

## Application Note

### Keywords

- LEDs
- Color
- Color rendering index
- Spectral output

### Techniques

- Emissive color measurement
- Irradiance

### Applications

- LED measurement
- CCT determination
- CRI measurement

# Miniature Spectrometers Address Challenges of LED Research and Production

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Thanks to the evolution of small, handheld spectrometers, applications such as the testing and binning of LEDs are more easily managed than with previous instruments. Indeed, spectrometers can be deployed to measure LED emission wavelengths as well as brightness and power output. To appreciate why miniature spectrometers are viable tools for LED measurement, it helps to understand the typical performance parameters being measured.

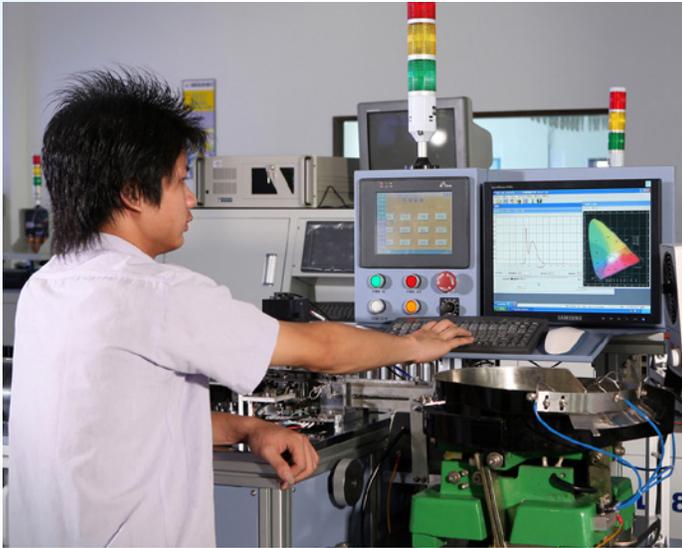
## Color and Spectral Output of LEDs

Although determining the correlated color temperature (CCT) of incandescent light sources is fairly simple, as these spectra fit nicely on a blackbody radiator curve, doing the same for fluorescent and LED light sources is much more challenging. Those sources have very different spectral shapes, making it harder to perform an accurate fit using traditional color filter-based instruments.



The simplest color meters use diodes or pixels covered by red, green and blue filters. More advanced systems use tristimulus filters. These types of systems work quite well for incandescent light sources but struggle to provide accurate answers for light sources such as LEDs. To detect small color changes, very high color resolution is necessary – resolution a spectrometer can achieve. A spectrometer captures the light reflected, transmitted or emitted by a sample and uses a dispersing element to split it into discrete wavelengths, capturing the spectral data for the sample under test. Because the instrument captures the complete spectral power distribution rather than merely measuring power in observer-specific wavelength bands, the resulting color measurement is more precise and robust. There has been much debate on how much wavelength resolution is needed to make an accurate color measurement, with competing resolution standards from CIE (International Commission on Illumination) and ASTM (American Society for Testing and Materials) varying from 1 nm to 20 nm.

Another standard LED measurement characteristic is color rendering index (CRI). CRI is a scale quantifying the effect artificial light sources such as LEDs have on color perception. Today's CRI scale is problematic as an indicator of color quality, particularly when applied to white LEDs that have several peaks in the spectra. CRI is based on only eight reflective samples, all of which have low to medium chromatic saturation. These samples do not adequately span the range of normal object colors. What's more, some lights that are able to accurately render colors of low saturation perform poorly with highly saturated colors.



**Figure 1. Miniature spectrometers perform well in LED sorting operations, where rapid data acquisition and measurement accuracy are critical.**

As standards-setting bodies devise new scales that better reflect a range of parameters – color rendering, chromatics discrimination and the like – researchers and QC professionals consider various measurement tools for a range of LED color and spectral output applications.

