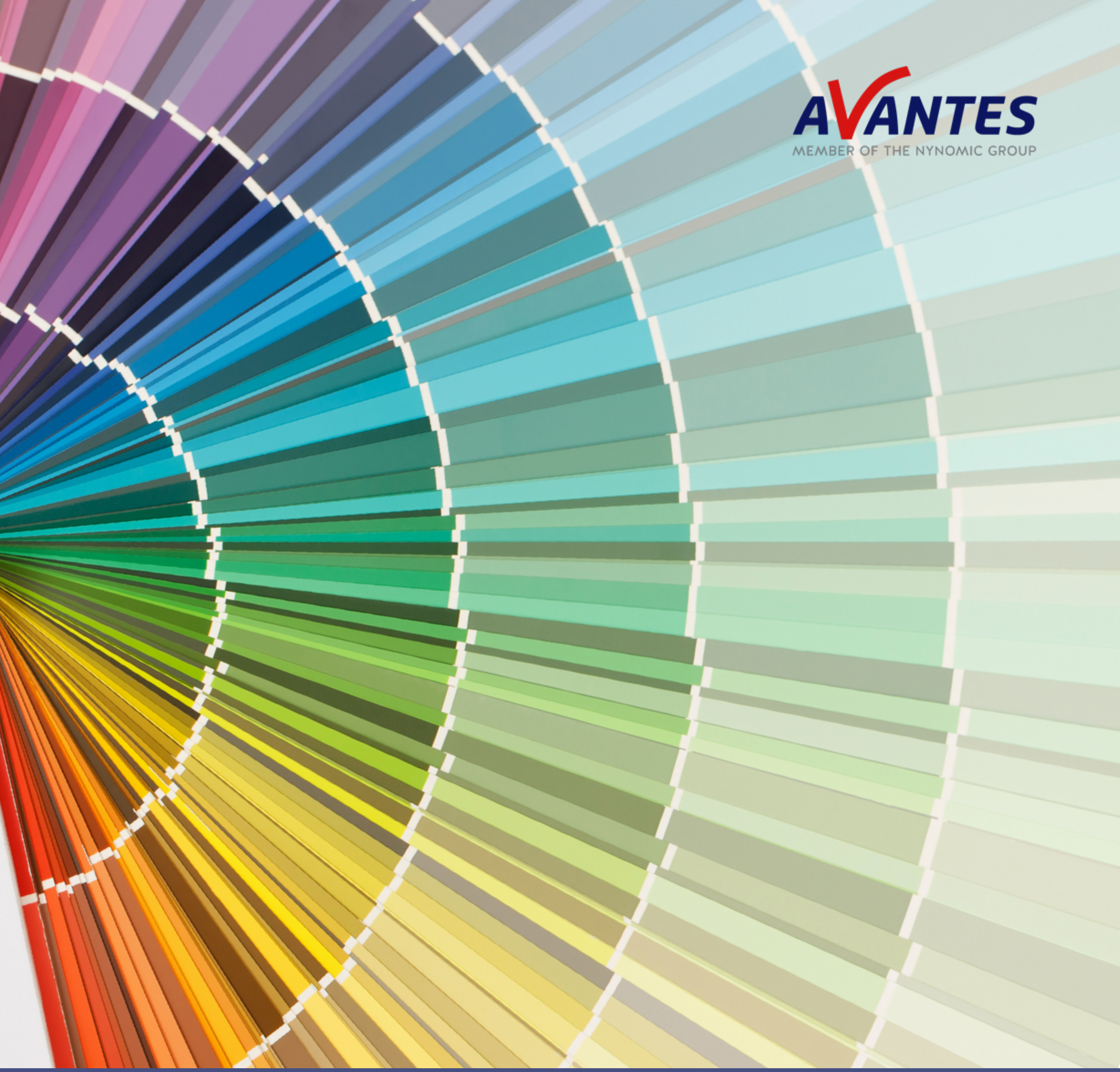
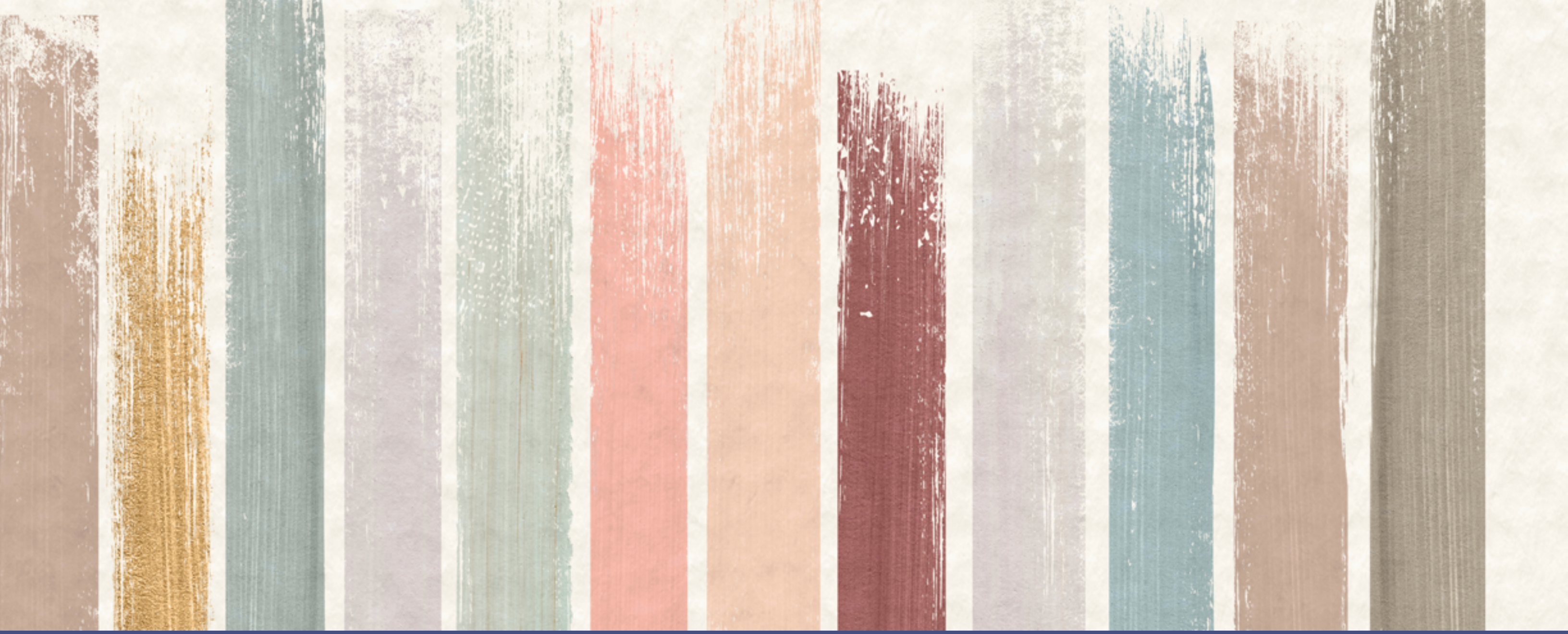


