A comparison between Filter Colorimeters and Spectroradiometers

Insuring that self-emissive technologies, such as information display monitors, LED lighting, or digital projectors, meet or exceed performance specifications requires precise characterization through accurate measurements. While there are several measurement technologies available for device characterization, two of the most commonly-used instrument types are filter colorimeters and spectroradiometers.

Filter Colorimeters

A basic filter colorimeter consists of:

- **Collection Optics:** This could be a lens, contact probe, translucent disc or integrating sphere, depending on the application.
- **Detector:** A light sensitive device that converts photons into electrons. A colorimeter may contain three or more detectors, which are typically photomultiplier tubes (PMT’s) or silicon photodiodes.
- **Tristimulus filters:** Red (two lobes X/red and X/blue), Green (Y) and Blue (Z) absorptive filters work with the x-detector and the International Commission on Light (CIE) Color Matching Functions to create a match to the color vision capabilities of the cone cells of the human eye. This functionality is also known as the CIE Standard Observer.

Figure 1 is a detailed illustration of an advanced filter colorimeter with rotating filter wheel. Each position in the wheel contains a Red, Green or Blue CIE filter. Sequential measurements are taken through each filter to obtain the CIE tristimulus values X, Y, and Z. Colorimeters of this caliber are supplied with hand matched CCIE filters.
The CIE recommends the following equations for determining the Red (X), Green (Y) and Blue (Z) values for any given color stimulus:

\[ X = \int_{360}^{830} R(\lambda)X(\lambda) \Delta(\lambda) \]  
\[ Y = \int_{360}^{830} R(\lambda)Y(\lambda) \Delta(\lambda) \]  
\[ Z = \int_{360}^{830} R(\lambda)Z(\lambda) \Delta(\lambda) \]

Where \( R(\lambda) \) is the spectral power, \( X(\lambda), Y(\lambda), Z(\lambda) \) are the CIE Color Matching Functions and \( \Delta(\lambda) \) is the data increment in nanometers.

The ultimate goal of the filters utilized by filter colorimeters is to modify the detector’s spectral responsivity to the desired function. Filters are typically constructed as laminates (multi-layered) or thin film deposits.

Figure 3 is a typical silicon photodiode response curve illustrating how much of a change is required to modify the detectors’ native spectral responsivity to create the Tristimulus functions necessary to conduct CIE chromaticity measurements.
**Colorimeter Benefits**

The primary benefit of a filter colorimeter is speed when measuring luminescence. In models that feature multiple detectors, each detector has its own CIE color filter and measurements are conducted in parallel, so it can be broken down by Red, Green or Blue. Colorimeter designs that feature a single detector perform sequential measurements through each filter.

Keep in mind that inaccuracies due to filter mismatch between the responsivity of the instrument to the target response function is a significant drawback to this technology. This is especially true for devices that differ spectrally from the standard used for calibration.

**Spectroradiometers**

Unlike colorimeters that collect color data utilizing absorptive filters, a spectroradiometer breaks the incoming signal into an intensity per wavelength spectrum, much like a prism converts sunlight into a rainbow (see Figure 4). Multiple detectors then measure each color in the diffracted spectrum. This “raw data” is converted into spectral radiometric values such as w/sr/m². From the spectral values, the CIE color calculations are performed (EQ 1-3).

![Spectrometer Block Diagram](image)

**FIGURE 4 – SPECTROMETER BLOCK DIAGRAM**

**FIGURE 5 - SPECTRAL RADIANCE OF WHITE LED**

**The Benefits of Spectroradiometer**

In addition to measuring luminescence, spectroradiometers also measure dominant wavelength. A spectroradiometer provides a more precise and accurate measurement than a filter colorimeter, because it does not rely on absorptive filters for color accuracy. Additionally, a spectroradiometer provides information on the spectral power distribution of the source, which is impossible to obtain from a filter colorimeter.
Making the Choice

When determining which chromaticity measurement solution will work for your application, keep in mind the accuracy of the solution. Although a lower cost technology like the colorimeter may seem sufficient, a more advanced solution, like the spectroradiometer, may ultimately deliver a better quality product that ensures accurate readings the first time.

For more information regarding colorimeter and spectroradiometer solutions offered by PHOTO RESEARCH, visit us at www.photoresearch.com or call us at 818-725-9750.