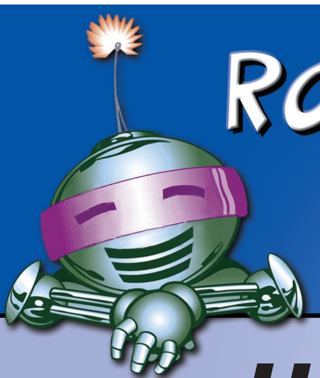


ROBOTICS RESOURCES

Tune in each month for a heads-up on where to get all of your "robotics resources" for the best prices!

BY GORDON MCCOMB

Using Lasers With Your Robots

When I was growing up, two technologies captivated both science and science fiction: robots and lasers. Both started out expensive and complicated, but today, these technologies are within reach on any budget. This is especially true of lasers, which just a generation ago were laboratory curiosities and the stuff of adventure novels. Now they are such an integral part of our lives we have all but forgotten about them. We've lost the appreciation of how useful they can be.

Thanks to advances in semiconductor technologies, you can purchase a fully functioning laser for just a few dollars. Given their low cost, and the unique properties and capabilities of laser light, you may want to consider combining these two stalwarts of sci-fidom into your next project. What follows are some ideas to pique your interest and, of course, a listing of online sources you can check out to further your education and experimentation into the world of lasers.

Lasers 101

Though there are many types of lasers, they all do pretty much the same thing: Lasers amplify a source of photons into an intense beam of light. The wavelength of the light varies across the visible, infrared, and ultraviolet spectrum. Most people are familiar with the ruby-red light of the common laser pointer. These operate at about 650-670 nanometers (nm), depending on their design. A newer class of laser pointers put out a green beam (about 530 nm), which is useful because the human eye is most sensitive to light of this wavelength. The green lasers are more expensive to manufacture, so they cost more.

Many devices such as CD and DVD players use infrared lasers that put out an invisible beam in the 750-780 nm range. While you can't see the beam, an infrared laser is nevertheless quite useful, especially when combined with sensors that are most receptive to light in the infrared region. These include most types of phototransistors and photodiodes, and both CMOS and CCD image arrays.

And, of course, there are lasers that emit light in the deep blue and even ultraviolet region. These are fairly expensive, finding typical uses in such things as high definition DVD players, and validating the authenticity of paper currency.

The vast majority of lasers today are the semiconductor variety. They are typically constructed of a sandwich of semiconducting material that has been cleaved at exactly the right angle to allow a pinpoint of amplified laser light to be emitted. At low currents, the laser operates like a light emitting diode (LED); with the proper operating current, the device emits true laser light, described below.

Semiconductor lasers can be further classified by their operating mode. Most of the devices we are most familiar with are designed for continuous light output. These are operated within a controlled region of current; if the current is too low, the light that is emitted lacks the laser characteristics. If the current is too high, the device will overheat and burn up. To maintain the proper operating output, a sensor inside the laser collects a portion of the emitted light and a control circuit varies the current to keep it within the prescribed range.

Other semiconductor lasers — capable of much higher light outputs — operate in a pulsed mode. They are operated by applying a series of pulses, each one of a short enough duration that the device will not overheat. The intensity of the laser is controlled by varying the duty cycle — the ratio of on time versus off time — of the pulses.

Diode lasers may be self contained, or they may require separate driver electronics. Self-contained diode lasers include the laser itself, as well as its control circuitry. You need only apply power. This is the case with laser pointers. Diode lasers without circuitry require a separate driver board. The board provides the correct voltage and current to the laser diode at all times.

One advantage to getting a laser diode and separate driver board is the extra flexibility in operating the laser. With a separate driver board, you often have more control over the intensity of the laser output. The better driver boards have a separate modulation input that allows you to use an external signal to turn the laser on and off very quickly. Modulation speeds of 5-10 kHz are common.

The older style of laser (still found on the surplus market) uses a tube filled with various gasses. A familiar version is the helium-neon laser, which emits a red beam of 632 nm. The laser itself is constructed of a glass tube filled with a mixture of helium and neon gasses. A high voltage is applied to terminals on either end of the tube. Carefully positioned mirrors on either end serve to amplify the light that bounces back and forth. One of the mirrors is fully reflective; the other is partially reflective. Once suitably amplified, the light escapes the partially reflective mirror and exits the tube.

There are yet more methods of producing lasers, including various crystals such as ruby and YAG, plasma, and even Jello. I'll leave it to you to research these if the subject is of interest to you.

The Properties of Laser Light

Laser light is special for a number of reasons. First is that unlike most light sources, the beam from a typical laser is composed of a single wavelength, or color. The single wavelength makes it possible to isolate the color, and ignore all others. For example, if you're designing a sensor that is only sensitive to the light of your laser source, you can filter out all but that light. You know whatever remaining light your sensor is picking up is probably from your laser.

