Improper laser use poses real safety hazards

Light fright

by Douglas Nix, C.E.T.

Someone once said that the laser is 'a solution looking for a problem'. Since it became a commercial technology in the 1960s, experts have used the laser for thousands of applications.

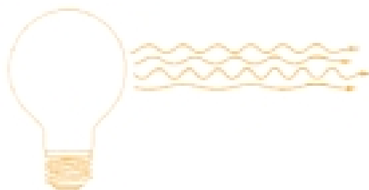
Lasers exist in thousands of forms — from picowatt semiconductor laser devices and megawatt fuel burning lasers in the Star Wars anti-ballistic missile defense system to the more simple lasers in PCs, CD Players and DVD players. One of the most versatile technologies in the workplace today, the laser measures, senses, cuts, welds and solders. In medicine, the laser works for eye surgery, to destroy cancers and for cosmetic surgery.

While lasers are useful, those using them must do so with safety in mind. Users must understand and follow safety guidelines and procedures necessary to protect themselves.

To understand the hazards, here's a bit of background on how lasers work. Lasers emit light in a unique way. Unlike regular light sources such as incandescent, fluorescent or neon lamps that emit incoherent light, lasers emit coherent, monochromatic light.

Incoherent Light Source

Incoherent light has many different wavelengths (colours) of light and varying intensities. (See illustration on the right.) The light radiates from the hot filament in the light bulb in every direction. You can directly view a common light bulb without harming yourself in most cases.



INCOHERENT — LIGHT BULB
Different wavelenghts (colours)

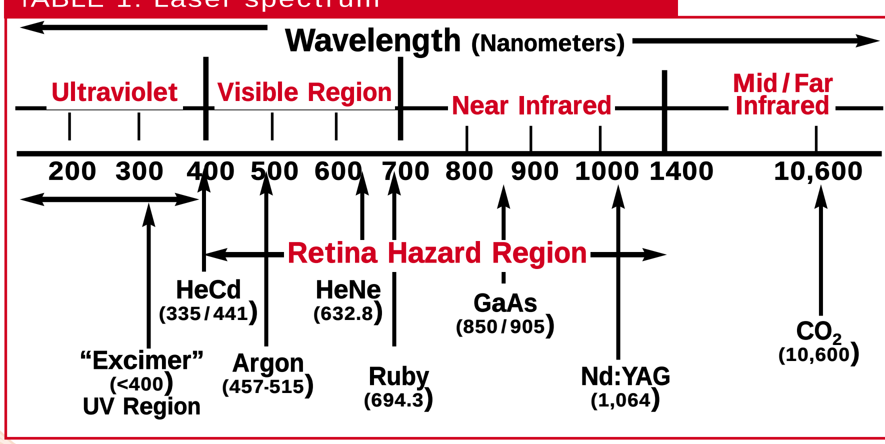
COHERENT or MONOCHROMATIC — LASER
Same wavelength (monochromatic)
Light waves in phase (coherent)

Coherent Light Source

Laser light is unique because it is both monochromatic and coherent. It's monochromatic because of the laser material, such as ruby, garnet or one of the gases like the helium-neon mix used in the HeNe laser. Coherency refers to the fact that the laser emits light-waves in perfect synchronicity.

Lasers emit energy through the band that includes infrared, visible and ultraviolet light. The hazards and the methods of prevention differ depending on the energy of the laser, the wavelength and the possible exposure that could occur in the application. Laser light most often affects the skin and the eye. Both parts are vulnerable to all wavelengths, but it takes higher energy levels before skin damage occurs.

TABLE 1: Laser spectrum



Wavelengths of light are normally expressed in nanometers ($1x10^{-9}$ meters or 0.000 000 001 m) or micrometers ($1x10^{-6}$ meters or 0.000 001 m). Table 1 shows the spectrum of light where lasers operate. Observe some of the more common lasers marked along the spectrum. Lasers such as the excimer laser are used for eye surgery. For example, the Lasik process is used to correct vision.

Lasers with long wavelengths, such as the Nd:YAG and CO_2 lasers are used for cutting, welding and soldering.

