



Seven Advantages of Lasers Over LEDs for Life Sciences Applications

- **Higher intensity**
- **Simpler integration**
- **Single wavelength**
- **Application optimized**
- **Consistent output**
- **Lower overall cost**
- **Superior performance**
- **Greater value**

Introduction

In most photonic based bio-instrumentation applications, the laser remains unchallenged as a superior solution despite recent advances in alternative “low cost” LED technologies. That’s because these applications require a source having very specific characteristics in terms of size, shape, intensity, wavelength and so forth. In this context, the laser offers superior performance, greater simplicity and lower overall cost per photon, which all translates into better value. Here we examine the top reasons how the laser provides this superior value, and also address some of the common misconceptions when comparing lasers vs. LEDs.

Higher Output Power

Whether an instrument is based on detecting fluorescence, scatter or absorption, the signal depends on the intensity of light at the sample. Intensity is roughly defined as optical power per unit area. Lasers are specified by their optical output power; a 1 watt laser produces 1 watt of light output. In contrast, LEDs are specified by their *electrical power consumption*. Thus, a 1 watt LED consumes 1 watt of *electrical* power. Since even the best LEDs rarely surpass 10% efficiency, a 1 Watt LED usually outputs 100 milliwatts or less of light. Moreover, the maximum current and voltage specifications are often specified for pulsed operation. Thus, a “1 Watt” LED might only be continuously operable at 750 milliwatts or less, which translates into an optical output of only 75 milliwatts! So trust the laser where the rated power is the real power.

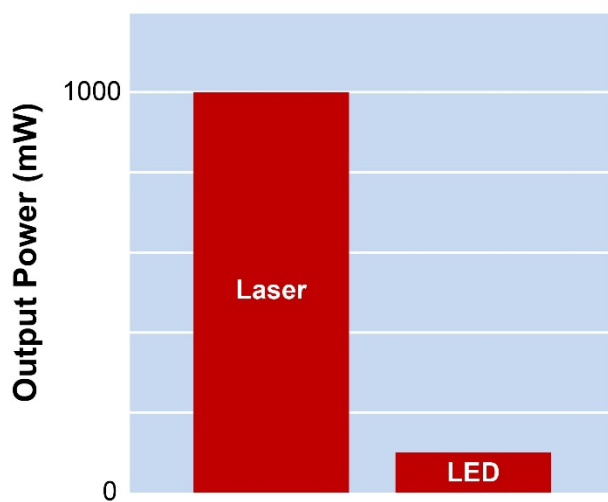


Figure 1. The real output power of a laser rated at 1 watt is 1 watt (1000 milliwatts). The output power of a 1 watt LED can be < 100 milliwatts.

Simple to Integrate

Besides dramatic differences in total output, the laser also offers a significant advantage in terms of how usable that power is to the optical system. Specifically, the laser is a point source of coherent light that produces a well-behaved beam. This allows virtually all the laser output power to be focused into a sub-micrometer spot or coupled into a single-mode fiber with a single lens. Many models are configured with a pre-aligned fiber to further simplify their use.