IN-HOUSE EXPERIMENT

EXAMINING ACCURACY AND RELIABILITY OF SPECTROSCOPY & COLORIMETRY FOR COLOR ANALYSIS

CONDUCTED BY KURT AMEKU



INTRO

BACKGROUND INFORMATION APPLICATION

Colorimetry is a measurement method used to quantify the color of a substance or object by the intensity and wavelength of light absorbed, transmitted, or reflected by the sample. This is often expressed in terms of the RGB (red-green-blue) scale but can also be represented in HEX scale and L*a*b*. The L*a*b* color space was originally defined by the International Commission on Illumination (CIE) in 1976, with L* defining lightness from black (0) to white (100), a* defining green (-128) to red (+127) and b* defining blue (-128) to yellow (+127). These values were defined such that a one unit change in any value would roughly correspond to a visually perceived change in color.

FIGURE 1 Paint samples and reference tile used for the experiment (from left to right: white reference tile, Blue Ember, Merlin's Robes, Deep Earth, Gondola, Four-Leaf Clover, Deep Mint, Cool Bluegrass, Green Water, Phoenix Tears, Spearmint Haze, Polar White, Ivory Lace, and Summer Gray).

This experiment aims to measure the color values with respect to the L*a*b* color space of 13 different paint samples, including two purple samples ('Blue Ember' and 'Merlin's Robes'), two brown samples (Deep Earth and Gondola), three white samples (Polar White, Ivory Lace and Summer Gray), and six green samples (Four-Leaf Clover, Deep Mint, Cool Bluegrass, Green Water, Phoenix Tears, and Spearmint Haze) (Figure 1). A white reference tile will be used as a reference material. Measurements will be taken in the visible (VIS) spectral range to purely compare color differences and not differences in the ultraviolet or infrared spectra.

