Laser diodes (almost) encompass the entire visible spectrum

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Green-, blue-, and red-emitting laser diodes are used alone or in combination for multifarious uses, often with enhancements such as fiber-coupling and wavelength stabilization.

The laser diode (LD) is by far the most common type of laser in the world, with millions being used in fiber-optic communications_and mass-market applications. Laser diodes that operate in the visible spectrum (usually stated to be 400 to 700 nm, although the human eye can see near-IR out to 780 nm, and further at high-enough intensities) can be found in such common items as computer mice, CD/DVD/Blu-Ray reading and recording devices, and low-end pointers. Visible LDs also serve as high-end sources for scientific, forensic, and other applications.

Red-emitting LDs were the first to come into general use, appearing widely in the 1980s in, for example, CD players. Today's red-emitting LDs are typically aluminum gallium indium phosphide (AlGaInP)-based and are available at wavelengths from the edge of the visible to as short as the 633 nm helium-neon (HeNe) laser line.

Gallium aluminum nitride (GaN)-based LDs, which appeared on the market at around the turn of the century, greatly expanded the array of colors that LDs could produce. These LDs can be made to emit at wavelengths ranging from the UV to longer than 500 nm; today's laser user can buy visible GaN-based LDs that emit in the violet, blue, or green. It should be noted that, due to the lack of suitable semiconductor structures thus far, no commercial yellow- or orange-emitting LDs exist.

Visible LDs, which are often hermetically sealed in a small windowed can, or combined into multi-emitter bars, can be purchased in many configurations: the bare LD or bar; the LD in a can; an LD plus a single-mode or multimode fiber pigtail; as a laser module, forming a rugged component that can be, for example, wavelength stabilized; or as part of an entire photonic system. Because a standard edge-emitting LD produces a diverging beam with an elliptical cone, collimating optics that expand the beam differently in orthogonal directions are often required.

The number of visible LD products and applications is vast; accordingly, this article can only present a sampling of the ever-widening selection of these devices on the market.

FIGURE 1. An iLLUMINA RGB laser projector containing red- and blue-emitting LDs is shown in a home-theater mockup; this product, which produces a wider color gamut than conventional projectors, will be sized up for movie-cinema use. *(Courtesy of Power Technology)*

Machine vision, life sciences

Coherent Inc. (Santa Clara, CA) makes visible LD products that typically incorporate the LD chip, a cooling system, collimating lens, beam-conditioning optics, a power supply, and control electronics. The purpose of these other components is to transform the bare diode laser into a high-performance, highly repeatable laser module with good power stability, low power noise, low optical noise, and a high degree of uniformity in the output profile, whether it's a simple beam or a complex structure. The turnkey modules are optimized for applications primarily in two high growth areas: life sciences and machine vision (especially 3D inspection).

According to Wallace Latimer, Coherent's product-line manager for machine vision, Coherent supports the machine-vision market with LD-based modules ranging across the visible spectrum (and into the near-UV and near-IR as well) that have output powers from a few milliwatts up to 7 W (see Fig. 4). Configurations range from very basic line projectors for simple sizing and alignment applications to modules that produce lines with high power and uniformity. The machine-vision laser product family also includes modules that project complex patterns and beam shapes tailored to particular applications and customers.

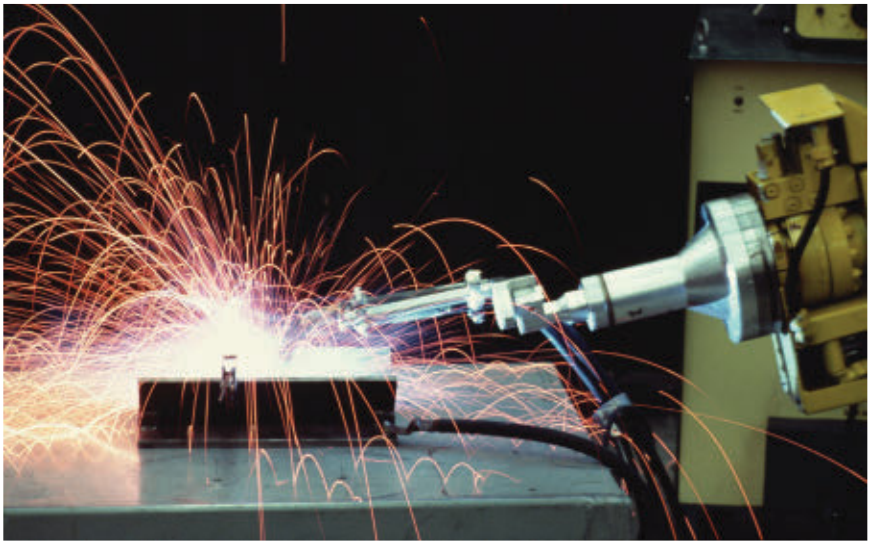

FIGURE 4. A machine-vision system that includes a red-emitting LD carries out in-process (real-time) inspection of weld seams. *(Courtesy of Coherent)*

For example, the StingRay-series of products consists of a laser head (LD plus collimating, line-generating, and focusing optics) and the option of either a separate drive electronics module or drive electronics integrated into the laser head. The driver supports analog and digital

modulation at speeds up to 500 kHz; the option of a separate, stand-alone driver reduces the laser head length to 52.9 mm, as opposed to 95.1 mm.

Wavelengths from 450 to 830 nm are available with output powers as high as 200 mW and output fan angles in the 1° to 75° range, notes Latimer. Pointing stability is better than 10 µrad/°C and line straightness is better than 0.1% over 25 mm; specified line intensity nonuniformity is ±5%, thanks to the use of a novel aspheric line generator that is designed specifically to be volume-manufactured. All StingRay products support "dynamic line balancing," which eliminates any intensity bias that occurs when using the laser at off-axis-illumination angles, says Latimer.

As for applications in the life sciences, some of the company's OBIS lasers incorporate LDs, most notably at 405, 488, 514, and 640 nm; these devices provide fast direct modulation, enabling imaging applications in microscopy. Miniaturization and high electrical efficiency are an advantage particularly in areas like flow cytometry, says Matthias Schulze, Coherent's director of marketing, OEM components, and instrumentation. Here, instrument builders and users often need to incorporate multiple laser wavelengths into a single instrument; in response, Coherent has introduced the OBIS Galaxy beam combiner, which enables "plug-and-play" multilaser (and thus multicolor) combination into a single-mode, single-fiber output.

The recent shift in several types of medical instrumentation from just pure research toward clinical use, and ultimately point of care, has created an even stronger emphasis on OEM laser sources that are compact and ultrareliable, says Schulze. These lasers must be very cost effective in order to overcome competition from LED-based light sources, which offer lower source price (although the total system cost for LED-based systems can actually be higher than for lasers, he notes). In response, Coherent introduced the BioRay module family at SPIE Photonics West 2014; these new modules deliver a particularly small footprint and low cost for applications in the burgeoning compact point-of-care device market. ➤

For a complete listing of companies making visible laser diodes, visit the *Laser Focus World Buyers Guide* (http://buyersguide.laserfocusworld.com/index.html). To locate Lasers & Sources vendors, visit its section (http://buyersguide.laserfocusworld.com/c/laser-sources-6632.html).