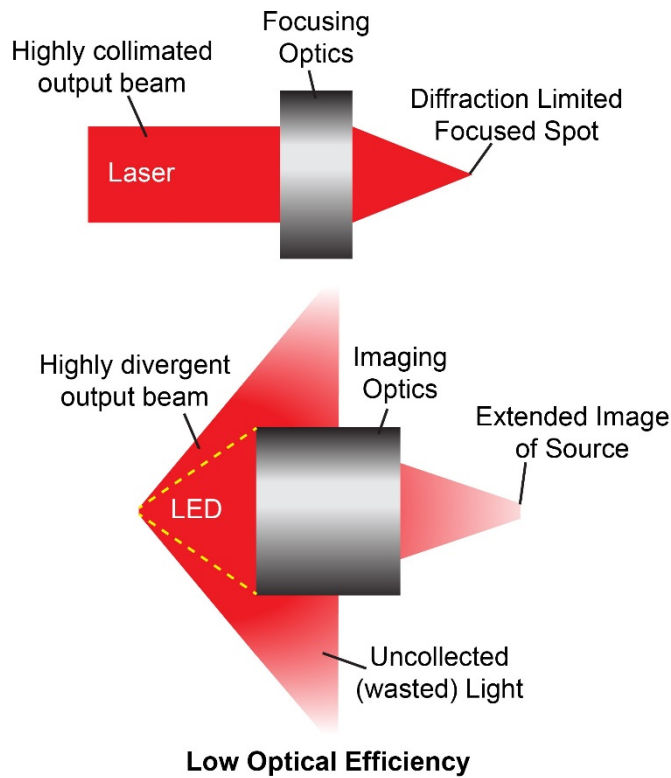


Figure 2. Virtually all the output power of a laser can be coupled into a target application and focused to a small, diffraction-limited spot where necessary. The LED emits in a wide swathe so only part of the output can be efficiently captured. A focused spot cannot approach the small dimensions (the “diffraction limit”) of a laser.

In contrast, the LED is an incoherent, extended light source, typically with high divergence. This light has to be collected using a variety of lenses and/or mirrors that must be mounted and carefully aligned. So, while LEDs are sometimes viable for large area illumination tasks, as the desired final spot size gets smaller, the efficiency of light collection diminishes quickly. (Coupling a useful amount of light from a LED into a single-mode fibers optical fiber is near impossible.) And out-of-focus stray light in an instrument often serves to increase signal to noise. Plus, there is no economy of scale; every single LED has to be aligned in this way.

Monochromatic

For life sciences instruments based on fluorescence, the wavelength of the light source is very important. Most instruments obtain high signal-to-noise by detecting fluorescence at (Stokes-shifted) longer wavelengths compared to the excitation light source. This wavelength-based discrimination is obviously dependent on using a light source with a narrow band of wavelengths. A laser is the ultimate monochromatic light source and naturally emits over a very narrow wavelength range (high spectral purity). Just as important, with wavelength scalable diode laser and OPSL technologies used in Coherent OBIS (and StingRay/BioRay) lasers, the wavelength can be chosen to be near the absorption maximum of the target fluorochrome.

In contrast, an LED has a broad emission spectrum that includes a long tail that usually overlaps with the emission spectrum. These “unwanted” photons complicate the separation of signal and scatter from the source that is key to high SNR in fluorescence detection schemes – see figure 3. Even for a single LED, the unwanted longer wavelength photons have to be blocked by using yet more optics (notch or cut-off filters), which introduce loss. Where multiple excitation wavelengths are required, the extended LED spectrum may have to be blocked on the shorter wavelength side, too.

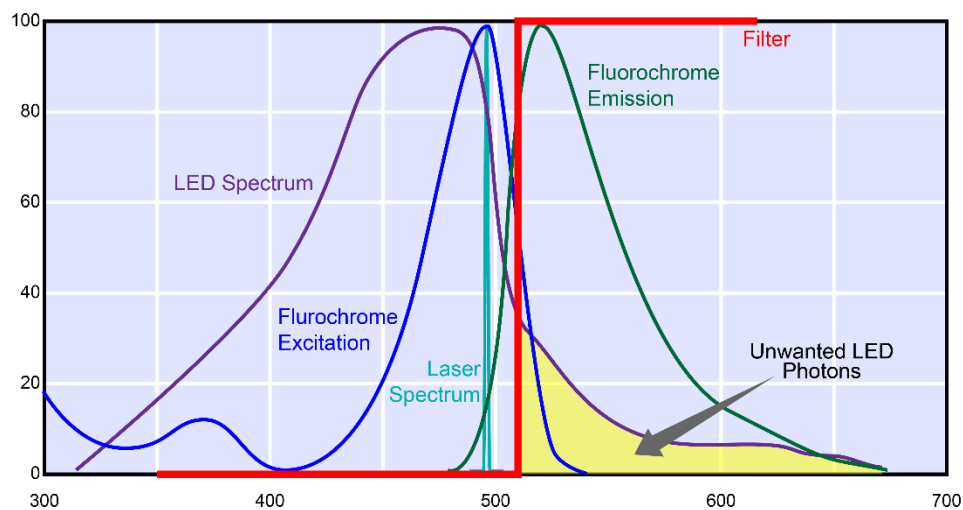


Figure 3. A laser can deliver all its power in a very narrow wavelength band. LEDs are broadband devices that need external filtering to eliminate unwanted photons at problem wavelengths.

