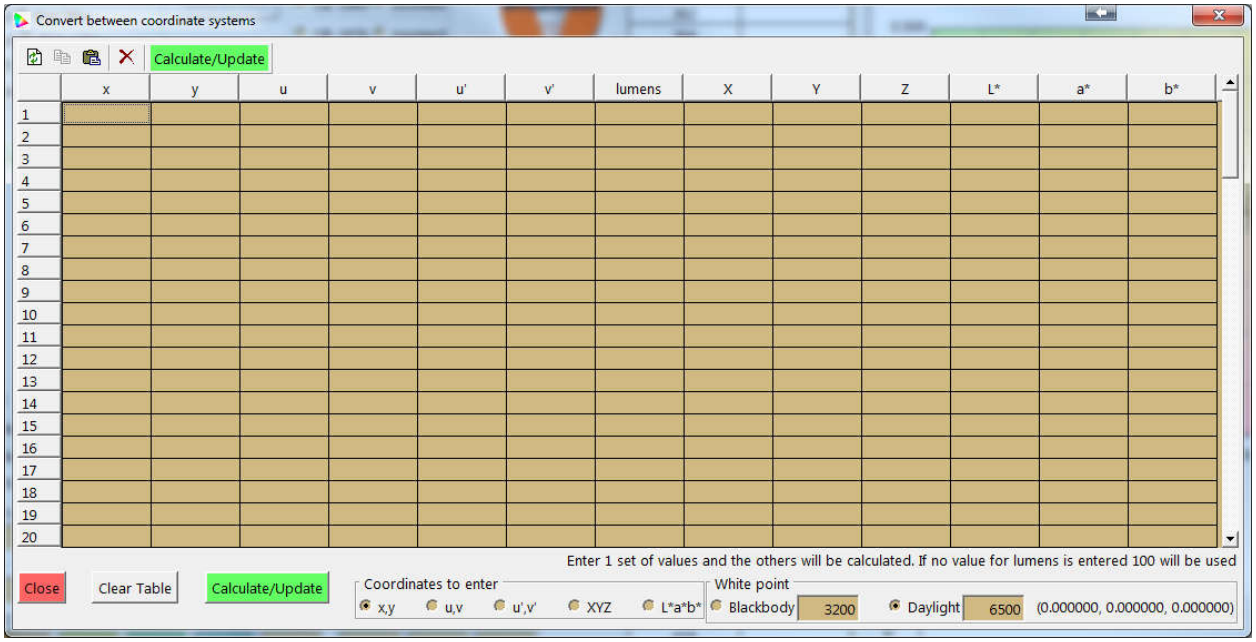


	CCT	Duv	x	y	CCT at x,y	Duv at x,y
1	2687	0.0001	0.46090	0.41105	2689	0.0001
2	4028	-0.0033	0.37685	0.36750	4031	-0.0033
3	5703	0.0105	0.32750	0.35760	5703	0.0104
4	2855	0	0.44750	0.40750	2857	0.0000
5	6771	-0.0022	0.31005	0.31595	6777	-0.0023
6	5457	-0.0044	0.33320	0.33320	5462	-0.0044
7	5001	0.0032	0.34555	0.35835	5006	0.0032
8	5504	0.0032	0.33230	0.34715	5508	0.0032
9	6504	0.0032	0.31260	0.32890	6510	0.0032
10	7507	0.0032	0.29890	0.31485	7514	0.0032
11	6426	0.0071	0.31305	0.33750	6426	0.0073
12	4223	0.0018	0.37195	0.37500	4227	0.0018
13	3449	0.0004	0.40840	0.39310	3452	0.0004
14	2940	-0.0011	0.43975	0.40250	2940	-0.0010
15	6343	0.0107	0.31370	0.34495	6349	0.0107
16	4148	0.006	0.37770	0.38795	4152	0.0060
17	6492	0.0032	0.31280	0.32905	6498	0.0032
18	4997	0.0032	0.34570	0.35845	5001	0.0032
19	4157	-0.0003	0.37380	0.37250	4156	0.0000
20	4998	0.0033	0.34565	0.35860	5003	0.0033
21	3997	0	0.38040	0.37665	4000	-0.0000
22	3002	-0.0003	0.43605	0.40250	3002	-0.0005
23						
24						

g. Convert Between Different Coordinate Systems

You can convert between different sets of color coordinates. Enter any set (xy or uv or u'v' or XYZ or L*a*b*) and the others sets will be calculated. You can enter a lumen level or, if none is specified, the program uses a default of 100. For conversion to and from CIELab space a white point must be entered. If you are not interested in the L*a*b* values this white point can be ignored.