Laser hazards

Different wavelengths affect different parts of the eye. The lens focuses light entering the eye on the back of the eye. The cells of the retina detect light and convert it to nerve impulses. At the center of the retina, the fovea, an area densely populated with optical cells, performs the function of fine focus we require for reading and other precise visual tasks.

Laser light, because it is coherent light, tends to focus intensely on one spot. If laser light enters the eye, it can damage or destroy any of the structures within. Damage to the fovea is especially serious. It will impair or eliminate the ability to focus on fine tasks and prevent a person from reading or using a computer. Blue and ultraviolet lasers can cause cataracts and surface burns to the cornea that can lead to temporary or permanent blindness.

Table 2 shows some biological effects of different wavelengths of laser light on the human body. In some cases, particularly with the UV band, only long-term exposure will cause the listed effects. UV lasers have limits for both acute

The optical damage threshold test station at NASA Langley Research Center has three lasers: ND:Yag laser, a Ti:Sapphire laser, and an He Ne laser.

TABLE 2: Wavelength vs. bioeffects

BAND	EYE	SKIN
UV-C (200-280 nm)	Photokeratitis (Welders flash)	Erythema (sun burn) Skin cancer
UV-B (280-315 nm)	Photokeratitis (Welders flash)	Accelerated skin aging Increased pigmentation
UV-A (315-400 nm)	Photochemical cataract	Pigment darkening Photosensitive reactions Skin burn
Visible (400-780 nm)	Photochemical and thermal retinal injury	Photosensitve reactions skin burns
IR-A (780 nm-1.40 µm)	Cataracts Retinal burns	Skin burns
IR-B (1.40-3.00 µm)	Corneal burns, aqueous flare, possible cataracts	Skin burns
IR-C (3.00-1000 µm)	Corneal burn only	Skin burns

Tables used with permission from Rockwell Laser Industries.

exposure and chronic exposure. Users of most UV lasers should limit exposure to eight hours or less per day to prevent sunburn, skin cancer and cataracts.

Laser classifications

A classification system for lasers helps users to understand the degree of hazard that the laser presents. Two classification systems are currently in use: the ANSI system used in North America and the European system. The two systems are similar but not identical, so it is important to understand how the individual laser is marked. This article will only describe the ANSI system.

The ANSI system divides the laser classes into four basic classes, 1 through 4. Class 1 represents the lowest hazard and Class 4 represents the highest hazard. The classes cover the wavelength, the energy and the exposure time. (See Table 3.)

Hazard assessments

Laser safety officers are responsible for hazard assessment. The LSO considers the wavelength of the laser, the output power, operating mode and other optical characteristics. The formulae given in ANSI Z136 combines these factors to give the key hazard data: Maximum Permissible Exposure (MPE), Nominal Hazard Zone (NHZ) and Optical Density (OD) for protective eyewear.

As an example, let’s use a typical Class 3a laser pointer. Laser pointers use inexpensive laser diodes and often have a range of wavelengths in their output and a high divergence angle in the beam. A lot of laser pointers project light waves at 630-680 nm, < 5mW. Using the ANSI Z136 standard, it’s

STANDARDS AND REGULATIONS

Canada, unlike Europe and the U.S., has no standards that specifically relate to lasers and laser systems. In Ontario, laser use is covered under the Occupational Health and Safety Act (OHSA) via Regulation 851, Industrial Establishments.

Regulation 851 requires a Pre-Start Health and Safety Review in any Ontario workplace when a laser is installed or modified (Reg. 851, Section 7). The review process includes a laser hazard analysis to ensure that the company has applied appropriate guarding and other safeguards. A trained laser safety officer or another person skilled in laser hazard assessment must complete a laser hazard analysis. If a user has more than one laser in use in a facility, that organization should have a trained laser safety officer in the plant to provide the ongoing monitoring and training necessary to ensure safe use of the equipment. Companies can also hire the services of trained people on an as-needed basis.

If no regulations exist, where can designers, technicians or technologists find laser resources?

Two voluntary North American standards cover lasers and laser systems: ANSI Z136 and ANSI B11.21, used in the U.S. and Canada, and EN 60825, used in the European Union. Some international standards may also be useful: ISO DIS 11553, Safety of Machinery - Laser Processing Machines - Safety Requirements and IEC 60825, the international equivalent of EN 60825.