DESCRIPTION OF SPECTROSCOPY SETUP

For our experiment we chose to use a setup using our Avaspec-ULS2048CL-EVO. The instrument has previously been used for absorbance and reflectance measurements, and is now being utilized for color measurements, highlighting its versatility. It has USB3.0 communication, which is 10 times faster than USB2, a CMOS detector, a fast AS-7010 microprocessor, and 50 times more memory capacity. This means it can store more spectra onboard and offer greater overall functionality. Additionally, the spectrometer can be tailored to specific application needs by using different slit sizes, gratings, and fiber optic entrance connectors. The light source used for this experiment was the AvaLight-XE-HP, a high-powered pulsed xenon light source. This light source comes in a compact housing, making it well-suited for integration into customer systems. Compared to the AvaLight-XE, which has a maximum power of 2 W, the AvaLight-XE-HP provides significantly more power (6 W). When connected to an AvaSpec spectrometer via our custom interface cable, the number of flashes per scan can be set in our AvaSoft software, and the flashes are synchronized with the data collected by the spectrometer.

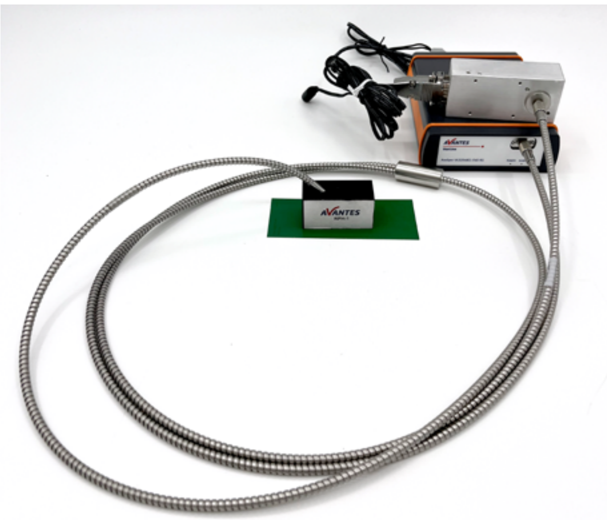


FIGURE 2 Experimental setup for paint measurement. Pobe is mounted into the probe holder, which is then placed on top of the paint sample.

Other accessories used for this experiment included a white reference tile (WS-2) that was used as the reference for both the reflection measurement and color measurement, a 200-micron core fiber optic reflection probe (FCR-7UVIR200-2-BX) to connect the integrating sphere to the spectrometer, a probe holder (RPH-1) to hold the probe consistently at a 45-degree angle, and a custom interface cable to connect the AvaLight-XE-HP to the AvaSpec-ULS2048CL-EVO to control flashes per scan and to power the light source. This interface cable was designed by our engineering team and highlights some of the custom build options that can be assembled for our customers

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DESCRIPTION OF METHODOLOGY

Each sample was a paint sample taken from a hardware store. The samples were stored in a drawer to ensure the colors did not change from sunlight exposure. The probe was mounted into the probe holder, which was individually placed on each paint sample for analysis. The probe holder established a consistent measurement distance, which in turn resulted in measurements that could be accurately compared. The white reference tile was measured first to set our reference, and it was also measured under the probe holder to ensure consistency in measuring distance.

For data analysis, we used two modes in AvaSoft, our exclusive custom software package. The first mode used was Color mode, which is included with AvaSoft-All or available as a single addon module. This mode is specifically designed for color measurements, with the ability to measure parameters such as L*, a*, b*, X, Y, and Z, as well as dL, da, db, and dE. A live chart displays the sample measurement on an L*a*b* graph, a separate reference color can be assigned for dL, da, db, and dE measurements, and all data can be saved to an Excel or text file. The second mode used was Reflectance mode. This mode is designed for reflection applications, where the reference measurement will report 100% and the dark measurement will report 0%. In this experiment, the white reference tile was used as the reference. We used an integration time of approximately 50 milliseconds, which can be adjusted to increase or decrease the amount of light being measured at one time and affects the overall magnitude of the reported spectrum. With a 50 ms integration time, the number of flashes per scan for the light source was set to 5, the maximum amount for this integration time. We set averaging to 10, meaning ten values were averaged together to provide more consistent spectra results.

TEST DATA AND RESULTS

Displayed below are the spectra of the samples in scope mode, the reflectance spectra of the samples, and a table of the Color mode data for each sample.