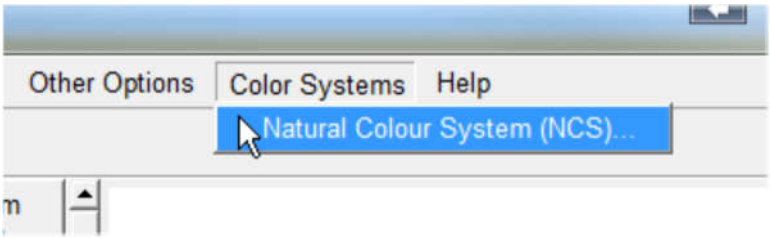


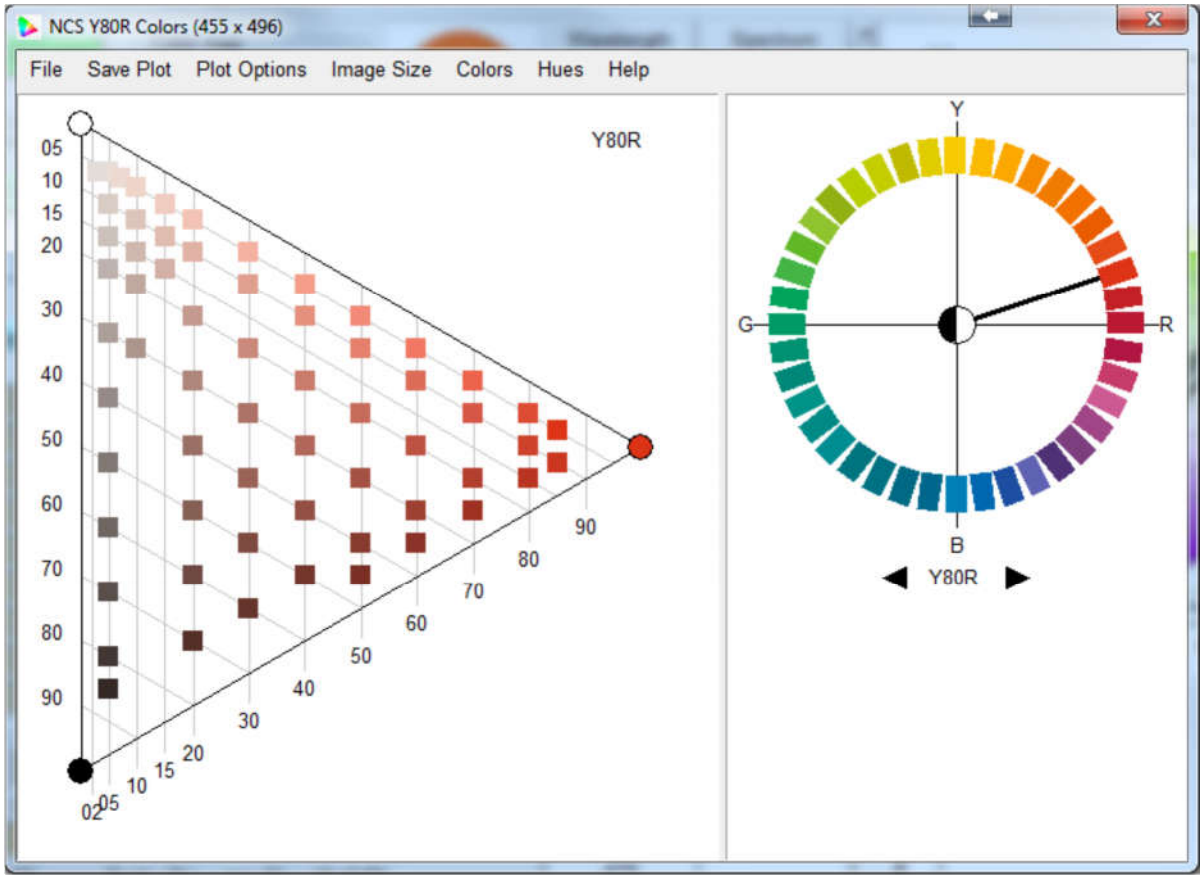


h. Natural Colour System (NCS)

The Natural Colour System®© is a color notation system developed and supported by NCS Colour and is the property of and used on licence from NCS Colour AB, Stockholm 2013. The system is comprised of 40 hues, a blackness level (vertical axis) and a chromaticness level (horizontal axis). More information can be found at http://www.ncscolour.com/.

These colors can be selected and used as user colors and can then be used to generate color rendering vector plots (CRV) to give a designer an indication as to how a light source will render a wide range of colors, section C. Figure 12 was made using all 1950 of the NCS colors as user colors. This plot is much more informative than the similar plots shown in Figure 8 which was made using the 14 CRI R-value colors.





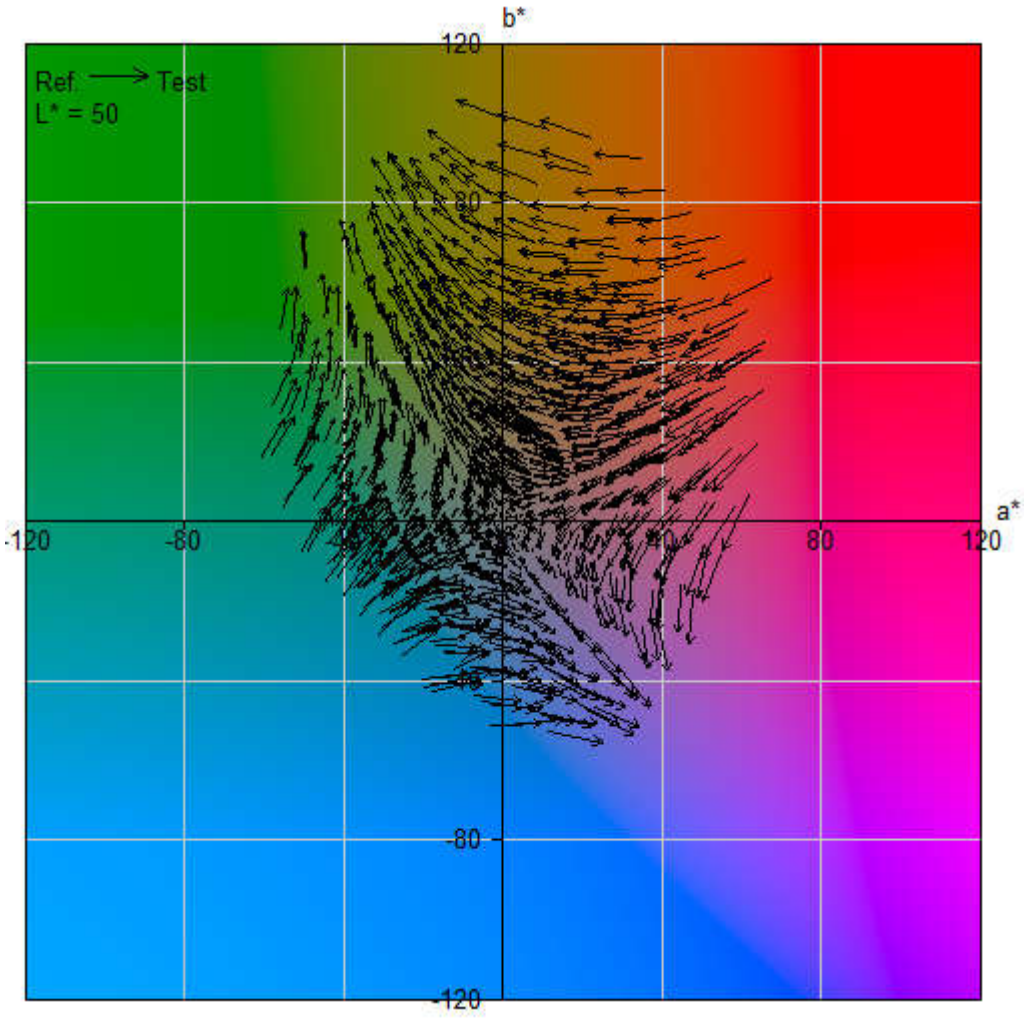


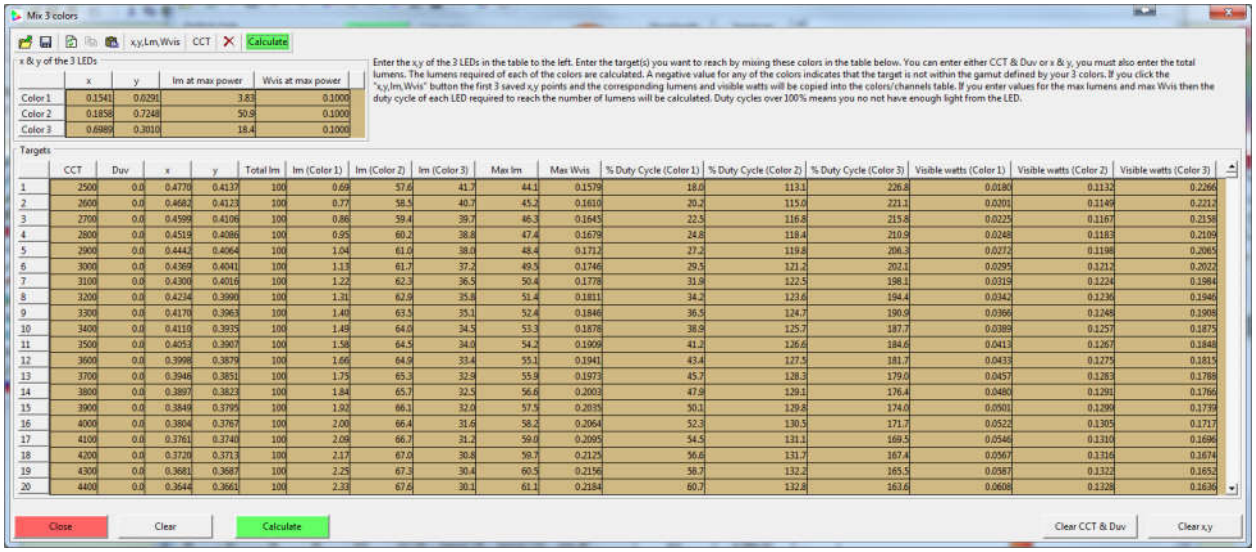
Figure 13. CIEL*a*b* plot of the 1950 NCS colors for the reference and test light source showing color rendering vectors (CRV).

i. Class A Light

J.P. Freyssinier and M.S. Rea of the Lighting Research Center at Rensselaer Polytechnic Institute and Alliance for Solid-State Illumination Systems and Technologies (ASSIST) have proposed a specification for what they call “Class A” lighting. Detailed information on this work can be found at http://www.lrc.rpi.edu/programs/solidstate/colorResearch.asp and http://www.lrc.rpi.edu/programs/solidstate/colorResearch.asp .

