Measuring Lighting And Display PARAMETERS That Matter With Modular Spectroscopy

Consumer-facing products come with many challenges including intense competition and continually evolving customer requirements. Constant innovation and continuous improvement are mandates for customer-facing industries, not just an option.

When consumer-facing products are woven throughout the daily lives of their customers - like the products in the Lighting and Display industries - these challenges rise to a new level. In the highly saturated Lighting and Display markets, consumers have many options. Remaining competitive in these industries requires relentless innovation and rapid product evolution.

Whether it is lighting and display products or kitchen appliances, consumers inform their buying decisions using well-known performance specifications comparable across manufacturers and product models. Consumers expect accurate and clear specifications to guide their purchases. In the Lighting and Display industries, there is some overlap in these performance specifications as well as some industry specific performance metrics. For example, both industries test and report color performance and light level specifications with the Display industry also concerned with metrics like resolution.

Lighting and Display Industry Measurements

Key performance parameters in the Lighting and Display industries center around specifications describing the visual experience. Various brightness and color accuracy specifications enable the consumer to directly compare performance across a vast array of products. These specifications go beyond subjective comparisons to provide critical performance metrics related to the viewing experience. By measuring these parameters, designers, manufacturers, reviewers and consumers have objective metrics for product comparisons and purchases.

Display and Lighting manufacturers measure a wide range of parameters to ensure aggressive performance metrics are met. Some key measurements include:

- Color Accuracy: Critical for applications where lighting can and will impact appearance - art galleries, museums, high-end retail stores and medical settings.
- Spectral Analysis: Illumination intensity as a function of wavelength – greenhouse lighting or UV curing or disinfection.

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- **LED and Laser Characterization:** Testing for key performance metrics – wavelength, peak shape and optical power output.
- **Quality:** Confirm product specifications are met - inconsistencies or defects in the final product.

These measurements and others require a radiometrically calibrated system capable of measuring absolute spectral irradiance (power per area per wavelength) from the lighting or display. A wide range of parameters are then calculated from the irradiance spectra. A list of some key parameters measured by the Lighting and Display industries are shown in the table.

Key Lighting and Display Parameters

Parameter	Description
Brightness (Luminance)	Perceived intensity of emitting areas
Lux	Brightness weighted to the photopic response
CRI	Color rendering index indicating color accuracy
TM30	Expanded color rendering index with more reference colors
CCT	Correlated color temperature indicating perceived color
Flicker	Frequency of intensity oscillations
Color Accuracy	Delta E (ΔE) - ensure true-to-life colors
Uniformity	Consistency of brightness and color to ensure image quality
Viewing Angles	Consistency of brightness, contrast and colors when viewed from different angles
Contrast Ratio	Ratio of luminance of the brightest white to the darkest black to evaluate dynamic range
Color Gamut	Range of colors produced
Peak Brightness	Maximum brightness achievable

Additional specialized Lighting and Display parameters are also measured for other applications. Parameters like PAR (photosynthetically active radiation) is used in the Horticulture industry with Melanopic Lux (light needed to suppress melatonin creation) in the Wellbeing and Health market.

Spectroscopy Solutions for the Lighting and Display Industries

Spectroscopy is used throughout the Lighting and Display industries for quality control and real-time monitoring of lighting. Manufacturers measure the spectral profile of their lighting systems and displays to ensure products meet published specifications. These specifications are critical to consumer buying decisions and must be accurately tested and reported. Spectrometers are also used to ensure products meet global regulations and standards as well as guiding adjustments to color characteristics and other parameters for specialized applications and product development. With their flexibility and the capability to measure detailed spectral information, high-speed modular spectrometers are used daily to make the measurements that matter to product design engineers, to the production floor and most importantly to their customers.

Ocean Optics offers a complete line of modular spectrometers and accessories for measuring key parameters in the Lighting and Display industries. Lighting and Display manufacturers can partner confidently with Ocean for their spectroscopy needs based on our ISO 9001:2015 certification (since 2009) for the design and manufacture of electro-optical equipment, optical filters and spectral imaging products. Ocean Optics also offers radiometric calibration services for spectrometers, performed in our ISO 17025-acredited lab. With ISO driving our processes and a global factory infrastructure, Lighting and Display companies can confidently measure the key specifications critical to the success of their products.