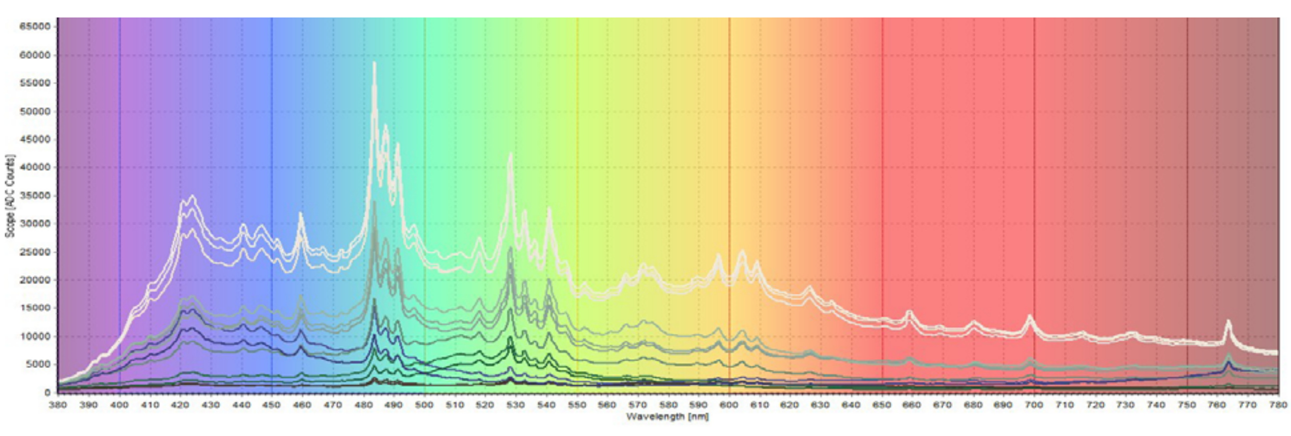

FIGURE 3: Spectra of all paint samples in Scope mode with each sample represented by their respective RGB values.

TEST DATA AND RESULTS

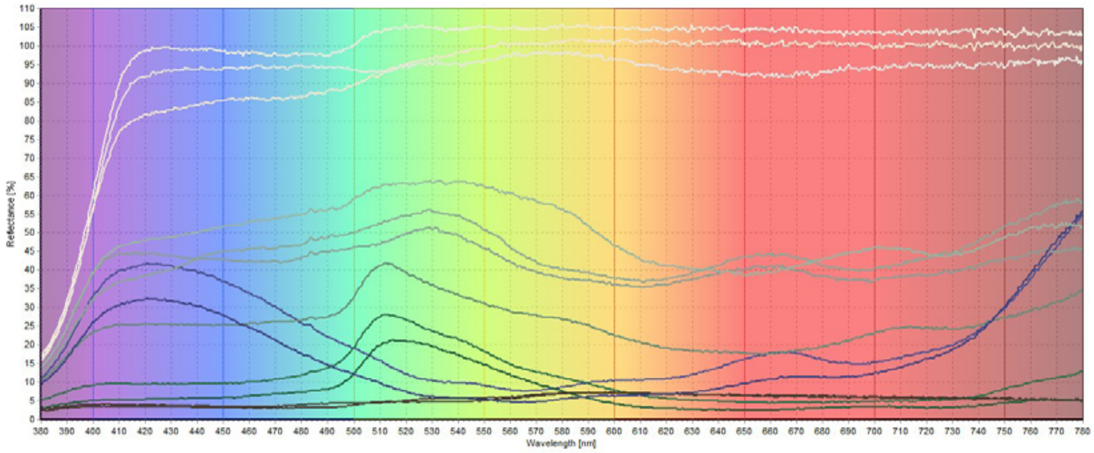

FIGURE 4: Reflectance spectra of all paint samples with each sample represented by their respective RGB values.

Color	L	a	b
Blue Ember	40.1	23.74	-41.95
Merlin's Robes	32.22	26.03	-42.83
Deep Earth	28.15	3.68	12.37
Gondola	29.24	1.5	11.77
Four-leaf Clover	40.46	-40.8	16.3
Deep Mint	46.28	-37.2	12.32
Cool Bluegrass	61.26	-19.58	4.78
Green Water	71.43	-9.77	-0.53
Phoenix Tears	73.76	-13.34	2.2
Spearmint Haze	79.52	-15.96	4.32
Polar White	101.78	-1.03	4.17
Ivory Lace	99.33	-0.72	9.15
Summer Gray	99.68	-0.59	1.49
WS-2	100.57	-0.03	-0.09