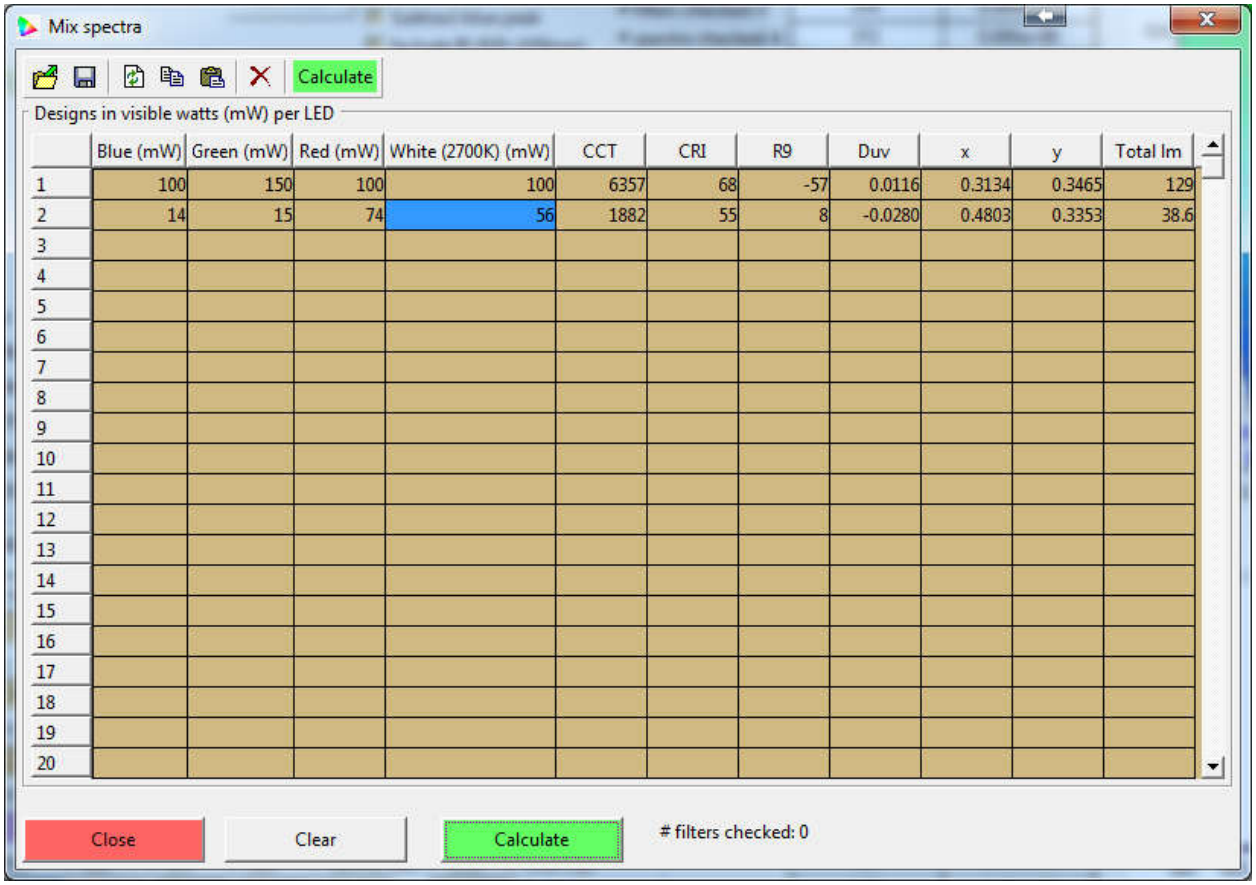
j. Three Color Mixing

The “Other options->Calculate 3 color mixing based on x,y…” menu item will show the following window. Enter the x,y coordinates of the three color sources in the top table. In the “Targets” table enter either the CCT and Duv or the x and y of the desired mixed light and the required lumen level of each of the three colors will be calculated. You can either enter a value in the “Total lm” column or leave it empty. If it is left empty then a default value of 100 lumens will be used.



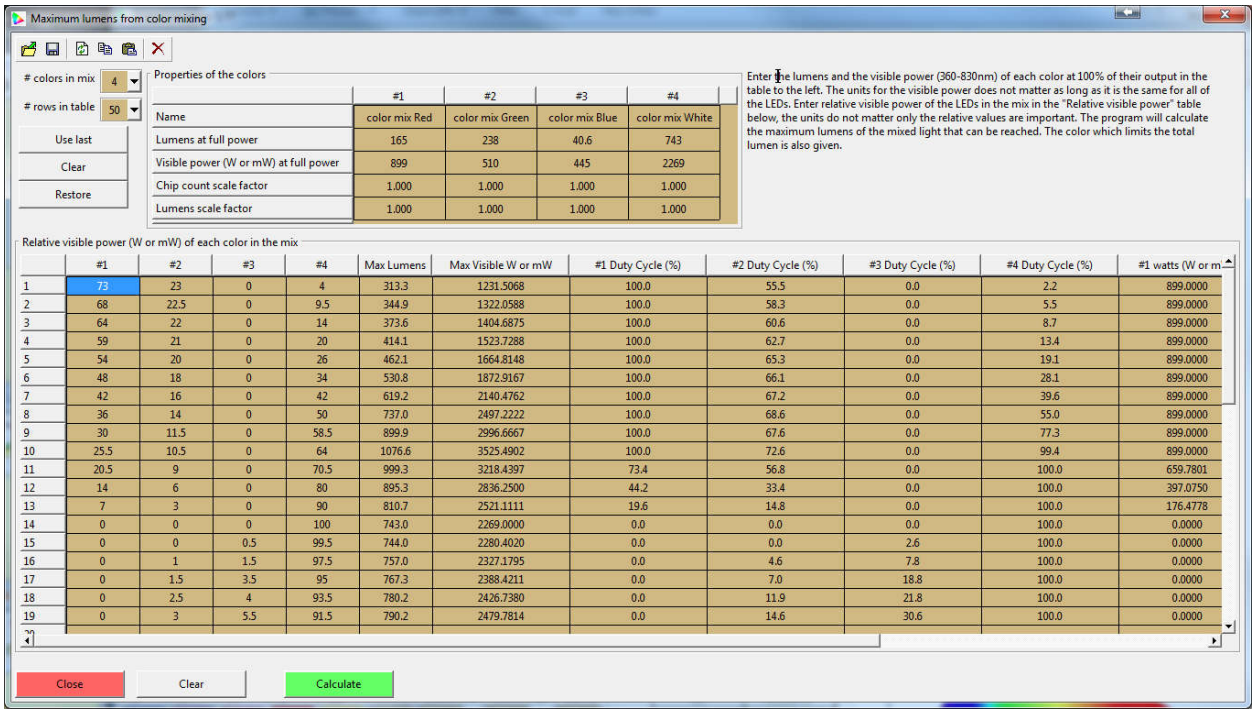
k. Spectra Mixing

The “Other options->Calculate color mixing based on spectra…” menu item will show the following window. The checked spectra (up to 4) from the main window will be used in these calculations. The watts or milliwatts of each color can be entered and the photometry will be calculated.