(In actuality, many lasers emit several specific wavelengths, called mainlines. These may be selectively filtered or split to obtain the desired color. For example, an argon gas laser emits both a green and a weaker blue light. A simple prism may be used to separate the mainlines of a laser, while not reducing the light output of the beam.)

Recall from high school physics that while light is made up of photons, the photons travel as a wave. Because a laser beam is made up of the same wavelength of light, the photons exit the laser and travel in synchronism. This is called coherence. One striking benefit of coherence is the effect of reflections of the laser light. These reflections cause the waves of light to interfere with one another. What was once practically a "solid" beam of light is now a mish-mash of light rays that commingle in measurable ways. Such so-called local interference forms the basis for a number of sensing techniques. I'll cover a few in a bit.

Another useful property of laser light is the limited degree to which it spreads as it travels through space. This is due to the nature of coherence, described above. All light eventually spreads out, but with the right laser and the right optics, it's possible to focus laser light into an extremely thin beam that stays thin for a longer distance than regular light. Without this property, we would not have CDs or DVDs.

For robots, we can use this property to ensure a small pinpoint of light regardless of the distance between the light source and its target. The spot caused by the laser beam will remain relatively small and compact whether the laser is a foot away from the target or 20 feet away. Simple collimating optics can further control the spread of the beam.

Last, and certainly not least, is the sheer intensity of a laser beam. A small pocket laser, operating on a couple of watch batteries, can emit a light as brilliant as noon day sun. Of course, the area of the light is limited to a small spot, but that works to our advantage. Even in average lighting conditions, it's relatively easy for people and sensors to spot the light of a laser beam.

Uses for Lasers in Robotics

Some applications for lasers in robotics are obvious, and some are not. First to mind are decorative uses — dressing up the bot with colored lasers that flash on and off as the machine drives down a darkened hallway. Combine a laser beam with a reflective diffraction grating, and the beam is split into multiple sub-beams that dance around the room as the robot travels. You can get metalized diffraction grating material at any party store. Just look for the stuff that makes a rainbow when you look at it under ordinary light.

More practical applications for using lasers with robots involve some type of sensor. Light-based sensors are already popular solutions in all types of robots, but the majority of these use standard non-laser (i.e., non-coherent) infrared or visible light. Such sensors work by detecting the amount or direction of light. The coherent nature of laser light permits additional sensory techniques.

One notable approach is to rely on the local interference of a laser beam reflected off a surface. To the naked eye, the local interference appears as "speckle," a grain-like pattern that moves as the light or the surface moves. You could use this idea as a way to measure movement and even distance. Point a laser toward the ground, and pick up the reflections using a suitable sensor. As the robot moves, the pattern of the speckle also moves in direct proportion to the direction and distance of that movement.

Systems of these types that rely on local interference typically warrant a multi-cell sensor array. A single light sensor is insufficient to detect the motion of the speckle pattern. However, sensor arrays, such as linear CCDs or even low-resolution CMOS camera chips, can be used to measure finite differences in the speckle pattern.

Lasers also find use in various beacon and landmark systems used for robotics. One or more lasers pointed upward from a stationary "lighthouse" are used to project a pattern of beams or lines onto a white ceiling. A traditional CMOS or CCD camera is pointed toward the ceiling, and with the right filtering, sees only the dots/lines of the laser. The unique orientation of the dots or lines reveals the location of the robot within the room. This is basically the same concept as the celestial navigation techniques used for centuries by mariners. It's already used in some commercial and experimental robotic navigation systems.

Recall above that because of the property of coherence, a laser beam will keep its pencil-thin shape for a longer distance than ordinary light. With appropriate optics, a single sensor can focus onto the same area that the laser beam is being projected onto. Using a variety of timing techniques, it's possible to construct a laser-based distance measurement device that can scan a room and build a 3D map of objects in front of the sensor. This is the basic idea behind the expensive laser-based rangefinder systems build by German electronics manufacturer SICK.

Determining the distance between

laser sensor and target can be accomplished in a variety of ways. With fast enough electronics, it's possible to measure distances using time of flight of the light itself, which travels about 186,000 miles per hour. Perhaps a more common method that does not require fast switching electronics is to modulate the laser beam with a fairly low frequency sine wave. The difference between the phase of the source laser beam modulation and its returned reflection indicates distance.

Laser Safety

The light from a laser is highly intense, and when aimed directly into someone's eyes can cause severe pain and optic damage. In the United States, lasers are regulated by the Food and Drug Administration, or more specifically, an FDA unit known as the Center for Devices and Radiological Health, or CDRH.

