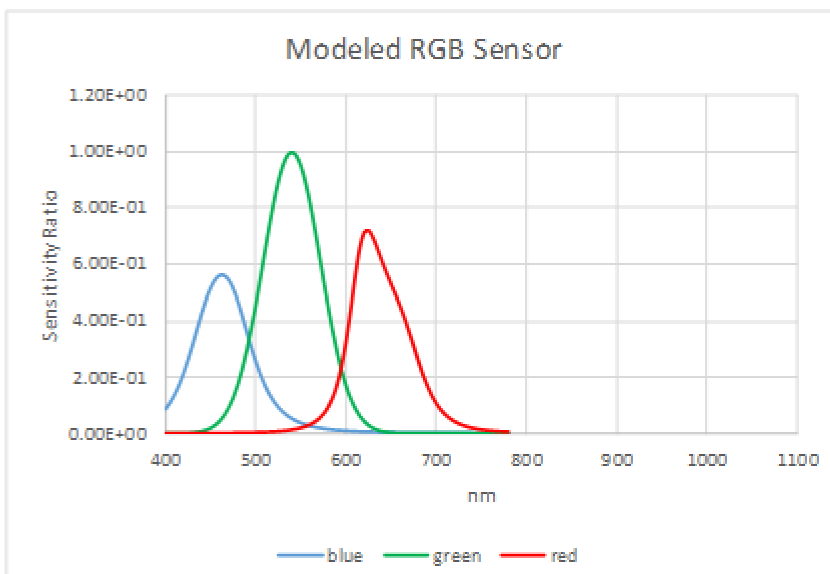
When Smart Sensors Require Smart Sources

How a spectral matching source simulator can differentiate RGB ambient light sensor performance

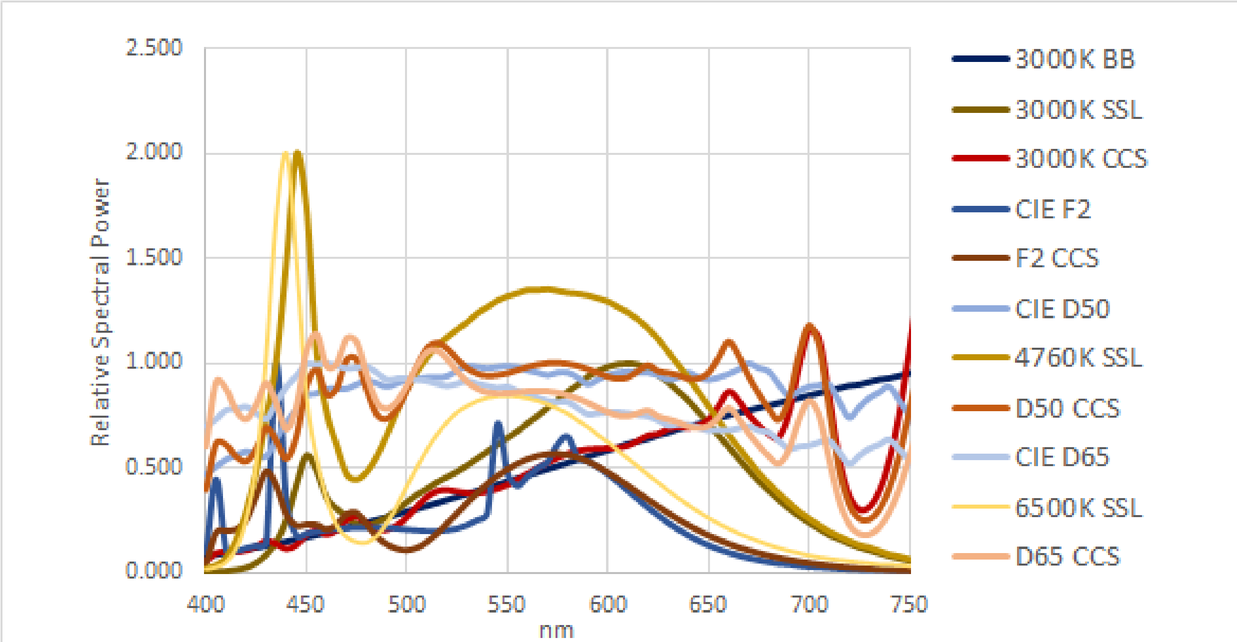
Ambient light sensors are designed to detect brightness in the same way that human eyes do. They are used wherever the settings in a system must be adjusted to the ambient conditions as perceived by humans. RGB ambient sensors can be calibrated to predict the indoor or outdoor ambient lighting conditions and be used to make appropriate corrections and trigger functions like auto-adjusting display brightness. To do this most effectively a smart calibration source is required. Sensor calibrations based solely on correlated color temperature (CCT), can misrepresent the actual ambient light conditions. To reduce this misidentification, tunable sources that can simulate indoor and outdoor lighting conditions can be used to calibrate the true spectral response of the sensor.