Mix spectra
Calculate
Designs in visible watts (mW) per LED
Blue (mW) Green (mW) Red (mW) White (2700K) (mW) CCT CRI R9 Duv x y Total lm
1 100 150 100 100 6357 68 -57 0.0116 0.3134 0.3465 129
2 14 15 74 56 1882 55 8 -0.0280 0.4803 0.3353 38.6
Close
Clear
Calculate
filters checked: 0

l. Maximum Lumens From a Color Mix

The “Other options-> Calculate maximum lumens from color mix...” menu item will show the following window. This is designed to calculate the maximum lumens you can get from a set of LEDs and a color mix. You define the performance of the LEDs in the upper table, inputting the lumens and visible watts at maximum power. In the lower table you enter your color mix, either based on the percent of visible watts in the spectrum from each LEDs or on the absolute watt level. The program then calculates the maximum lumens achievable and the intensity limiting LED and the duty cycle. This calculation is also available in the “Run combinations” method described in section III/3 of this report.



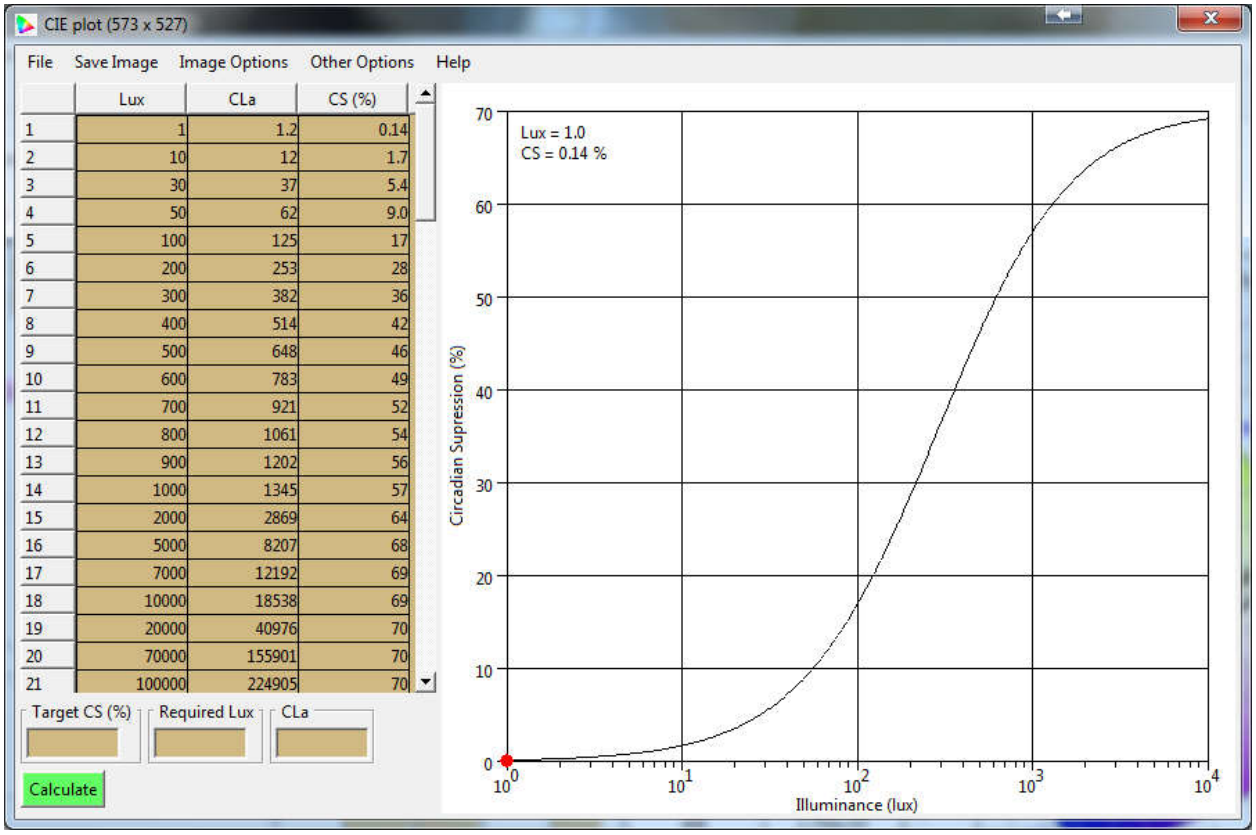
	#1	#2	#3	#4
Name	color mix Red	color mix Green	color mix Blue	color mix White
Lumens at full power	165	238	40.6	743
Visible power (W or mW) at full power	899	510	445	2269
Chip count scale factor	1.000	1.000	1.000	1.000
Lumens scale factor	1.000	1.000	1.000	1.000

	#1	#2	#3	#4	Max Lumens	Max Visible W or mW	#1 Duty Cycle (%)	#2 Duty Cycle (%)	#3 Duty Cycle (%)	#4 Duty Cycle (%)	#1 watts (W or m
1	73	23	0	4	313.3	1231.5068	100.0	55.5	0.0	2.2	899.0000
2	68	22.5	0	9.5	344.9	1322.0588	100.0	58.3	0.0	5.5	899.0000
3	64	22	0	14	373.6	1404.6875	100.0	60.6	0.0	8.7	899.0000
4	59	21	0	20	414.1	1523.7288	100.0	62.7	0.0	13.4	899.0000
5	54	20	0	26	462.1	1664.8148	100.0	65.3	0.0	19.1	899.0000
6	48	18	0	34	530.8	1872.9167	100.0	66.1	0.0	28.1	899.0000
7	42	16	0	42	619.2	2140.4762	100.0	67.2	0.0	39.6	899.0000
8	36	14	0	50	737.0	2497.2222	100.0	68.6	0.0	55.0	899.0000
9	30	11.5	0	58.5	899.9	2996.6667	100.0	67.6	0.0	77.3	899.0000
10	25.5	10.5	0	64	1076.6	3525.4902	100.0	72.6	0.0	99.4	899.0000
11	20.5	9	0	70.5	999.3	3218.4397	73.4	56.8	0.0	100.0	659.7801
12	14	6	0	80	895.3	2836.2500	44.2	33.4	0.0	100.0	397.0750
13	7	3	0	90	810.7	2521.1111	19.6	14.8	0.0	100.0	176.4778
14	0	0	0	100	743.0	2269.0000	0.0	0.0	0.0	100.0	0.0000
15	0	0	0.5	99.5	744.0	2280.4020	0.0	0.0	2.6	100.0	0.0000
16	0	1	1.5	97.5	757.0	2327.1795	0.0	4.6	7.8	100.0	0.0000
17	0	1.5	3.5	95	767.3	2388.4211	0.0	7.0	18.8	100.0	0.0000
18	0	2.5	4	93.5	780.2	2426.7380	0.0	11.9	21.8	100.0	0.0000
19	0	3	5.5	91.5	790.2	2479.7814	0.0	14.6	30.6	100.0	0.0000

m. Circadian System Response

The “Other options->Calculate Circadian system response…” menu item will show the following window. First you must select and perform a calculation from the main window. You can enter the Lux values and

