Specifying LEDs: Important Performance Parameters To Consider

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Light-emitting diodes (LEDs) are available in more wavelengths and at higher power levels than ever before, opening the door to a wider range of applications, including forensic science, biomedical, military, and security. For example, just five years ago, medium- to high-power applications such as fluorescence and photodynamic therapy were designed using gas lasers or filtered lamps. At the time, there were no ultraviolet-visible LED products available to cover the most common fluorescing dies. However, as higher optical density packages and LED arrays in the 1 to 5 watt output range become available, it is possible to use LEDs in many applications where gas lasers, filtered lamps, and other emitters were used in the past.

Unfortunately, over the entire commercial range of LEDs – from near-ultraviolet (360 nm) to near-infrared (950 nm) – there is no consistency in defining specifications. This makes it challenging for users to compare the relative efficiencies of LEDs in the visible region to LEDs outside it. Particularly in the visible region, it is difficult for users to specify LEDs in a manner that correlates well to the system application. This article provides an overview of the important LED performance parameters, enabling users to select the product that best meets the needs of their particular application.

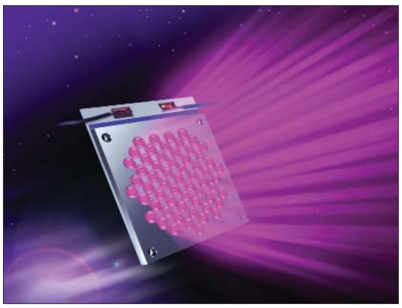

Figure 1: LED arrays are being used in applications that previously required gas lasers, filtered lamps, or other emitters.

Tools For Measuring LED Output Parameters

There are two basic tools for measuring LED output, and both can be purchased from several sources in both North America and Europe. The first, and more versatile of the two, is called an integrating sphere. This device captures all of the light emitted from the LED and measures it using a silicon photodiode. One advantage of this measurement technique is that it correlates well from one location and manufacturer's equipment to another. Our experience suggests a correlation within 5% is normal.

The second piece of equipment for measuring LED output is a tube with apertures for measuring on-axis intensity. Typically, there are two apertures within the tube to define the cone angle; the LED under test is inserted into one end and the measurement detector is at the other.

Photopic LED Specifications

LEDs in the visible range are most often specified in terms of photopic output. The measurement techniques are weighted to emulate human eye sensitivity. Human eye sensitivity is defined by the CIE (Commission Internationale de l'Éclairage) photopic curve. The peak eye sensitivity is 555 nm, and the 50% points are approximately 505 and 605 nm. Lumens, candelas, and dominant wavelength are the photopic parameters most often specified for visible LEDs.

The lumen is a measurement of the total luminous output and is defined as 1/683 watts at 555 nm. To accurately measure lumens, an integrating sphere with a photopic filter over the detector is required.

The candela is a measurement of the luminous intensity and is defined as 1/683 watts at 555 nm within one steradian. It is measured as the on-axis intensity over a defined cone angle, usually with an aperture tube/photopic filtered detector at one end and the LED under test at the other.

Dominant wavelength is defined specifically in the CIE 15:2004 Technical Report on Colorimetry. In general terms, though, it is the measurement of the spectral output of the LED and a value assigned based on the human eye perception of the color. Using dominant wavelength as a guide for applications such as fluorescence can be very problematic. For instance,

Table 1: Optical Parameters for LEDs

Parameter	Photopic	Radiometric
Total Optical Output	Lumens	Watts
On Axis Intensity	Candela	Watts per Steradian
Spectral Output	Dominant Wavelength	Peak or Centroid Wavelength

a 620 nm dominant wavelength LED will typically have a peak wavelength of about 645 nm. Also, the dominant wavelength is affected by the symmetry of the spectral output, so a 620 nm dominant wavelength from one manufacturer may not have anywhere near the same peak wavelength as a 620 nm LED from another.

