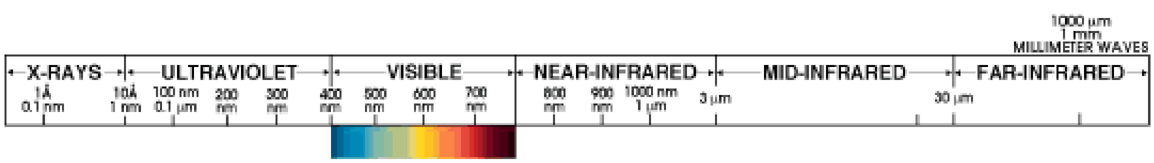
Laser Institute of america
Laser Applications and Safety

This brief bulletin has been prepared by LIA's Laser Safety Committee to educate new laser users on the concerns and issues related to laser safety.

What is a Laser?

LASER is an acronym which stands for Light Amplification by Stimulated Emission of Radiation. The energy generated by the laser is in or near the optical portion of the electromagnetic spectrum (see Figure 1). Energy is amplified to extremely high intensity by an atomic process called stimulated emission. The term "radiation" is often misinterpreted because the term is also used to describe radioactive materials or ionizing radiation. The use of the word in this context, however, refers to an energy transfer. Energy moves from one location to another by conduction, convection, and radiation. The color of laser light is normally expressed in terms of the laser's wavelength. The most common unit used in expressing a laser's wavelength is a nanometer (nm). There are one billion nanometers in one meter.



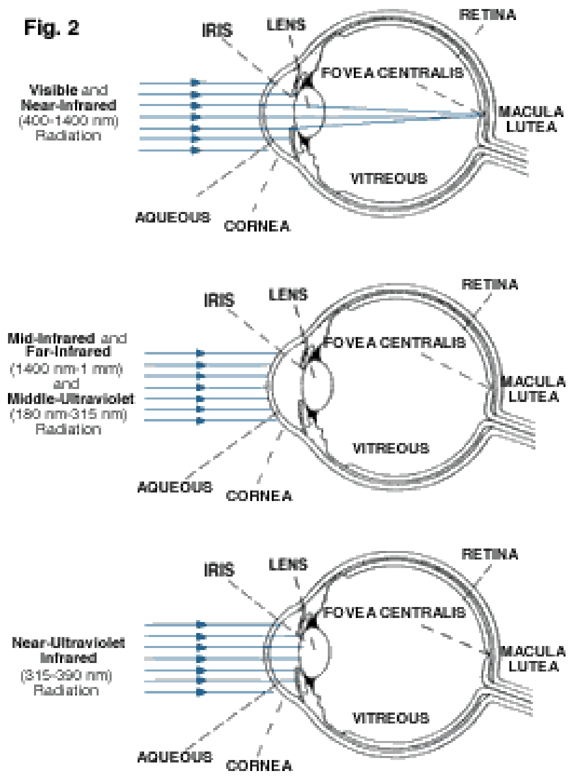
The optical spectrum. Laser light is nonionizing and ranges from the ultra-violet (100 - 400nm), visible (400 - 700nm), and infrared (700nm - 1mm).

Laser Hazards & Beam Hazards

The laser produces an intense, highly directional beam of light. If directed, reflected, or focused upon an object, laser light will be partially absorbed, raising the temperature of the surface and/or the interior of the object, potentially causing an alteration or deformation of the material. These properties which have been applied to laser surgery and materials processing can also cause tissue damage. In addition to these obvious thermal effects upon tissue, there can also be photochemical effects when the wavelength of the laser radiation is sufficiently short, i.e., in the ultraviolet or blue region of the spectrum. Today, most high-power lasers are designed to minimize access to laser radiation during normal operation. Lower-power lasers may emit levels of laser light that are not a hazard.