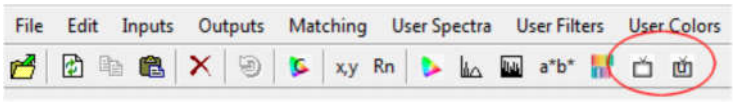
have the program calculate the resultant CL_A and CS values, or enter a target CS value and the required Lux and CL_A values will be calculated. The Circadian system response calculation is based on work by M.S. Rea, M.G. Figueiro, J.D. Bullough, A. Bierman and R. Hamner at the Lighting Research Center, Rensselaer Polytechnic Institute, Troy, New York, USA.



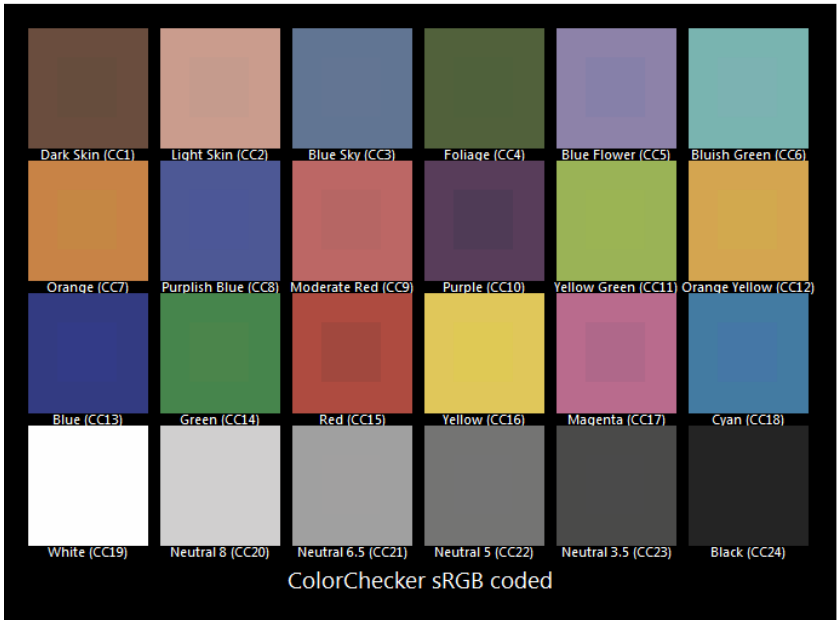
	Lux	CLa	CS (%)
1	1	1.2	0.14
2	10	12	1.7
3	30	37	5.4
4	50	62	9.0
5	100	125	17
6	200	253	28
7	300	382	36
8	400	514	42
9	500	648	46
10	600	783	49
11	700	921	52
12	800	1061	54
13	900	1202	56
14	1000	1345	57
15	2000	2869	64
16	5000	8207	68
17	7000	12192	69
18	10000	18538	69
19	20000	40976	70
20	70000	155901	70
21	100000	224905	70

n. TLCI-2012 Metric

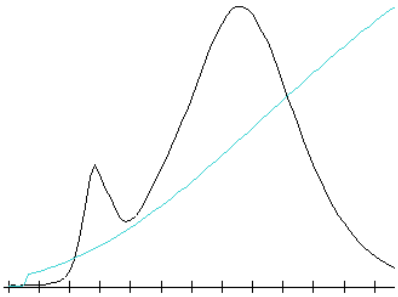
The TLCI-2012 metric refers to the Television Lighting Consistency Index, as specified in EBU Tech 3355. It is used to evaluate the suitability of a light source for use in television. A complete description is available on the web at https://tech.ebu.ch/tlci-2012. Below shows sample output for the 2700K white LED included in the program. There are 2 buttons with slightly different TLCI calculations. The button on the left will run the calculation with the reference light source as defined in the standard. The button on the right will allow the user to select the spectrum to use as the reference light source.



White (2700K) : CCT = P2688 (0.0)
TLCI-2012 : 72 (P2688)



Sector	Lightness	Chroma	Hue
R	++	++	0
R/Y	0	0	----
Y	0	-	--
Y/G	0	0	0
G	0	0	+
G/C	0	+	0
C	0	++	--
C/B	0	0	--
B	0	-	--
B/M	++	0	++
M	++	++	+++
M/R	++++	+	+



IV. Description of Menu Commands

A brief description of each menu command will be given. For many of these the meaning is obvious or it can be easily ascertained by trying them.

1. Main Window

a. File Menu

i. "Open design file…"

Open a previously saved design file. This contains all of the settings you can set in the UI.

ii. "Save design as…"

Saves the current state of the UI to a file. These setting can be read back in using the “Open design file” command.

iii. “Clear recent project list”

Clears the list of the recently used design files. This will be grayed out if no design files have been used.

iv. “Open photometry.txt file”

Opens the photometry.txt file in a simple text editor. This file contains a surrey of all of the runs performed since the program was last started. It is overwritten each time the program is restarted. This file is only written to if the “Write to Excel” button is pressed or if the menu item “Data->Write photometry data to a file (photometry.txt)” is checked.

v. “Open photometry.xls file”

Opens the photometry.xls file in excel. This file contains a surrey of all of the runs performed since the program was last started. It is overwritten each time the program is restarted. This file is only written to if the “Write to Excel” button is pressed or if the menu item “Data->Write photometry data to Excel file (photometry.xls)” is checked.

vi. “Open asa_out.txt file”

Open a text file with results from any optimization runs. The contents of this file will not be described here.

vii. “Exit”

It does what is says.

b. Edit Menu

i. “Select entire table”

Selects the content of the table where the spectrum is displayed.

ii. “Copy selection to clipboard”

Copies the selected cells in the table to the clipboard. These values can then be pasted in other software.

iii. “Paste selection to clipboard”

Allows values to be copied from other software, such as Excel, to be pasted in to the table. These values must already be in the clipboard and can only be pasted when the program in the one of the input modes.

c. Inputs Menu

i. "Input power units (milliWatts)"

Sets the watts units for the spectra to milliwatts. These are the values you enter into the UI to set how much of each spectrum you have. This does not affect values of any spectra which are read from files.

ii. "Input power units (watts)"

Sets the watts units for the spectra to watts. These are the values you enter into the UI to set how much of each spectrum you have. This does not affect values of any spectra which are read from files.

iii. "Input units for filters and colors (fraction 0-1)"

Sets the input units for filters and colors to fractional values. The values must be in the range of 0 to 1.

