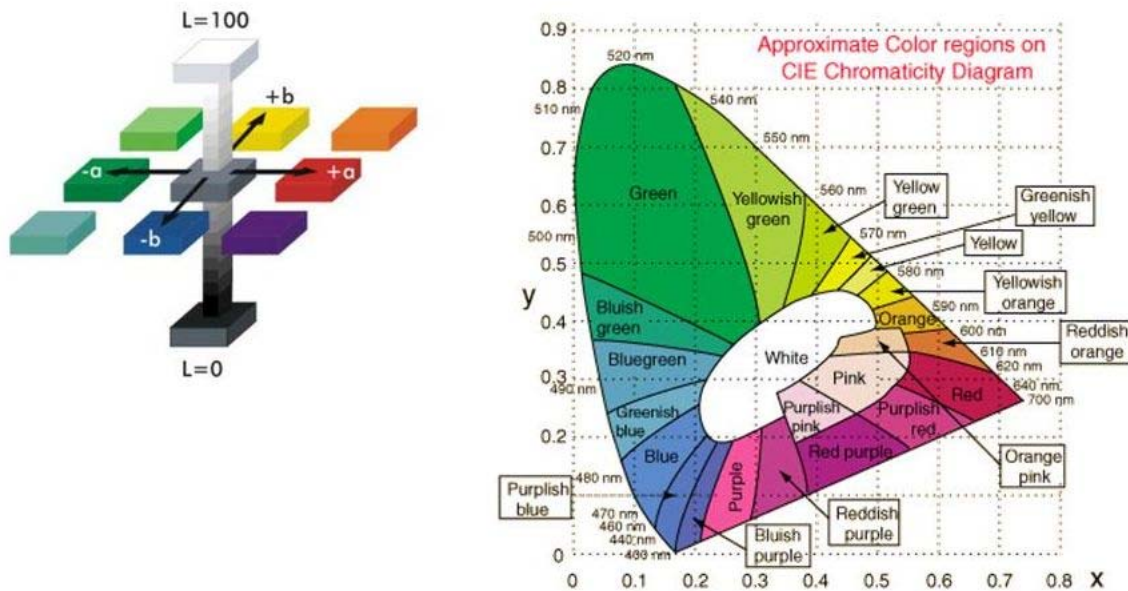


**Introduction:**

The CIE color coordinate application is used to determine the CIE tri-stimulus values (X, Y, Z), color scales (L\*, a\*, b\*), Euclidean vector distance (delta-E), chroma (C\*ab) and hue difference (dH\*ab) of a sample following the ASTM E308 Standard Practice. Additionally, the application computes the Saturation, Yellowness, Whiteness and Tint Index following the ASTM E313 Standard Practice. The results are displayed as numerical values to the i-LAB® screen in addition to being saved to the log.

The CIELAB color measurement is a standardized means of condensing the full color spectrum of a sample into a simpler set of numbers that characterize the color. The color space is broken down into three parameters defined by a\*, b\* and L\*. a\* represents the color change in the red color space, being positive in the red direction and negative in the green direction. b\* represents the color change in the yellow color space, being positive on the yellow direction and negative in the blue direction. L\* represents the change in shade from white to black. These parameters are based on the CIE tri-stimulus values (X,Y,Z) and referenced against a white standard. Figure 1 depicts the CIE Chromaticity Diagram.

**Figure 1: CIE Chromaticity Diagram**



## Methods:

1. Lab\_Backg
2. Lab\_XYZ

## Process flow:

1. A background or reference sample is acquired and stored with the Lab\_Backg method. This is used both as the background spectrum as well as the reference sample that is used to calculate the CIE parameters.
2. Next a sample is acquired and analyzed using the LabXYZ method. All the CIE parameters are calculated from the sample and the results are reported to the i-LAB<sup>®</sup> screen and saved to the log. Multiple analyses can be performed on a single background; however it is recommended that a new background be stored with Lab\_Backg after every 20 samples.

## What is displayed to the screen:

Lab\_Backg: The method will display instructions to scan the background and will display calibration and acquiring status to the screen as it acquires the background. The method will exit to the iLab Ready screen when finished.

Lab\_XYZ: The method will display instructions to scan the sample and will display acquiring status as it acquires the sample. It then outputs delta E, chroma, saturation and delta H to the screen. All other parameters are saved to the log.

## What is saved to the Library/Log:

Lab\_Backg: The background spectrum is saved to the library for use by the Lab\_XYZ method and is not accessible to the user.

Lab\_XYZ: The sample spectrum and all the CIE parameters are saved to the log. These are saved in user variable format and require i-LAB Datalogger to download and format properly into their respective parameters.

## Basic Methodology:

### 1. Lab Backg:

The background or reference sample spectrum is acquired and saved to the i-LAB<sup>®</sup>'s internal library. This reference sample should be a clear sample used to define a 1.0 transmission spectrum. (A substance with a 100% transmission will have a 1.0 transmission spectra, a substance with a 0% transmission will have a 0.0 transmission spectra.) The CIE calculation requires a reference standard as close to 1.0 as possible to produce the proper results.