The green filtered response of an ambient light sensor (ALS) can be used to monitor the illuminance (lux) on the sensor. The RGB signal ratios can be used to identify the spectral character and type of ambient light when the RGB sensor is calibrated appropriately. The spectral sensitivity responses $S_{B\lambda}$, $S_{G\lambda}$ and $S_{R\lambda}$ of a typical RGB sensor are shown here. It should be noted that some sensors have a second response peak in the blue for better response matching to the human eye.



Ambient Sources, Simulations and CCTs
To understand how this simulated RGB sensor will respond when illuminated by a source, compare the standard indoor and outdoor spectral illuminants, solid state (LED) light sources with matching CCT, and standard illuminant spectrums reproduced by a tunable source spectrum simulator. Data for the

illuminants are plotted from CIE data tables. The solid-state sources were measured and the spectral simulated data is the spectral output from Labsphere's CCS-1100 tunable spectral light source.



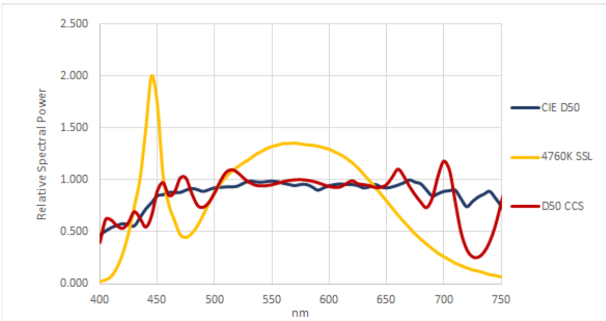
The sources shown included are:

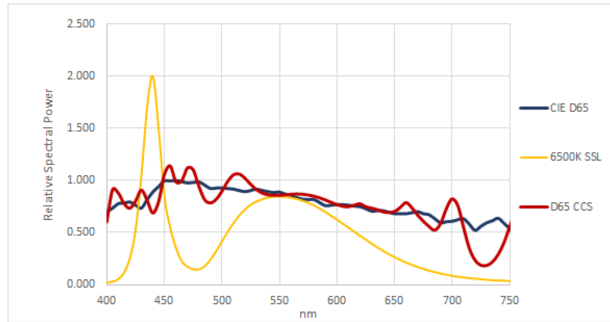
- 3000K BB: Black Body depicting Illuminant A or typical tungsten source
- 3000K SSL: Broadband Solid State Phosphor Lamp
- 3000K CCS: 3000K Black Body simulation with CCS tunable source
- CIE F2: Cool White Fluorescent
- F2 CCS: Cool White Fluorescent simulation with CCS tunable source
- CIE D50: Standard Illuminant D50 Horizon Light
- 4760 SSL: 4760K Broadband Solid State Phosphor
- D50 CSS: Standard Illuminant D50 simulation with CCS tunable source
- CIE D65: Standard Illuminant D65 Mid-morning / Mid-afternoon Daylight
- 6500K SSL: 6500K Broadband Solid State Phosphor
- D50 CSS: Standard Illuminant D65 simulation with CCS tunable source