iv. "Input units for filters and colors (percent 0-100)"

Sets the input units for filters and colors to percentage values. The values must be in the range of 0 to 100.

v. "Spectrum from 360-830nm (2nm)"

Set the wavelength range and interval for the spectrum copied into the main table for the "Direct spectrum input" mode to 360-830nm in 2 nm steps.

vi. "Spectrum from 360-830nm (1nm)"

Set the wavelength range and interval for the spectrum copied into the main table for the "Direct spectrum input" mode to 360-830nm in 1 nm steps.

vii. "Spectrum from 380-780nm (2nm)"

Set the wavelength range and interval for the spectrum copied into the main table for the "Direct spectrum input" mode to 380-780nm in 2 nm steps.

viii. "Free format spectrum"

Set the wavelength range and interval for the spectrum copied into the main table for the "Direct spectrum input" mode to any range and any interval. The program does the photometry calculations from 360 to 830 in 2 nm steps. The inputted data will be extrapolated to fit this range and set to 0 if not data is provided. This input format is the most general and can always be used.

ix. "Input units for spectrum"

Set the units of the inputted spectrum to either: W/nm, milliWatts/nm, microWatts/nm or photon/s. These units are only in effect when "Direct spectrum input" is checked.

x. "Invert values in table"

When pasting in a spectrum, filter or color into the table requires that the wavelengths values are arranged short to long, 360-830nm. If your data is in the opposite order (long to short) you can paste it in then click this command and the values will be flipped in the table.

xi. "Limit umol/s-W to 400-700nm"

Limits the calculation of the umol/s-W to the range of 400-700nm. If this is not checked then the umol/s-W will be calculated over the range of 360-830nm of 360-1050nm if the "Include IR" option is checked.

xii. "Hide spectrum data when possible"

The table with the spectrum data will be hidden unless you are in one of the input modes or are displaying a matching spectrum.

xiii. "Set empty cells in spectrum to 0"

When inputting a spectrum any wavelength values not entered in the table will be set to zero. If this is not checked then any empty cells will cause an error.

xiv. "Use original spectral intensity if lumens or watts are blank"

If this is checked the user can leave both the watts and lumen values empty and the program will use the value of the original spectrum. If this is not checked then any empty cells will cause an error.

xv. "Clear spectrum data from table"

Clear the table of any user entered data. This can also be accomplished using the red "x" button on the toolbar.

xvi. "Clear all saved x,y values (0/2000)"

Clears any saved x,y data from memory. After a spectrum is calculated you can click the "x,y" toolbar button to save the x,y values to an array. Also, if you selected several spectra and click the "Cal. Individual" button then each of the checked spectrum will be calculated individually and not summed, then the x,y values will automatically be saved to the x,y array. These saved values can then be pated into the Duv table (accessible by clicking the Duv toolbar button) and used to make more customizable CIE plots.

xvii. "Clear all saved R-values and Q-values (0/7)"

Clears any saved R, Q data from memory. After a spectrum is calculated you can click the "Rn" toolbar button to save the R and Q values to an array. These can then be used to make R or Q values plots like that shown in Figure 5. You can use the current values or all of the saved values to make your plot by using the menu commands in the R-values plot window (accessible with a toolbar button).

xviii. "Clear input data on start-up"

By default the program will start each time with the final values from the last time it was run. Checking this will always start the program with no spectrum selected and lumen or watt values.

xix. "Reset all program default values"

Reset any user changeable values to their default settings with no spectrum selected and no lumen or watt values. This can also be accomplished by deleting the ColorCalculator.ini file located in the same directory as the ColorCalculator.exe file. Note that any user spectra, filters or colors will not be affected; these are stored in separate files.

xx. "Update decimal format"

The program is "international" aware, meaning that it asked the operating system whether to use a dot or comma for the decimal separator. You can reset this is the operation system and use this command to have the program reset itself to use the new value.

d. <u>Outputs Menu</u>

i. "Write current spectrum data to a text file"

The current contents of the spectrum table will be written to a text file of your choosing. This can be read in using another command. This is in addition to being able to cut and paste the data to a file for saving.

ii. "Write u'v' for the R-values, Q-values, and any checked User Colors to Excel file (CRI_CQS_u'u'.xls)"

Calculates the u'v' for the individual R-colors, Q-colors and any user colors under the test and reference light sources and writes then to an Excel file names CRI_CQS_u'u'.xls.

iii. 'Write the photometry data to a file (photometry.txt)"

The results of each calculation will be written to a text file.

iv. "Write the gamuts, COI, Class A, TLCI & umol/s-W to the photometry.txt file"

Write these quantities to the text file after each run.

v. "Write all photometry data to Excel file (photometry.txt)"

The main photometric quantities will be written to an Excel file after each run.

vi. "Write u'v' for the R-values, Q-values, and any checked User Colors to Excel file (CRI_CQS_u'v'.xls)"

Write data for any checked user colors to an Excel file.

vii. "Write the binning runs to a file"

The individual x,y points from a binning run will be written to a text file.

viii. "Gamut based on 1976 (u'v') diagram"

The gamut areas based on the 1976 diagram will be displayed in the UI.

ix. "Gamut based on 1960 (uv) diagram"

The gamut areas based on the 1960 diagram will be displayed in the UI. Note that the gamuts themselves are ratios and have the same values on the 1976 and 1960 diagrams. Only the gamut areas are different.

e. Matching Menu

i. "Matching mode"

Adds a third column to the spectrum table. An additional spectrum can be pasted into this 3rd column to be plotted along with the original spectrum. The name of the matching spectrum can be changed in the spectrum plot window.

ii. "Plot normalized data"

Normalize the original and matching spectra before plotting.

iii. "Use photopic ($\bar{y}$) curve as the matching spectrum"

Use the photopic ($\bar{y}$) curve as the matching spectrum, the spectra will be normalized before plotting.

iv. "Use scotopic ($\bar{y}$) curve as the matching spectrum"

Use the scotopic ($\bar{y}$) curve as the matching spectrum, the spectra will be normalized before plotting.

v. "Use photopic ($\bar{x}$) curve as the matching spectrum"

Use the photopic ($\bar{x}$) curve as the matching spectrum, the spectra will be normalized before plotting.

vi. "Use photopic ($\bar{z}$) curve as the matching spectrum"

Use the photopic ($\bar{z}$) curve as the matching spectrum, the spectra will be normalized before plotting.

vii. "Plot spectrum difference"

Plot the original and matching spectra along with the difference between the two.

f. User Spectra Menu

i. "Save as a user spectrum…"

After a spectrum has been calculated it can be saved for future use. The spectrum can be from a combination of existing spectra, pasted into the table or read from a file. You can enter any name you like and enter an LPW if it is known. Any saved user spectra are saved to a file called "userSpectra.spec" in the directory where the ColorCalculator.exe is. It is a plain ascii file and can be read in most text editors. You can move the file around, make copies or rename it. Each time the program starts it looks for a file called "userSpectra.spec" and reads in any spectra found within.

ii. "Import user spectra (add to current ones)…"

Open and read in saved spectra. You will be prompted for a file to open. This file must be in the correct format so it is almost always a previously renamed "userSpectra.spec" file. The spectra read-in will be added to any existing user spectra.

iii. "Read a saved user spectra file (replace current ones)…"