Photopic measurements are useful for applications such as indicator lights, traffic signals, and general lighting. On the other hand, they become problematic in scientific and test and measurement applications, where an engineer is trying to compare different products at different wavelengths. For scientific applications, a difference of just 50 nm, or comparing green to blue, can give an error of 5 when comparing LEDs by the candela output. For applications outside of human eye sensitivity, such as camera surveillance systems and material density measurements, photopic measurements are not useful.

In addition, when faced with photopic values, a user has no easy and accurate way to compare visible wavelength LEDs to ultraviolet (UV) or infrared (IR) LEDs. By definition, UV and IR LEDs will have photopic values of zero or near zero, since the light is not visible. To compare and specify LEDs of different wavelengths, they need to be defined in radiometric terms, using parameters that are independent of wavelength effects (see *Table 1*).

Radiometric LED Specifications

The most common radiometric figures of merit are watts, radiant intensity, peak wavelength, and centroid wavelength. The measurement techniques used are nearly equivalent to the photopic measurements, with the exception of removing the photopic filter and replacing it with a radiometric filter to make the detector response relatively flat over a wide wavelength range.

The unit for measuring total power is a watt (W). This is the total optical energy emitted from the LED, and it must be measured using an integrating sphere. There is a tendency among original equipment manufacturers (OEMs) to verify this measurement using an optical power meter. However, while this instrument is ideal for measuring collimated laser output, it is incapable of capturing the entire LED output over angle and provides a result that is far lower than the actual total power.

Radiant intensity is the on-axis intensity of the LED and is expressed in units of watts per steradian (W/sr). Radiant intensity is measured using the aperture tube with a detector on one end and the LED under test at the other. This value is extremely useful for determining power per unit area in the far field, but is difficult to correlate from one manufacturer's equipment to another. The cone angle is not standardized and is extremely important to know when comparing one manufacturer's LED to another.

Peak wavelength is, as you would suspect, the highest point in the spectral curve of the LED. In LED technologies that produce a nearly symmetrical spectral curve, the peak wavelength is usually adequate for defining the LED. In practical terms, the dominant wavelength is the point in the emitted spectrum where half of the integrated power is shorter than the dominant wavelength and half is at a longer wavelength. There are equations published that vary slightly from this premise, but in practical terms the definition given is adequate for narrowband applications. This measurement can be very useful for applications where excitation, such as fluorescence, occurs within a narrow spectral band and the amount of excitation is very wavelength-dependent (see *Figure 2*). Missing the peak excitation band by as little as 10 nm can result in fluorescence 25% lower than the peak potential.

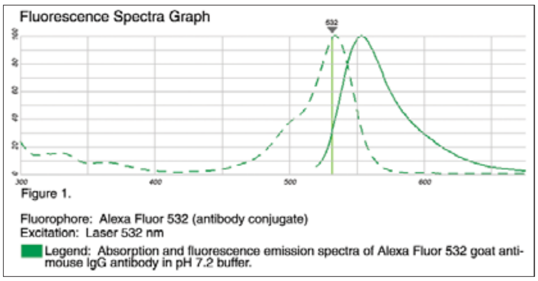

Figure 2: This graph shows the absorption and fluorescence emission spectra of the Alexa Fluor 532 antibody conjugate excited using a laser source at 532 nm. (Courtesy: Invitrogen Corporation)

Selecting An LED Vendor

Now that you understand the basic performance parameters of LEDs, you're ready to select one. Choosing an LED vendor that speaks the language of your application – lumens, watts, peak or dominant wavelength, or other parameters – is as important as understanding the basic LED performance parameters themselves. Whether you need a standard product or a completely custom LED array with a particular shape and wavelength, the manufacturers that are most successful in producing large arrays or complicated assemblies have automatic die-sorting capabilities. These capabilities ensure greater throughput and yield, because die can be purchased to standard specifications from many different sources and sorted to meet the specific OEM requirements.