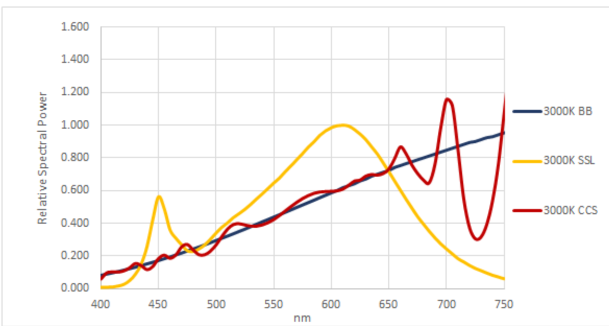
The table below shows the color parameters of the light sources. These are derived using standard CIE colorimetry of light source methods for determining chromaticity coordinates x, y and associated CCT from the spectral data present above.

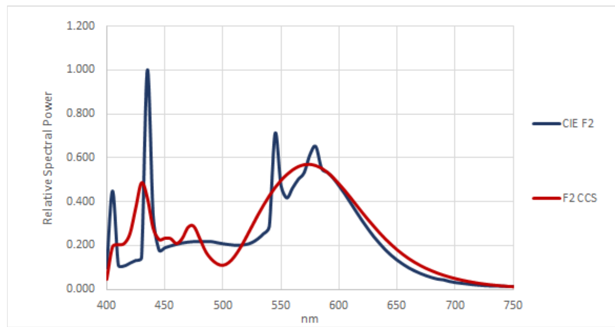
	3000K BB	3000K SSL	3000K CCS	CIE F2	F2 CCS	CIE D50	4760K SSL	D50 CCS	CIE D65	6500K SSL	D65 CCS
x	0.4370	0.4349	0.4386	0.3721	0.3753	0.3453	0.3529	0.3470	0.3131	0.3121	0.3139
y	0.4042	0.3989	0.4059	0.3751	0.3775	0.3521	0.3623	0.3614	0.3297	0.3295	0.3319
CCT	3000K	2999K	2988K	4224K	4148K	4999K	4760K	4964K	6478K	6532K	6419K

Note that the x, y and CCT coordinates are very similar, but a good tunable source spectrum simulator can closely match the spectral output of the reference light sources and provide the spectral and color parameters needed for calibration of the RGB sensor used to detect ambient light conditions. The plots below show typical standard ambient illuminants 3000K, F2, D50 and D65. These are broken out from spectral plots above.









How may the RGB sensor respond to the ideal standard Illuminants, vs. CCT sources and simulated ideal spectrums?

If we look at the total spectral response from each filtered sensor it can be described as:

$$S = \int_{400}^{800} S_\lambda P_\lambda d\lambda$$

Where:
S is the total signal (counts) from the filter sensors (R, G or B) when illuminated by the reference source
S_λ is the spectral sensitivity of the filter sensors (R, G or B)
P_λ is the spectral power (or spectral irradiance) from the reference source incident on the sensor

The total response for each source can now be predicted. The table below shows the total response from each sensor for the given spectral reference source. This represents the relative signals from the RGB sensor when illuminated with the presented light sources.

	Blue	Green	Red
3000K BB	9.92	32.65	37.02
3000K SSL	13.83	47.14	40.71
3000K CCS	9.87	33.32	37.16
CIE F2	11.05	29.22	12.58
F2 CCS	11.14	30.41	14.34
CIE D50	36.51	76.15	50.45
4760K SSL	19.36	47.04	24.59
D50 CCS	36.56	77.54	50.69
CIE D65	40.65	70.12	38.33
6500K SSL	26.34	56.46	19.91
D65 CCS	41.05	71.71	38.72

With this, the Red/Green (R/G) and Blue/Green (B/G) responses are used to create a reference table for the chosen reference sources and potential calibration sources. The R/G B/G responses to the sources are shown in the table below as well as the CCT of each source.