Open and read in saved spectra. You will be prompted for a file to open. This file must be in the correct format so it is almost always a previously renamed "UserSpectra.spec" file. The spectra read-in will replaced any existing user spectra. A file called "userSpectra_bck.spec" will contain the contents of the old "userSpectra.spec" file if any existed.

iv. "Edit user spectra…"

Opens a new window allowing the user to rename, reorder, change the LPW, or delete any user spectra in the current file.

v. "Create Gaussian peak user spectra…"

You can enter the peak center and FWHM to define a Gaussian peak which will be added to your user spectra.

vi. "Standard illuminates"

You can select standard illuminates to be added to your user spectra.

vii. "Import *.isd SpecWin data file…"

You can select files created by the SpecWin software and directly import them as user spectra.

viii. "Import *.txt SpectraSuite data file…"

You can select files created by the SpectraSuite software and directly import them as user spectra. You will be prompted to enter the intensity units (W/nm, mW/nm or µW/nm) for the spectrum.

ix. "Import data file (1st column is nm, 2nd column is intensity) …"

These files can be from any source and any wavelength range or interval. The data can be separated by spaces or tabs, commas may also work depending on the symbol used as the decimal point. You will be prompted to enter the intensity units (W/nm, mW/nm or µW/nm) for the spectrum. In this file format you can have up to 100 spectra in the same file in different columns as long as they all have the same wavelengths, only the first column is used for the wavelength, the other columns will be considered as holding the intensity.

x. "Import data file (1st column is intensity, 2nd column is nm) …"

These files can be from any source and any wavelength range or interval. The data can be separated by spaces or tabs, commas may also work depending on the symbol used as the decimal point. You will be prompted to enter the intensity units (W/nm, mW/nm or µW/nm) for the spectrum. In this file format you can have only 1 spectrum in the file.

g. User Filters Menu

i. "Save as a user filter…"

After a filter has been entered and calculated it can be saved for future use. The filter must paste into the table when in "Filter input" mode. You can enter any name you like. Any saved user filters are saved to a file called "userFilters.fils" in the directory where the ColorCalculator.exe is. It is a plain ascii file and can be read in most text editors. You can move the file around, make copies or rename it. Each time the program starts it looks for a file called "userFilters.fils" and reads in any filters found within.

ii. "Import user filters (add to current ones)…"

Open and read in saved filters. You will be prompted for a file to open. This file must be in the correct format so it is almost always a previously renamed "userFilters.fils" file. The filters read-in will added to any existing user spectra.

iii. "Read a saved user filters file (replace current ones)…"

Open and read in saved filters. You will be prompted for a file to open. This file must be in the correct format so it is almost always a previously renamed "userFilters.fils" file. The spectra read-in will replaced any existing user filters. A file called "userFilters_bck.fils" will contain the contents of the old "userFilters.fils" file if any existed.

iv. "Edit user filters…"

Opens a new window allowing the user to rename, reorder, or delete any user filters in the current file.

v. "Uncheck all user filters"

Uncheck any checked user filters.

vi. "Allow values greater than 1 or 100%"

If this option is checked than values greater than 1 or 100% will be allowed. If this is not checked a warning will be shown.

h. User Colors Menu

i. "Save as a user color…"

After a color has been entered and calculated it can be saved for future use. The color must paste into the table when in "Color input" mode. You can enter any name you like. Any saved user colors are saved to a file called "userColors.cols" in the directory where the

ColorCalculator.exe is. It is a plain ascii file and can be read in most text editors. You can move the file around, make copies or rename it. Each time the program starts it looks for a file called "userColors.cols" and reads in any colors found within.

ii. "Import user colors (add to current ones)…"

Open and read in saved colors. You will be prompted for a file to open. This file must be in the correct format so it is almost always a previously renamed "userColors.cols" file. The colors read-in will be added to any existing user colors.

iii. "Read a saved user colors file (replace current ones)…"

Open and read in saved colors. You will be prompted for a file to open. This file must be in the correct format so it is almost always a previously renamed "userColors.cols" file. The spectra read-in will replaced any existing user colors. A file called "userColors_bck.cols" will contain the contents of the old "userColors.cols" file if any existed.

iv. "Edit user colors …"

Opens a new window allowing the user to rename, reorder, or delete any user colors in the current file.

v. "Check all user colors"

Check all of the user colors.

vi. "Uncheck all user colors"

Uncheck any checked user colors.

i. CIE Plot Menu

More options are available in the main CIE diagram window. Additional customizations involving MacAdams ellipses and point symbols, colors and labels are also available from the Duv toolbar button.

i. "Ccolor filled CIE space"

Fill the CIE diagram with color.

ii. "Unfilled CIE space"

Do not fill the CIE diagram with color, it will be white.

iii. "Show raw spectra with points and lines"

A point representing each individual checked spectra along with a dotted line connecting it to the sum of the check spectra will be displayed.

iv. "Show grid lines"

Show grid lines in the CIE plot.

v. "Show wavelength markers"

Show the wavelength markers on the outer CIE horseshoe.

vi. "Show black body locus"

Show the black body locus on the diagram.

vii. "Show black body locus or daylight locus"

Show the black body locus below 5000K and show the daylight above 5000K.

viii. "Show black body locus and daylight locus"

Show the black body and the daylight loci.

ix. "Show TM-30 locus"

Show the TM-30 locus on the diagram.

x. "Show no locus"

Do not show either the black body or daylight locus on the diagram.

xi. "Show 100K CCT lines"

Show tick marks every 100K on the blackbody locus.

xii. "Show ANSI C78.377-2011 quadrangles"

Show the ANSI C78.377-2011 quadrangles.

xiii. "Show ANSI C78.377-2008 quadrangles"

Show the ANSI C78.377-2008 quadrangles.

xiv. "Write the photometry on the CIE diagram"

An abbreviated summary of the photometry will be displayed on the CIE diagram. In the main CIE diagram window the location of this label can be moved.

xv. "Enable SmartZoon (center at x,y)"

Center the CIE diagram at the x,y of the spectrum.

xvi. “Gamuts”

Select standard gamuts to be drawn on the CIE diagram.

xvii. “Solid gamut lines”

Draws the gamut lines as solid line if checked, if not checked each line is drawn with a different dashed line.

xviii. “MacAdam ellipse”

Select which of the MacAdam ellipses to display. These ellipses are based on equations from: Chickering, JOSA V57 n4, 1967, "Optimization of the MacAdam-Modified 1965 Friele Color-Difference Formula" and Chickering, JOSA V61 n1, 1971, "FMC Color-Difference Formulas: Clarification Concerning Usage"

xix. “u’v’ circles”

Draw the u’v’ circles, as defined in CIE TN 001:2014, on the CIE diagram.

xx. “Symbol size”

Select the size of the x,y point symbol

j. Spectrum Plot Menu

More options are available in the main spectrum plot window.

i. “Plot with white background”

Do not fill the plot with color.

ii. “Plot with rainbow under curve”

Fill the plot with color only under the curve.

iii. “Plot with rainbow background”

Fill the entire plot with color.

iv. “Draw color patch (at 6500K) on plot when plotting colors/filters”

Display a patch representing the color/filter under 6500K daylight on the plot.