ANSI Z136 outlines the training requirements for laser safety officers. This standard defines the level of training required for users and maintainers of each class of lasers and provides training syllabi for each level. The standard also defines the allowable exposure levels for different wavelengths and provides methods to analyze the hazards involved.

ANSI B11.21 provides specific safety requirements for equipment using lasers for processing materials. This product-family standard details the requirements for safeguarding lasers and laser systems found in clear that a laser pointer produces an approximate hazard range of 680 to 730m depending on the exact wavelength that the laser is producing. If the beam divergence is greater, the distance of approximate hazard damage will be less; if the divergence is less the distance will be longer . Exposure of the unprotected eye to either the direct or reflected beam at distances less than this will lead to eye damage.

The average Class 3a laser pointer is approximately 1500 times brighter than the sun. It's clear that even the most common laser can be hazardous at long distances.

Safeguarding methods

For Class 1 through Class 2a lasers, no optical or skin protection is required. Users must take care not to directly expose the eye to the laser light, but these classes are unlikely to cause skin damage and will not cause fires.

People should use protective eyewear if the beam path is fully or partially exposed. Any direct eye exposure to a Class 3 laser can lead to injury. Invisible Class 3 lasers can do damage before an exposed person is aware that a hazard exists. Depending on the power and the other characteristics of the laser, eye and face shields and protective skin creams may be required.

Laser pointers generate particular concern. Class 3a laser pointers are commonly available in office supply stores for under $50. Many eye injuries have occurred because of children playing with the devices. In training and lecture halls, exposure to the beam has caused injury. Officials in Europe and the UK are so concerned that they have banned all Class 3a and higher laser pointers. As you can see from the hazard assessment calculation above, the risk exists at long distances. Exercise caution when pointing the beam and never point it at people.

Equipment owners can guard Class 3 lasers with metal enclosures and install view ports using special materials with the correct optical characteristics to absorb any direct or

Below: A spectroscopic experiment using a Lambda Physik ScanMate dye laser.

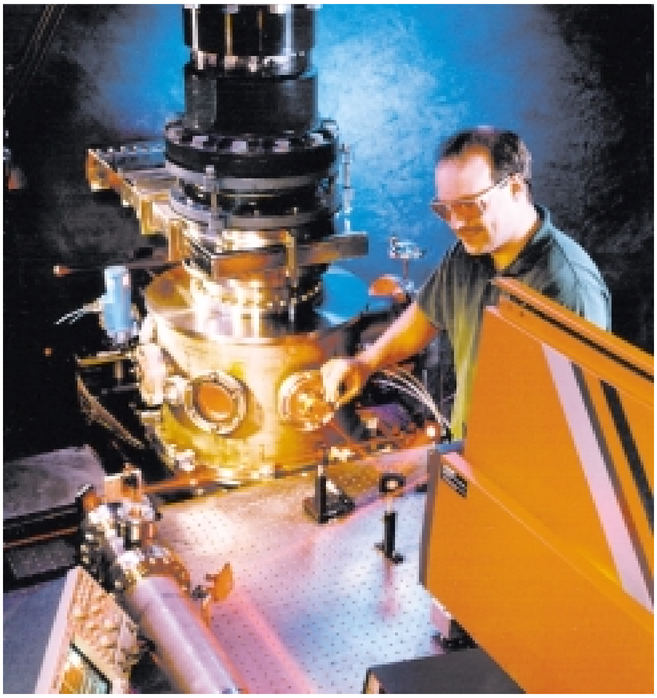


Photo courtesy Lambda Physik USA, Inc.

Laser safety statistics

Data from Rockwell Laser Industries, based in the U.S., shows that laser accidents in the U.S. fall into one or more of the following categories:

- unanticipated eye exposure during alignment
- available eye protection is not often used
- equipment malfunction causes many unwanted exposures
- improper methods of handling high-voltage lead to severe shock and even death
- protection for non-beam hazards is often lacking
- improper restoration of equipment following service frequently causes undesired hazards
- incorrect eyewear selection and/or eyewear failure are frequent causes of unwanted exposure

industry. Pre-start reviews on industrial laser systems should include analysis based on one or both of the ANSI standards.