Lasers are roughly classified by the potential damage they can cause; this damage is defined by relying on simple metrics, such as whether the beam is visible or invisible to the human eye, if the light of the laser is ever exposed outside of the device it's used in, the power output of the beam (usually expressed in milliwatts or watts), and whether the beam is stationary or constantly in motion.

As noted on the FDA website, laser devices are separated by class. The lower class numbers are the least dangerous. Each of these classes has its own warnings and restrictions for use.

- Class I products include laser printers and CD players where the laser radiation is usually contained within the product.

- Class II and IIa products include bar code scanners.

- Class IIIa products include laser pointers.

- Class IIIb and IV products include laser light shows, industrial lasers, and research lasers.

The vast bulk of lasers available to consumers is Class IIIa. Note that the laser in a CD player is ordinarily a Class I device (but that's when it's used inside the player where its light is never exposed). Used outside — you've hacked a CD player and raided its optics — the laser is most likely a Class IIIa.

Also note that the FDA limits Class IIIa devices to five milliwatts, as indicated by a light meter specifically designed to measure laser output levels. It's technically possible to operate some laser pointers with a higher-than-normal voltage, or even to pulse them with significantly higher voltages. The result is an increase in power output that makes these devices non-compliant.

Class IIIa and lower lasers are generally considered safe, but only in their intended application. Whether or not the laser light may be harmful to people or animals depends on the output power of the laser, whether the laser is visible, and if the beam is held stationary for a long enough period of time. I'd recommend never using anything above a Class IIIa laser in a robotics project, and then only use a visible light laser.

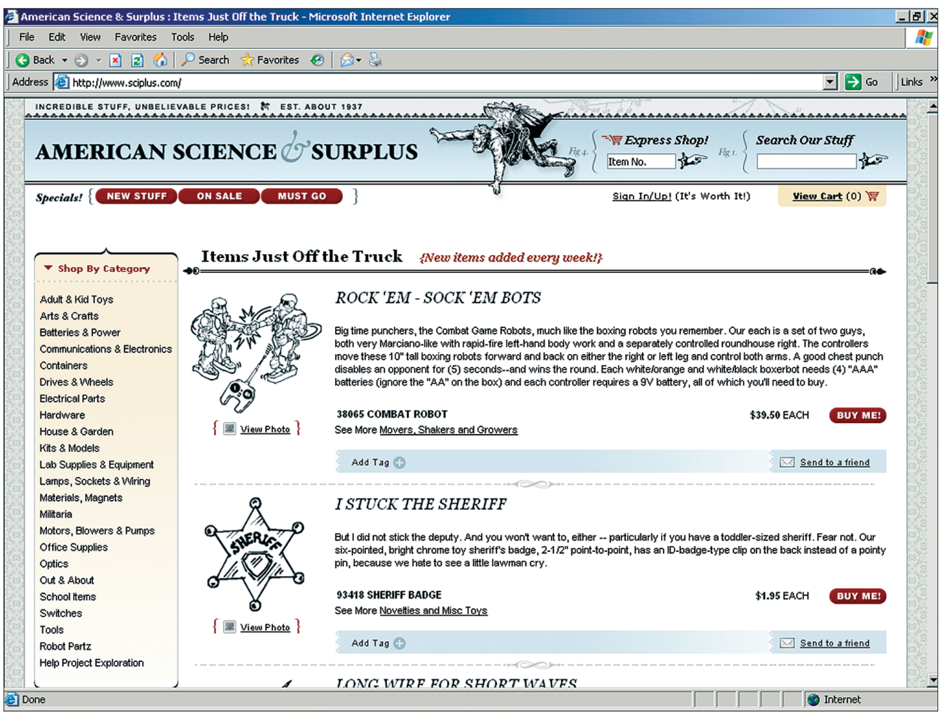
The beam of an infrared laser can be damaging to the eyes, and when strapped to a robot, an unsuspecting person or animal may be inadvertently exposed to the effects of the beam. When an infrared laser must be used, consider only employing it in a fashion where its beam is pointed down to the ground, and not out or up.

If you must use a higher power laser, do so only with appropriate research and safety training, and be sure to follow all laws and regulations. If your goal is to design a mobile light show robot, employing high power 10 watt diode lasers, do so only after you have fully immersed yourself into the study of laser safety.

Be aware that operating certain Class IIIb and above lasers in public without the appropriate safety measures may be against the law, and could expose you to severe fines.

Finally, should you opt for older fashioned tube lasers on your robot, know that these require high voltages to operate. These voltages — typically in the 1-2 kilovolt range — can cause nasty shocks. Be sure all wiring is covered. Lasers with glass tubes (like helium neon) should be suitably protected in plastic or metal enclosures, to avoid the risks of broken glass.

American Science and Surplus often carries optics and sometimes laser components.



Sources

In addition to the sources listed

here, be sure to check out the regular advertisers in both *SERVO* and *Nuts & Volts*, as many of them carry surplus lasers and optics.