### Advantages of Miniature Spectrometers for LED Measurement

For years, most portable color measurement systems utilized a small, compact spectrometer such as the Ocean Optics USB2000+. Thousands of these systems have been deployed for testing and binning of LEDs inside high-volume testing machines (Figure 1). Light emitting diode manufacturers need to test the emission wavelength of each device to ensure the output is within  $\pm 0.5$  nm of the specified emission wavelength.

Miniature spectrometers not only provide quantitative data, they assess other metrics like brightness and output power for efficiency calculations. In most cases, it is more cost effective for a high-volume LED user -- consider the example of a manufacturer of LEDs used in signage -- to test and sort a large number of LEDs into smaller bins than it is to tighten the specifications for the LEDs from the manufacturer. This would be impossible to do without the speed and accuracy of the color measurement from a miniature spectrometer (see Figure 2).

Let's consider speed: Some LED sorters process as many as 8,000 pieces per hour. Most miniature spectrometers can measure and process spectral data for each LED within 10-50 milliseconds. Spectral data can be quickly digitized and processed by computer to determine dominant and peak wavelength values, CIE color values and irradiance (lumens). Armed with these results for each LED, the sorter can transport each die or chip to the appropriate collection bin for storage.

Also, because the spectrometer has no moving parts, it can more easily withstand the rigors of continuous operation in an industrial setting.

Color resolution is another consideration. Most handheld color meters deliver less than 20 wavelength bands, not enough for accurate or scientific studies. So what if you want to make a high-resolution color measurement, but can't tolerate the size



**Figure 2. Small-footprint miniature spectrometers are ideal for monitoring LEDs and other sources in lab and production environments.**

## Applications in the Field and Beyond

LEDs are in use for all sorts of applications, but this one caught us by surprise: LEDs in horticulture. LEDs are configured to stimulate plant growth in greenhouse environments – and their use for such applications is, well, growing. Horticulturists are interested in the effects of light on the growth of their crops, with much analysis of how the intensity of blue and red light affects both the growth rate and blossoming of various floral crops.

Until now farmers and horticulturists were limited in their options to control and measure the illumination of their crops. But recently the horticultural industry has been experimenting with the addition of red, blue and white LEDs to existing illumination systems. The idea is to better tune the spectral content to match the needs of the crops. Continuously monitoring the LED emission spectrum with a miniature spectrometer enables growth patterns to be correlated with the illumination spectra (see Figure 3).

Also, it is important to measure photometric parameters in situ for applications such as street lighting, advertising signage and hospitality lighting. Miniature spectrometers have the advantage of being easily reconfigured for different spectral ranges and resolution requirements.

As LED measurement needs evolve, miniature spectrometer technologies and solutions will continue to adapt and provide accurate, flexible and cost-effective solutions to a host of applications. Capturing and reporting of the spectral data is evolving as well. Color and other measurement values are now available wirelessly on the iPhone, for instance, or can be transmitted over the Internet to a private network. The possibilities are as vast as the colors of the rainbow. 🌈

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**Figure 3. Measuring the output of LEDs used in greenhouse operations helps growers adjust LED output to optimize plant growth.**

or weight of the laptop or even a tablet computer to make your measurement? The latest miniature spectrometer systems – more like microspectrometers, really – are specifically designed to perform portable measurements and can operate in the field without a PC.

Our Jaz spectrometer, for instance, is a family of stackable, modular and autonomous components that share a common electronics and communications infrastructure. Its two key elements are a crossed Czerny Turner CCD 2048 pixel array spectrometer that can be optimized for a variety of radiometric measurements and a microprocessor with on-board display. The unit can be spectrally and radiometrically calibrated pixel by pixel and adjusted for an accurate analysis of a broad range of illumination sources. The instrument also provides an irradiance spectrum and additional calculated colorimetric parameters in the field. The output can also be viewed as photometric values such as lux and lumens; colorimetric values including x, y; and correlated color temperature values and color rendering indices.