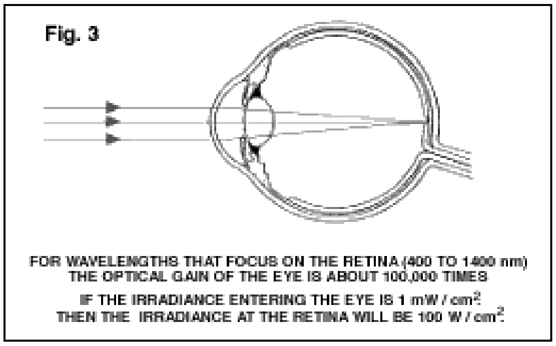
The human body is vulnerable to the output of certain lasers, and under certain circumstances, exposure can result in damage to the eye and skin. Research relating to injury thresholds of the eye and skin has been carried out in order to understand the biological hazards of laser radiation. It is now widely accepted that the human eye is almost always more vulnerable to injury than human skin. The cornea (the clear, outer front surface of the eye's optics), unlike the skin, does not have an external layer of dead cells to protect it from the environment. In the far-ultraviolet and far-infrared regions of the optical spectrum, the cornea absorbs the laser energy and may be damaged. Figure 2 illustrates the absorption characteristics of the eye for different laser wavelength regions. At certain wavelengths in the near-ultraviolet region and in the near-infrared region, the lens of the eye may be vulnerable to injury. Of greatest concern, however, is laser exposure in the retinal hazard region of the optical spectrum, approximately 400 nm (violet light) to 1400 nm (near-infrared) and including the entire visible portion of the optical spectrum. Within this spectral region collimated laser rays are brought to focus on a very tiny spot on the retina. This is illustrated in Figure 3.

Fig. 2



Absorption characteristics of the human eye (From Sliney & Wolbarsht, Safety with Lasers and Other Optical Sources, Plenum Press, 1980)

In order for the worst case exposure to occur, an individual's eye must be focussed at a distance and a direct beam or specular (mirror-like) reflection must enter the eye. The light entering the eye from a collimated beam in the retinal hazard region is concentrated by a factor of 100,000 times when it strikes the retina. Therefore, a visible, 10 milliwatt/cm2 laser beam would result in a 1000 watt/cm2 exposure to the retina, which is more than enough power density (irradiance) to cause damage. If the eye is not focussed at a distance or if the beam is reflected from a diffuse surface (not mirror-like), much higher levels of laser radiation would be necessary to cause injury. Likewise, since this ocular focussing effect does not apply to the skin, the skin is far less vulnerable to injury from these wavelengths.



Focussing effects of the human eye(From Sliney & Wolbarsht, Safety with Lasers and Other Optical Sources, Plenum Press, 1980)

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Non-Beam Hazards

In addition to the direct hazards to the eye and skin from the laser beam itself, it is also important to address other hazards associated with the use of lasers. These non-beam hazards, in some cases, can be life threatening, e.g. electrocution, fire, and asphyxiation. Table 1 indicates some of the potential non-beam hazards associated with laser usage. Because of the diversity of these hazards, the employment of safety and/or industrial hygiene personnel to effect the hazard evaluations may be necessary.

Safety Standards

There are a variety of laser safety standards including Federal and state regulations, and non-regulatory standards. The most important and most often quoted is the American National Standards Institute's Z136 series of laser safety standards. These standards are the foundation of laser safety programs in industry, medicine, research, and government. The ANSI Z136 series of laser safety standards are referenced by the Occupational Safety and Health Administration (OSHA) and many U.S. states as the basis of evaluating laser-related occupational safety issues.

ANSI Z136.1 Safe Use of Lasers, the parent document in the Z136 series, provides information on how to classify lasers for safety, laser safety calculations and measurements, laser hazard control measures, and recommendations for Laser Safety Officers and Laser Safety Committees in all types of laser facilities. It is designed to provide the laser user with the information needed to properly develop a comprehensive laser safety program.

For manufacturers of laser products, the standard of principal importance is the regulation of the Center for Devices and Radiological Health (CDRH), Food and Drug Administration (FDA) which regulates product performance. All laser products sold in the USA since August 1976 must be certified by the manufacturer as meeting certain product performance (safety) standards, and each laser must bear a label indicating compliance with the standard and denoting the laser hazard classification.