The set of normalized tri-stimulus weighting factors ( $W_x$ ,  $W_y$ ,  $W_z$ ), pre-stored in the i-LAB<sup>®</sup>'s internal library are used as regression spectra to process against the background spectrum to generate the CIE X, Y, and Z tri-stimulus values for the reference sample. These calculated values are stored to the i-LAB<sup>®</sup>'s internal library.

Using the X, Y, Z values just calculated and known  $X_n$ ,  $Y_n$ ,  $Z_n$  values (from a known spectrum defined as 1.0 transmission), the CIELAB tri-stimulus values  $L^*$ ,  $a^*$  and  $b^*$  are calculated for the blank sample and stores in the i-LAB®'s internal library. These calculations are performed using the equations from the ASTM Standard E308:

$$L^* = 116 * [Y/Y_n]^{1/3} - 16$$

$$a^* = 500 * ([X/X_n]^{1/3} - [Y/Y_n]^{1/3})$$

$$b^* = 200 * ([Y/Y_n]^{1/3} - [Z/Z_n]^{1/3})$$

Using these values and the equation below, the chroma is then calculated for the reference spectrum:

$$C^*_{ab} = [(a^*)^2 + (b^*)^2]^{1/2}$$

This result is also saved to the i-LAB®'s internal library.

## 2. Lab XYZ:

The sample spectrum is acquired and saved to the log as well as the internal library. The reference spectrum is retrieved at this point to be used for the CIE calculations.

The set of normalized tri-stimulus weighting factors ( $W_x$ ,  $W_y$ ,  $W_z$ ) are used as regression spectra to process against the sample spectrum to generate the CIE X, Y, and Z tri-stimulus values for the unknown sample by the equation presented in the ASTM Standard Practice E308. (This calculation uses the Spectral Tri-stimulus Values (Color-Matching Functions) of the CIE 1931 Standard (2°) observer and Relative Spectral Power Distributions  $S(\lambda)$  of CIE Standard Illuminants C (North Sky Daylight 6774K)). These calculated values are then stored to the log.

Using the X, Y, Z values just calculated and known  $X_n$ ,  $Y_n$ ,  $Z_n$  values (from a known spectrum defined as 1.0 transmission), the CIELAB tri-stimulus values  $L^*$ ,  $a^*$  and  $b^*$  are calculated for the unknown sample and saved to the log. These calculations are performed using the equations from the ASTM Standard E308:

$$L^* = 116 * [Y/Y_n]^{1/3} - 16$$

$$a^* = 500 * ([X/X_n]^{1/3} - [Y/Y_n]^{1/3})$$

$$b^* = 200 * ([Y/Y_n]^{1/3} - [Z/Z_n]^{1/3})$$

The CIELAB tri-stimulus values  $L^*$ ,  $a^*$  and  $b^*$  for the reference sample are then retrieved from the i-LAB®'s library. These values are used to calculate the Euclidean distance value  $\Delta E$  between the reference sample and the unknown sample. This calculation uses the equation from Standard E308:

$$dE = [(dL^*)^2 + (da^*)^2 + (db^*)^2]^{1/2}$$

The  $dE$  value is displayed to the i-LAB®'s screen in addition to being saved to the log.

Using the CIELAB tri-stimulus values from the unknown sample and the equation below, the chroma is then calculated for the unknown sample:

$$C^*_{ab} = [(a^*)^2 + (b^*)^2]^{1/2}$$

The chroma value is displayed to the i-LAB®'s screen in addition to being saved to the log.

Using the dE, dC (change in chroma) and dL (change in tri-stimulus light value), the Euclidean distance value DeltaH is calculated. This value represents the change in spectral hue between the unknown sample and the blank samples. This value is calculated using the equations:

$$dH^*_{ab} = [(dE^*_{ab})^2 + (dL^*)^2 + (dC^*_{ab})^2]^{1/2}$$

ASTM Standard E313 is then used to calculate Saturation (s), Yellowness (WI), Whiteness (YI) and Tint Index (TI) with the following equations:

$$s = C^*_{ab}/L^*$$

$$x = X/(X + Y + Z); y = Y/(X + Y + Z); \text{ and } z = Z/(X + Y + Z)$$

$$WI = Y + (WI, x) (x_n - x) + (WI, y) (y_n - y)$$

$$TI = T, x (x_n - x) - T, y (y_n - y)$$

$$YI = 100(C_x X - C_z Z)/Y$$

These values are saved to the log.

### **Additional Information:**

1. i-LAB® Internal Storage: There are two locations within the i-LAB® that one can store information – the Library and the Log. The library is an internal location that can be used by future analyses. The library is not accessible to the user under normal operations. These two methods use the library to store and retrieve the reference sample information – allowing additional unknown samples to be analyzed by “Lab\_XYZ” against this reference sample. The Log is an internal storage location that can be used to allow the user access to the data. Spectra and results can be stored to this location by a method. These spectra and results can then be downloaded and reviewed using the i-LAB® Spectrum or Datalog Software after the method has been completed.
2. ASTM Standards: Additional information on ASTM standards, including ASTM E308 and ASTM E313 can be found by visiting the ASTM web site at [www.astm.org](http://www.astm.org).
3. CIE Color Standard: Additional information on the CIE 1931 color standard can be found by visiting the CIE web site at [www.cie.co.at](http://www.cie.co.at).