v. “Write the photometry or the filter/color name on the plot”

Display a summary of the photometry or the filter/color name on the plot.

vi. “Position text and color patch top right of spectrum plot”

Draw the caption and color patch in the top right corner.

vii. “Position text and color patch top left of spectrum plot”

Draw the caption and color patch in the top left corner.

viii. “Keep y-axis for filters and colors at full scale (1 or 100)”

For filters and color plots do not scale the y-axis, keep it at 1 or 100%.

ix. “Show grid lines”

Draw vertical grid lines.

x. “Enable mouse wheel zoom”

When this is checked scrolling the mouse wheel when over the spectrum plot will zoom the wavelength axis in or out. The zoom will take place centered at the wavelength where the mouse is positioned.

k. TM-30 Menu

i. “IES TM-30-15 icon and distortion plots“

Uses the last calculated spectra to make the plot. Use the “Image Type” menu item in the plot window to switch between the two plot types.

ii. “IES TM-30-15 chroma shifts and hue Rf histograms“

Uses the last calculated spectra to make the plot. Use the “Image Type” menu item in the plot window to switch between the two plot types.

iii. “IES TM-30-15 color patches“

Uses the last calculated spectra to make the plot.

iv. “IES TM-30-15 Rg versus Rf plot“

Uses the last calculated spectra to make the plot.

v. “IES TM-30-15 a’b‘ plot“

Uses the last calculated spectra to make the plot.

vi. "Write IES TM-30-15 J'a'b' and $R_{f,i}$ values to a file…"

l. Other Calculations Menu

i. "CIEL*a*b* plot with user inputted values..."

Opens a new windows where you can enter your own L*a*b* values to make a CIELab plot.

ii. "Calculate CIEDE2000 with user inputted values..."

Opens a new window where you can L*a*b* values and calculate various CIEDE2000 quantities.

iii. "Calculate CCT & Duv from x,y…"

Opens a new window where you can enter x, y values and the corresponding u'v', CCT and Duv values will be calculated. You can also make highly customized CIE plots from this window. You can enter x,y points to plot, select different MacAdams ellipses, specify your own, change the point size, symbol, color and add captions to the points. This window can also be open with the Duv toolbar button. This is the main function to make customized CIE plots.

iv. "Calculate x,y from CCT & Duv…"

Opens a new window where you can enter CCT and Duv values and the corresponding x,y values are calculated.

v. "Convert coordinates (xy/uv/u'v'/XYZ/L*a*b*)..."

Opens a new window where you can enter one set of coordinates and the other sets of coordinates are calculated.

vi. "Convert between RGB, HSV and HSL systems"

Opens a new window where you can enter one set of values and the other sets of values are calculated.

vii. "Calculate the black body locus and CCT lines…"

Opens a new window where you can enter minimum and maximum CCT values and the x,y coordinated of the black body line will be written to a tab delimited file called "blackBodyLocus.txt".

viii. "Calculate the coordinates of MacAdams ellipse or u'v' circle…"

Opens a new window where you can enter an x,y point along with the size of the MacAdams ellipse or the u'v' circle and points representing the ellipse or circle will be calculated.

ix. "Calculate circadian system response…"

Opens a new window where you calculate the circadian/melatonin suppression metric based on work by M.S. Rea, M.G. Figueiro, J.D. Bullough, A. Bierman and R. Hamner at the Lighting Research Center, Rensselaer Polytechnic Institute, Troy, New York, USA..

x. "Calculate binning from x,y and lumens…"

Opens a new window where you can enter x, y and lumens along with wavelengths and Cx, Cy bin widths and Monty Carlo simulations are used to estimate the expected variation in color.

xi. "Calculate photometry from x,y and lumens…"

Opens a new window where you can enter x, y and lumens of several light sources and the resultant photometry of all of the light sources combined is calculated.

xii. "Calculate 3 color mixing based on x,y…"

Opens a new window where you can enter the x,y values of your three colors. In another table you enter the target CCT and Duv or x and y, and the total lumens you want. The program will then calculate the lumens required of each of the three colors to hit your target.

xiii. "Calculate maximum lumens from color mix…"

Opens a new window where you can enter the x,y values of your colors. If you check LEDs in the main window and press the "Cal. Individual" button before open this window you wll be able to press the "Use last" button to copy the LED data into the table, you can also enter values into this table manually. You enter the color mixes in terms of visible watts and the maximum lumens you can are reported.

xiv. "Calculate color mixing based on spectra…"

Opens a new window where you can mix up to 4 spectra. These must be checked in the main window before you click this command. You can enter different intensities of these peaks and the photometry will be calculated.

m. Other Options Menu

i. "Program font…"

Change the font used for the UI.

ii. “Write the R1-R15 colors to a R_values.cols file”

Writes the reflectance spectra of the 15 CIE test colors to a file. These can then be read-in as user colors or used in other software.

iii. “Write the Q1-Q15 colors to a Q_values.cols file”

Writes the reflectance spectra of the 15 CQS test colors to a file. These can then be read-in as user colors or used in other software.

iv. “Write the CES colors to a CES_values.cols file”

Writes the reflectance spectra of the 99 CES test colors to a file. These can then be read-in as user colors or used in other software.

v. “Write photometry coefficients file”

Writes several of the photometric constant to a file. The following files are written: "XYZ_coeff.xls", "TCS_VS_coeff.xls", "CCT_coeff.xls", "daylight_coeff.xls".

vi. “Play sounds”

Beeps when a run is completed.

vii. “Enable sticky menus”

Keeps certain menus open after a selection is made.

viii. “Resize window to fit screen size”

When changing screen resolution the main window may be slightly off the screen, this command will resize and reposition it so it fits.

ix. “Show all standard LEDs”

Shows all of the standard spectra what come with the software. User spectra are shown.

x. “Do not show generic pure color standard LEDs”

Do not show any of the pure color spectra what come with the software. User spectra are shown.

xi. “Do not show IR standard LEDs”

Do not show the standard spectra for the IR LEDs what come with the software. User spectra are shown.

xii. “Do not show any standard LEDs”

Do not show any of the spectra what come with the software. User spectra are shown.

xiii. "Show CIE and CQS test colors and TM-30 hue colors"

Set the background color of the individual R, Q and TM-30 R_f values cell to an approximate representation of the actual R, Q or TM-30 hue value at D65.

xiv. "Show tab highlight colors"

Highlights the "Spectra", "Filters", "Colors", "Optimization" tabs with colors to make them more visible.

n. Color Systems Menu

i. "Natural Colour System (NCS)…"

Opens a new window where you can access the colors in the NCS system. These colors can be individually selected and saved as user colors.

Help Menu

i. "Web site"

Opens a web browser to the home page of this program. You can check if a new version is available.

ii. "Check the web site for updates"

Checks to see if a new version of the software is available.

iii. "Check for updates at start-up every 30 days"

Checks to see if a new version of the software is available when you start the program every 30 days.

iv. "Open pdf User Guide"

Opens a pdf version of this file if it exists in your local directory.

v. "View license agreement"

Display the license agreement.

vi. "OSRAM Opto Semiconductors web site of LED spectra"

Opens a brower to a web site with the spectra of current OSRAM Opto Semiconductors LEDs.

vii. "About"

Gives some very general information about this program.