Laser Hazard Classification

Research studies, along with an understanding of the hazards of sunlight and conventional, man-made light sources have permitted scientists to establish safe exposure limits for nearly all types of laser radiation. These limits are generally referred to as Maximum Permissible Exposures (MPE's) by laser safety professionals. In many cases it is unnecessary to make use of MPE's directly. The experience gained in millions of hours of laser use in the laboratory and industry has permitted the development of a system of laser hazard categories or classifications. The manufacturer of lasers and laser products is required to certify that the laser is designated as one of four general classes, or risk categories, and label it accordingly. This allows the use of standardized safety measures to reduce or eliminate accidents depending on the class of the laser or laser system being used. The following is a brief description of the four primary categories of lasers:

Class 1
A Class 1 laser is considered safe based upon current medical knowledge. This class includes all lasers or laser systems which cannot emit levels of optical radiation above the exposure limits for the eye under any exposure conditions inherent in the design of the laser product. There may be a more hazardous laser embedded in the enclosure of a Class 1 product, but no harmful radiation can escape the enclosure.

Class 2
A Class 2 laser or laser system must emit a visible laser beam. Because of its brightness, Class 2 laser light will be too dazzling to stare into for extended periods. Momentary viewing is not considered hazardous since the upper radiant power limit on this type of device is less than the MPE (Maximum Permissible Exposure) for momentary exposure of 0.25 second or less. Intentional extended viewing, however, is considered hazardous.

Class 3
A Class 3 laser or laser system can emit any wavelength, but it cannot produce a diffuse (not mirror-like) reflection hazard unless focused or viewed for extended periods at close range. It is also not considered a fire hazard or serious skin hazard. Any continuous wave (CW) laser that is not Class 1 or Class 2 is a Class 3 device if its output power is 0.5 W or less. Since the output beam of such a laser is definitely hazardous for intrabeam viewing, control measures center on eliminating this possibility.

Class 4
A Class 4 laser or laser system is any that exceeds the output limits (Accessible Emission Limits, AEL's) of a Class 3 device. As would be expected, these lasers may be either a fire or skin hazard or a diffuse reflection hazard. Very stringent control measures are required for a Class 4 laser or laser system.

The Laser Safety Officer

ANSI Z136.1 specifies that any facility using Class 3b or Class 4 lasers or laser systems should designate a Laser Safety Officer to oversee safety for all operational, maintenance, and servicing situations.

This person should have the authority and responsibility to monitor and enforce the control of laser hazards. This person is also responsible for the evaluation of laser hazards and the establishment of appropriate control measures.

The Laser Safety Officer (LSO) may be a full or part-time position depending on the demands of the laser environment. This person may be someone from occupational health and safety, industrial hygiene, or similar safety related departments. The LSO may also be part of the engineering or production department. In any case, the LSO must be provided the appropriate training to properly establish and administer a laser safety program.

Some of the duties the LSO may perform include hazard evaluation and establishment of hazard zones, control measures and compliance issues, approval of Standard Operating Procedures and maintenance/service procedures, approval of equipment and installations, safety training for laser personnel, recommendation and approval of personal protective equipment, and other administrative responsibilities.

Controlling Laser Hazards

Like any other potentially hazardous operation, lasers can be used safely through the use of suitable facilities, equipment, and well trained personnel. The ANSI Z136 series of laser safety standards provide a detailed description of control measures which can be put into place to protect against potential accidents.

These control measures are divided into two distinctive categories, Engineering Controls and Administrative/Procedural Controls. Examples of Engineering Controls include protective housings and interlocks, protective filter installations, key-controls, and system interlocks. Administrative/Procedural Controls include standard operating procedures and personal protective equipment.

Engineering Controls are generally more costly to develop but are considered far more reliable by removing the dependence on humans to follow rigorous procedures and the possibility of personal protective equipment failure or misuse.

Administrative/Procedural Controls are designed to supplement Engineering Controls to assure that laser personnel are fully protected from potential laser hazards. The focus of these controls are to provide adequate education and training, provisions for protective equipment, and procedures related to the operation, maintenance and servicing of the laser.

Safety training is desired for those working with Class 3 lasers and systems. Operation within a marked, controlled area is also recommended. For Class 4 lasers or systems, eye protectors are almost always required and facility interlocks and further safeguards are used. Control measures for each laser classification are defined fully in the ANSI Z136.1 laser safety standard. This document is the single most important piece of information regarding the safe use of lasers and should be part of every laser safety program. For more information on laser safety, please refer to this standard. ANSI Z136 laser safety standards may be obtained by contacting Laser Institute of America at 407-380-1553 or http://www.laserinstitute.org

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