	R/G	B/G	CCT
3000K BB	3.733	0.304	3000K
3000K SSL	2.942	0.293	2999K
3000K CCS	3.764	0.296	2988K
CIE F2	1.139	0.378	4224K
F2 CCS	1.287	0.366	4148K
CIE D50	1.382	0.479	4999K
4760K SSL	1.27	0.411	4760K
D50 CCS	1.386	0.471	4964K
CIE D65	0.943	0.580	6478K
6500K SSL	0.756	0.466	6532K
D65 CCS	0.943	0.572	6419K

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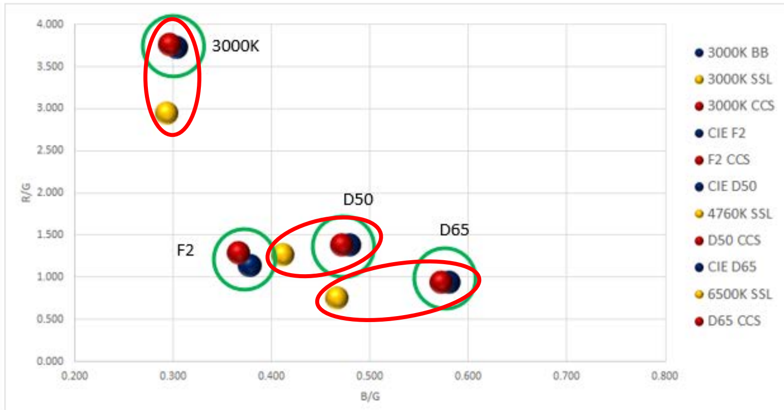
Since the R/G and B/G ratios are used to determine the ambient conditions, it is imperative that the source correctly represent the unique spectral signature during calibration. These ratios are plotted here.

Note the tight matching between the Standard Illuminants and the simulated spectra from the tunable source as indicated in the green circles. This is achieved by spectrally matching the CCS calibration source to the desired reference ambient illuminants.

However, one should not assume that a source of the same CCT will produce the same R/G B/G ratios for sensing the desired ambient illuminant.



The red ovals show the tunable sources and SSL sources that are intended to represent the standard illuminant for the same CCT. Even though the CCTs are similar, the ratios for the solid state phosphor sources do not represent the desired ambient illuminants.

Although the 3000K SSL source has the same CCT as the 3000K BB Illuminant the R/G B/G ratios are very different. The same is true for D50 and D65. In fact, the D50 SSL source is closer to the CIE F2 Illuminant than it is to the D50. Similarly, the 6500K SSL source could be mistaken for a D50 source as it is closer to the D50 Illuminant than it is to the D65 illuminant.

An objective of the ambient sensor is to identify the ambient source of light and ambient illuminance levels on a smart mobile device. In this exercise the spectral responsivities of the RGB ambient sensor in the visible regions were modeled to determine how the sensor would respond to simulated standard illuminants and broadband sources of similar CCTs for ambient source recognition. The results show the RGB sensor calibrated with a source that only matches the CCT, does not accurately identify the target ambient source. The results show that calibrating the RGB sensor to spectral reference illuminant sources that match spectral content, x, y, and CCT, is a more accurate method for identifying the ambient source based on the R/G, B/G ratios.

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Greg McKee is the Chief Technologist and Product Marketing Manager at Labsphere Inc. Mr. McKee served as an Executive Officer on the Council for Optical Radiation Measurements (CORM) Board of Directors for nine years. He has also served as Chairman of CORM Technical Committee Subcommittee CR-4 Integrating Flux Devices and Chairman of the Illuminating Engineers Society of North America (IESNA) Technical Procedures Committee for the Photometry of Light Source where he managed the creation and revisions of standard test procedures of light sources