Application Optimized

There are many laser products from Coherent optimized specifically for certain life sciences application. These range from multiwatt lasers at 577 nm for photocoagulation treatments, to low power lasers at 808 nm to enable the latest anti-Stokes detection schemes in microscopy. Lasers are available with fiber coupling for simplified use with confocal microscopes or as multi-laser modules to match the needs of multi-parameter flow cytometry. If a new wavelength, power level or beam shape is needed for a life sciences application, laser manufacturers quickly respond with an optimized source. Conversely, LEDs are produced in massive volume to match applications such as displays and automotive illumination. To put this in perspective, the number of LEDs used in just displays dwarfs by several orders of magnitude the entire number of light sources needed in biophotonics. As a result, LED manufacturers pay little - if any - attention to the needs of biophotonics applications. The task of mating a mismatched LED to a life sciences instrument then falls entirely on the instrument builder.



Figure 4. Lasers are available in a diverse variety of standard and custom packages and formats, optimized for different applications in life sciences. LEDs are available as bare devices only.

Consistent Output

Similarly, the difference in applications emphasis is reflected in other aspects of light source performance. Lasers are typically characterized by tightly controlled optical specifications in terms of wavelength, power, beam diameter, beam divergence, beam pointing and so forth. An instrument builder can replace a 532 nm laser in a ten year old instrument with a new 532 nm laser today and obtain exactly the same performance. Not so with LEDs. Their optical properties vary unit to unit and even more so between different production batches. For example, the typical center wavelength tolerance for a visible wavelength LED is ± 20 nm. That's because their main applications involve low unit value in illumination and displays, which simply don't need scientific-grade consistency. Moreover, LED manufacturers will not select devices, even for a premium cost. The only way to ensure consistent instrument performance and service is for the instrument manufacturer, or intermediate agent, to purchase sufficient devices from a single batch to cover the lifetime of the instrument product line. Devices are then measured and binned with the rejected majority then commonly offered for resale on the open market.

Lower Overall Cost

The cost of a bare LED is almost always considerably less than the cost of a single laser. However, such a simple comparison is completely misleading. The *overall cost* to generate the required excitation spot or pattern, and thereby ensure instrument success, is invariably much less for the laser-based solution. For a laser, the downstream optics can be as simple as a fiber or focusing lens. But with a LED, the overall cost includes the light source, the optics needed to capture and configure the output to match the instrument or fiber input, the cost of low optical efficiency, the cost for extra wavelength filters, the cost to buy, select, and inventory a large number of LEDs, and the skilled labor costs for all these tasks.

Superior performance

Even when all these steps are carefully implemented with a LED, the instrument signal to noise ratio will usually be inferior to that achieved using a laser as the source, because the laser generates a stronger signal and provides superior discrimination against unwanted background light from the sample. And as a rule of thumb, the smaller the focused spot, the larger performance advantage of the laser over the LED.

A note about source noise. Lasers also can exhibit a unique type of noise called mode noise, and some LED advocates highlight this as a reason to use a LED. The fact is that mode noise is usually less than other noise sources, so its impact is irrelevant. The only situation where mode noise is sometimes an issue is when counting very small cells, such as platelets. For these applications, laser manufacturers provide specialized lasers free from mode noise – another example of the laser being configured to match the application, instead of vice versa with a LED.

Summary – Greater Value

The combination of all these advantages means that the laser delivers the most important advantage of all for both OEMs and end users: higher value. This, in turn, enables the instrument builder to offer a higher value product to their own end user. In the current economic climate characterized by smaller margins driven by intense competition and reduced product differentiation, the value of using a laser simply cannot be overstated.