TABLE 1: Color mode data for all paint samples and the white reference tile

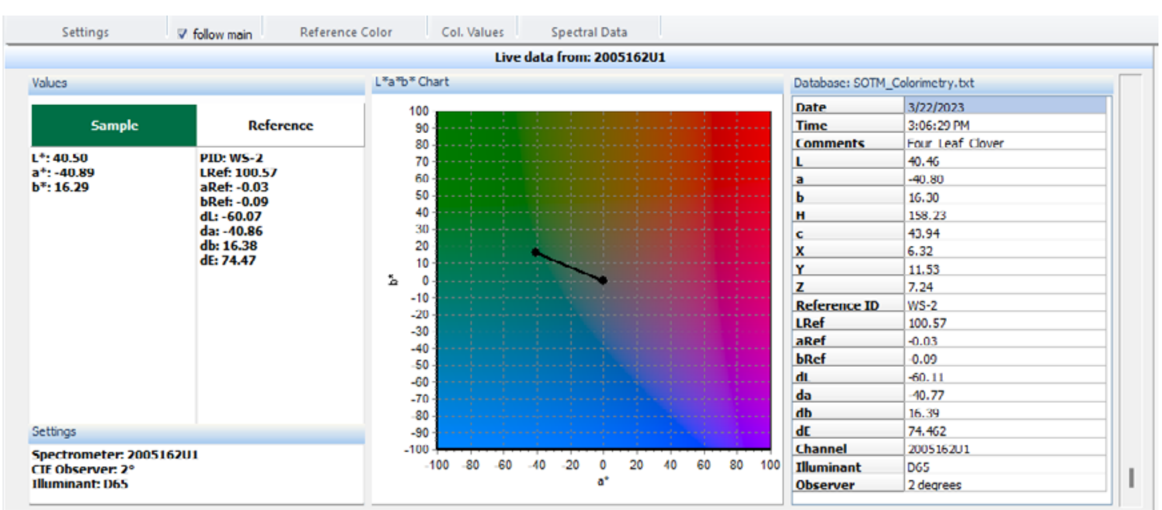

FIGURE 5: Screenshot of Color mode module with the measurement of Four-Leaf Clover paint sample

ANALYSIS AND CONCLUSION

While measurements for the paint samples were taken in Reflectance mode and Color mode, a graph of the paint samples in scope mode was also included (Figure 3). These spectra show why this mode is not ideal for color measurements. While it is clear that the white paint samples have the highest count intensity and the brown paint samples have the lowest number of counts, the purple samples are between the green samples, showing little indication which sample is which without the color labeling of each data set. The Reflectance mode spectra are much more informative, with the white samples having high reflectance across the visible spectrum, the green samples ranging from medium to low reflectance across the visible spectrum but always showing increased reflectance in the green region, the purple samples showing higher reflectance in the blue-purple region, and the brown paint samples showing low reflectance across the visible spectrum (Figure 4).

The L*a*b* color space values for each sample are given in the table (Table 1). The purple paint samples have relatively low L* values, indicating they are a darker lightness. The positive a* and negative b* values mean they are a mix of red and blue, which results in purple. The brown paint samples have even lower L* values, meaning they are measured to be darker than the purple samples. The a* values being close to zero means they have a very even mix of green and red, and the positive b* values suggest the samples are more yellow than blue. These seem to be accurate descriptions of typical shades of brown. The green paint samples had a wide range of L* (40.46 to 79.52) and b* values (-0.53 to 16.2), but all samples had negative a* values, albeit with a wide range as well (-9.77 to -40.8). These negative a* values indicate more green than red in each sample, which is obvious for green samples. The range of b* indicates the sample range from slightly blue to moderately yellow. The range of L* is indicative of the range of lightness in the green paint samples. Lastly, the white paint samples all showed high L* values close to 100, indicating they have high lightness, and a* and b* values close to zero, showing a balanced mix of green, red, blue, and yellow shades. This is consistent with the fact that white is a combination of all colors in the visible spectrum. The slightly higher b* value of Ivory Lace can be seen in that it appears slightly more yellow than the other two white paint samples. An image of the Color mode module is included to provide an example of the addon in use (Figure 5).

CONCLUSION

In conclusion, the present experiment highlights the use of both the Reflectance mode and Color mode in AvaSoft to measure color samples, with Reflectance mode giving a general idea of the broad spectrum of a sample and Color mode giving quantitative values in terms of the L*a*b* color space. The AvaSpec-ULS2048CL-EVO is well suited for a variety of uses, including absorbance and reflectance measurements as shown previously and color measurements as shown in this experiment. The AvaLight-XE-HP is Zenon light source that is well-suited for applications where high power is needed or compact form factor is a must. The interface cable connecting the AvaLight-XE-HP and the AvaSpec-ULS2048CL-EVO highlights the capabilities of our engineering team to provide custom assemblies and solutions for customer needs. Please contact Avantes for more information on the configuration that is best suited for your data collection.

CONTACT

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