The Ontario Ministry of Labour offers help through the Radiation Protection Service. You can access the service by calling (416) 235-5922. This group can measure the output characteristics of the laser and help the equipment owner to analyze the hazards presented by the equipment.

Rockwell Laser Industries, www.rli.com, provides training and laser safety equipment around the world. It also maintains the largest database of laser-related accident reports currently available. This data can be accessed via its Web site.

The Laser Institute of America, www.laserinstitute.org/, provides similar resources and also provides courses.

The Laser Institute of America was instrumental in establishing the Board of Laser Safety in the U.S. (www.certified-lso.org). BLS has established a certification program for laser safety officers and offers the CLSO designation to qualified individuals. Any organization that uses lasers and laser systems should have a trained laser safety officer on staff. The CLSO designation makes it that much easier to make sure that the person is qualified.

QPS Evaluation Services, www.qps.ca, can provide assistance with laser hazard assessments and offer consulting on guarding and safeguarding requirements, either as part of a pre-start review or as a separate consulting service.

The standards mentioned in this article can be purchased from Global Engineering Documents, www.global.ihs.com/, from ILI Infodisk, www.ili-info.com/us/, or directly from ANSI, www.ansi.org.

TABLE 3: ANSI Laser classification

CLASS	POWER	HAZARD	APPLICATIONS
1	< 0.4 µW Visible spectrum or Higher power totally enclosed	Not known to be able to cause biological injury.	Measuring devices, sensing devices, laser pointers OR welding, cutting, soldering systems that are totally enclosed during operation.
2	< 1 mW 1/4 s exposure maximum	Ocular hazard for chronic viewing. Visible light only. Protection relies on the blink reflex.	Measuring devices, sensing devices, laser pointers, barcode scanners, CD players, CD ROM drives, etc.
2a	Cannot exceed Class 1 exposure limits for viewing periods < 1000 s.	Hazardous ony for chronic viewing conditions. Not intended for viewing.	Barcode scanners and other scanning applications using higher powered lasers with scanning systems that limit exposure to very short periods.
3a	1-5 mW Infrared and visible	Chronic viewing hazard when observed with optical instruments such as binoculars, telescopes, etc.	Laser pointers, laser levels, measuring devices, sensing devices.
Class 3b	< 0.5 W Visible and invisible lasers.	Eye and skin hazard by direct exposure.	Measuring devices, sensing devices.
Class 4	> 0.5 W Visible and invisible lasers	Eye and skin hazard by direct or indirect exposure. Fire hazard.	Welding, cutting, soldering, surgery.

reflected laser light. Owners should install beam stops to absorb any laser light that passes through the target. If mirrors are used to redirect the beam, they should also install beam stops to absorb the beam if the mirror is missing or damaged for any reason.

Class 4 lasers require all of the same protective equipment as Class 3, plus fire protection. Users can fit temperature sensors onto beam stops to shut the laser down if the beam stop overheats. Another safety feature is interlocking mirrors and other optical devices to prevent the operation of the beam if they are missing.

Some types of lasers use toxic gases or dyes as the laser medium. Safe handling procedures must be in place to prevent exposure.

Use only eyewear specifically intended for use with lasers. Any other eyewear may not provide adequate protection. Manufacturers clearly mark laser eyewear and specify the wavelengths that they will protect against. They also mark the optical density (OD) on laser eyewear. Beware of eyewear with too low an OD. This could lead to exposure and injury. In our laser pointer example above, eyewear rated for 630-680 nm with an OD of 3 (or an attenuation factor of 1000) is required to protect the eyes from a direct beam.

Non-beam hazards

Processing materials with a laser beam can release toxic materials in much the same way some welding processes do. Cutting can release metal fumes, plastic fumes, smoke, and particulate materials. The site should have fume extraction systems to remove these pollutants from the working environment.

Some types of lasers use toxic gases or dyes as the laser medium. Safe handling procedures must be in place to prevent exposure. Accidental spill management procedures and hazardous material training may be required. Companies using these lasers may need to build special chemical containment facilities.

Lasers require optical pumping systems to stimulate the laser material, usually arc lamps or other high-voltage light sources. The electrical systems used to operate this equipment can expose users and maintenance staff to high-energy electrical hazards.

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