Almaz Optics
www.almazoptics.com

Even lasers need the occasional lens. This outfit sells optics for conventional and laser light applications.

American Science and Surplus
www.sciplus.com

Variable surplus merchandise, so check their catalog. Often carries optics and sometimes laser components. Low prices.

Anchor Optics
www.anchoroptics.com

Low-cost optics and laser (diode and gas) products.

Coherent, Inc.
www.cohr.com

Leading manufacturer of industrial, educational, and laboratory lasers. The site contains numerous application notes and other useful information.

Industrial Fiber Optics
www.i-fiberoptics.com

Manufacturer of educational grade lasers. Check out their informational pages.

Information Unlimited
www.amazing1.com

Lasers, laser products, and optics for all sizes and types of interesting projects.

Instapark
www.instapark.com

Online retailer of laser pointers and diode laser modules. Fairly low prices, even for the green lasers.

Jameco
www.jameco.com

Small — but impressive — selection of diode lasers and laser pointers.

Laser Glow
www.laserglow.com

Red, green, yellow, and even blue laser pointers and diode laser modules.

Jameco has a small — but impressive — selection of diodes and laser pointers.

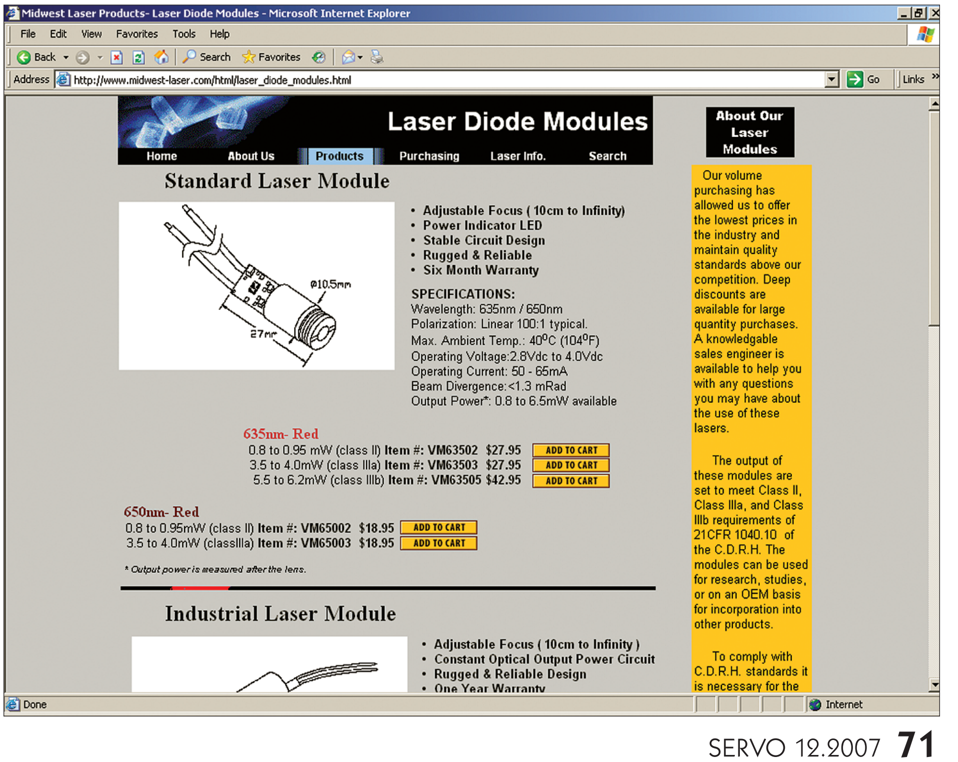
Laser Surplus Sales
www.lasersurplus.com

Laser Surplus Sales carries lasers and optics, at surplus prices. This includes variety of gas, solid-state, and crystal (e.g., ruby) lasers, and upporting optics.

Melles Griot
www.mellesgriot.com

Maker of laser components, optics, and complete laser systems,

Another established company, Midwest offers a number of higher powered diode lasers, including Class IIIb units of 40 mW and more.



from educational to industrial. Check out their online tutorials, such as the section on fundamental optics.

Meredith Instruments
www.mi-lasers.com

Meredith Instruments is one of the oldest names in hobby and educational lasers. Good selection of low-cost red diode lasers, collimating lenses, and line-producing optics.

Midwest Laser Products
www.midwest-laser.com

Midwest Laser Products is another established company, offering a number of higher powered diode lasers, including Class IIIb units of 40 mW and more.

US Food and Drug Administration CDRH website
www.fda.gov/cdrh

Main portal to the CDRH pages at the United States Food and Drug Administration. Plenty of useful information and factoids about lasers, laser use, and laser safety. **SV**

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