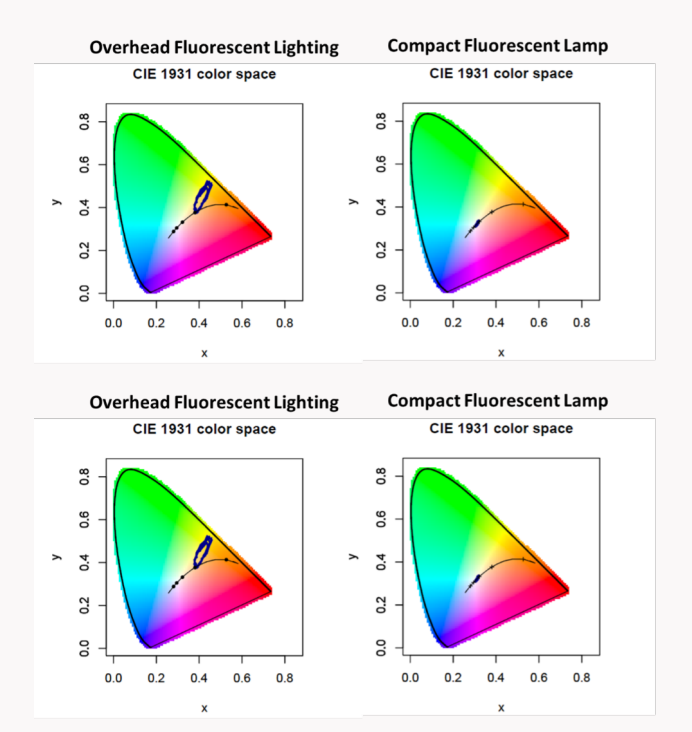
Emissive Color

Emissive color is a key measurement in the Lighting and Display industries. The use of spectroscopy for color measurements offers many advantages over other technologies like filter-based color meters. Spectrometers are far more accurate than the human eye and provide detailed, quantitative, spectral information. Spectroscopy is also more flexible than other color measurement techniques enabling calculation of color parameters and even the capability to vary factors like the observer and illuminant if needed. By capturing the complete spectrum, the spectrometer-based color measurement provides a more detailed analysis of color including critical metrics like CRI, TM-30, blue light hazard and Melanopic Lux not available when using a filter-based colorimeter. Colorimeters and analyzers based on broadband optical filters miss critical information used to characterize key performance metrics.

Emissive color measurements are made for LEDs, LCDs, plasma screens and other display and lighting technologies. Beyond the detailed characterization of key color metrics, emissive color is also used for non-destructive testing and defect detection in displays. Emissive color is measured using a sampling optic to collect emitted light from the sample where it is routed to a spectrometer for the measurement and calculation of key performance parameters. These measurements are used in a wide range of applications and industries from imaging in Medical Diagnostics to ripeness, quality and even plant health in the Food and Agriculture markets.

In Figure 1, example chromaticity diagrams are shown for 4 different light sources measured with an Ocean Optics high speed spectrometer. Ocean offers the Ocean SR2, Ocean HR2 and Ocean FX models for high speed measurements. In addition to showing the color properties, emissive color data was measured over time to determine the impact of intensity oscillations (flicker) on the color coordinates.

Figure 1: High speed spectrometers (Ocean SR2, Ocean HR2, Ocean FX) for measuring light source chromaticity. Color coordinates were measured over time to assess variation in color coordinates with light source intensity oscillations (flicker).



See the complete Application Note – Ocean FX High speed Applications in Home Lighting – for additional details.

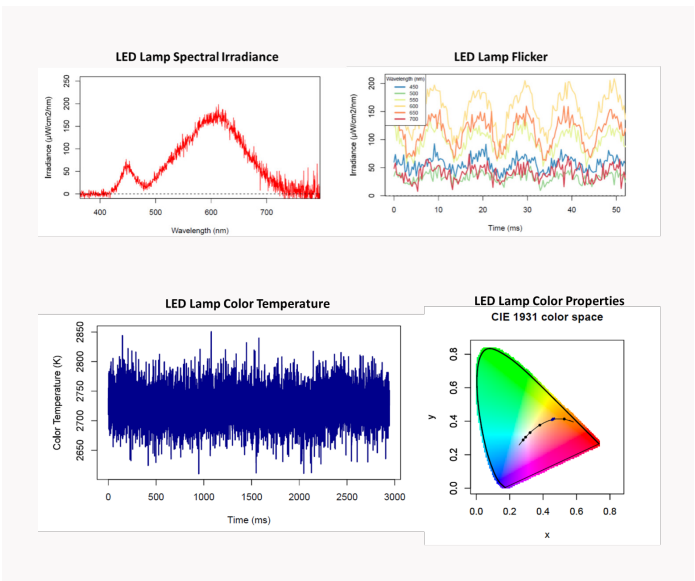
Led Characterization

LEDs are used for a wide range of applications from lighting to horticulture. LEDs used for greenhouse lighting give farmers and growers the power to control crop illumination to impact growth characteristics and yield. Continuously monitoring the LED emission spectrum with a modular spectrometer enables growth patterns to be correlated with the illumination. LED manufacturers use color measurements for binning their products (sorting by performance and other criteria) to ensure product consistency and quality. Emissive measurements of LEDs are also used in biomedical applications and research where the impact of LED illumination wavelength is explored for health and wellbeing applications.

LEDs are highly characterized devices. Measurements for these devices include photopic output in lumens, dominant and peak wavelength, correlated color temperature (CCT) and CIE color coordinates. Another standard LED measurement is color rendering index (CRI) used to quantify the effect that artificial light sources like LEDs have on color perception. With the evolution of small, handheld spectrometers like the Ocean SR2, Ocean HR2 and Ocean FX, LED measurements are more flexible and accessible than ever before. These spectrometers are deployed to measure LED emission wavelengths as well as brightness and power output in a range of settings and environments.

In Figure 2, we show example data collected with a high speed spectrometer (Ocean SR2, Ocean HR2 and Ocean FX) to measure several LED room lighting parameters. The use of a spectrometer enabled a range of key measurements including the spectral profile, color characteristics and flicker. These results demonstrate flicker in the fluorescent light source along with long-term CCT stability and color coordinates.

Figure 2: High speed spectrometers (Ocean SR2, Ocean HR2 and Ocean FX) for measuring LED parameters - Spectral Irradiance, Flicker, Color Temperature and Chromaticity



Flicker Measurements Using Modular Spectroscopy

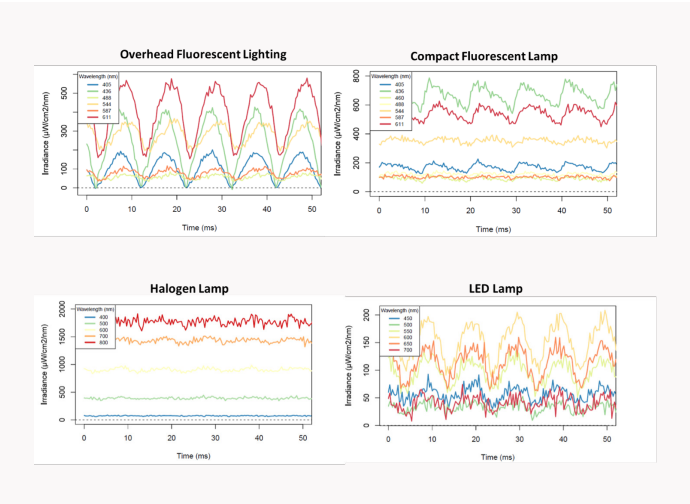
Light source flicker occurs when intensity fluctuates with time. The resulting oscillations in intensity cause changes in visual perception and eye discomfort. Flicker can cause eye strain, headaches and even seizures in people with epilepsy. Light source flicker is caused by a few different conditions including voltage fluctuations and wiring issues. Some light sources (fluorescent, LED or HID (high intensity discharge) are more susceptible to flicker. Several standards address flicker levels including IEEE standard 1789-2015, IEEE 1789, EPA ENERGY STAR, California Title 20 and Title 24 and IEC/TR 61547-1.

The rapid scan rates of the Ocean SR2, Ocean HR2 and Ocean FX spectrometers are ideal for measuring flicker. Unlike

dedicated flicker meters, spectrometers can also measure color and other spectral properties of light in real time along with light source flicker.

In Figure 3, data collected with a radiometrically calibrated high-speed spectrometer connected to a 1 meter, 400-micron VIS/NIR optical fiber and a cosine corrector was used to measure several home lighting devices. Flicker was evaluated using a series of discreet wavelengths corresponding to gas emission lines as well as broader peaks when gas emission lines were not present.

Figure 3: High speed spectrometers (Ocean SR2, Ocean HR2, Ocean FX) for measuring lighting flicker



See the complete Application Note – Ocean FX High speed Applications in Home Lighting – for more details.

Other Applications Using Spectroscopy to Measure Light Emission

Beyond the Lighting and Display industries, high speed spectrometers are used in other industries requiring light emission measurements. In the list below, several industries requiring measurements like those in the Lighting and Display industries are shown.

- **Automotive:** LED headlights and taillights are now commonly used in vehicles.
- **Healthcare:** Fluorescence microscopy and medical imaging technologies rely on light emission.
- **Industrial Inspection:** Light is used to detect flaws or imperfections in materials during quality control testing.
- **Horticulture:** Growing techniques utilize artificial light for precision illumination.
- **Environmental Monitoring:** Impact of artificial lighting on health measured with continuous monitoring to ensure optimal illumination.
- **Semiconductor Manufacturing:** Plasma monitoring during fabrication requires tight control and optimization of plasma etching and deposition processes.

These are just a few of the industries that benefit from the use of modular spectroscopy during the design, manufacture and quality assurance testing of their products. Through the implementation of spectroscopy techniques, companies can provide accurate specifications to their consumers to inform purchasing decisions, research new lighting technologies, continuously monitor and control lighting and so much more. Advanced, accurate and agile spectroscopy solutions available from Ocean Optics are used every day to guarantee our visual experience with lighting and displays, protect our health through optimization of ambient lighting and improve crop yields with precision illumination.

If you are ready to add spectroscopy to your lighting, display or other application, Ocean Optics is here to partner with you. Let's talk.