

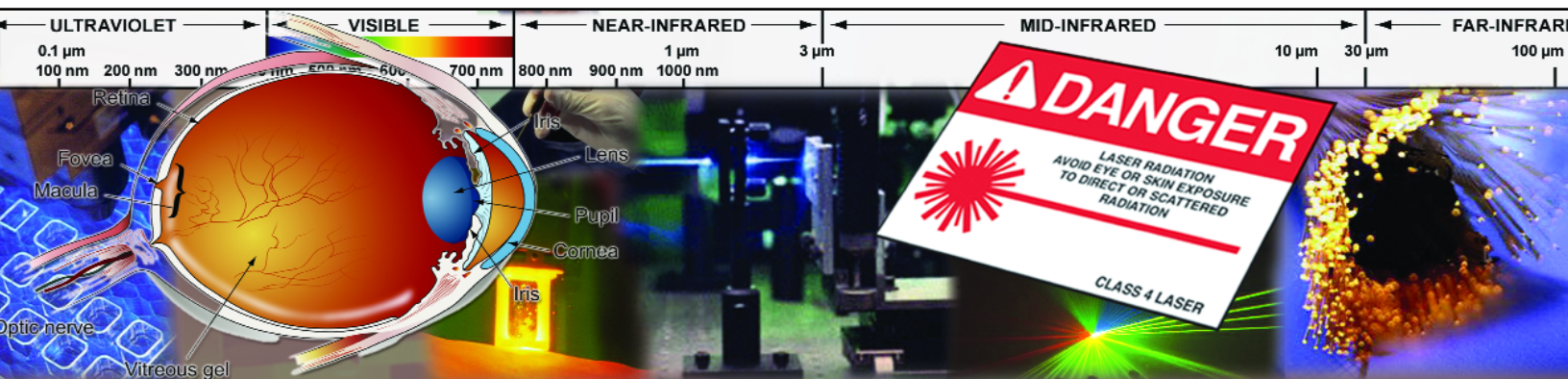


**Laser Institute  
of America**  
*Laser Applications and Safety*



# laser safety

## Information Bulletin



This brief bulletin has been prepared as a product of the Laser Institute of America (LIA) and the Occupational Safety and Health Administration (OSHA) Alliance. OSHA and LIA recognize the value of establishing a collaborative relationship to foster safer and healthier American workplaces. This brief bulletin is intended 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.

## Laser Hazards

### Laser 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.

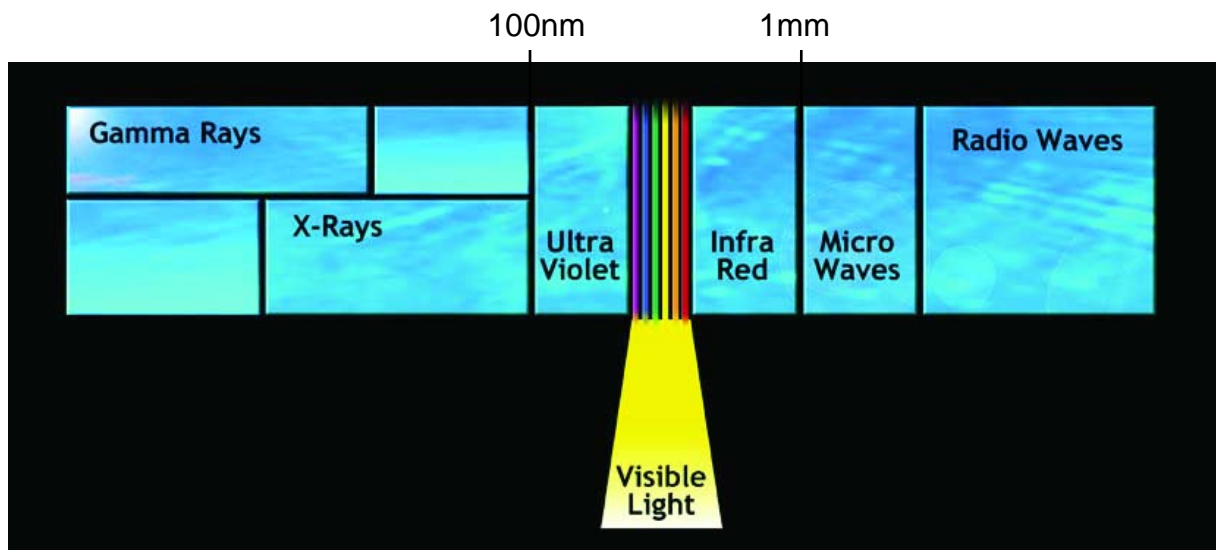
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*Lasers have the potential to damage both the eye and the skin*

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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.

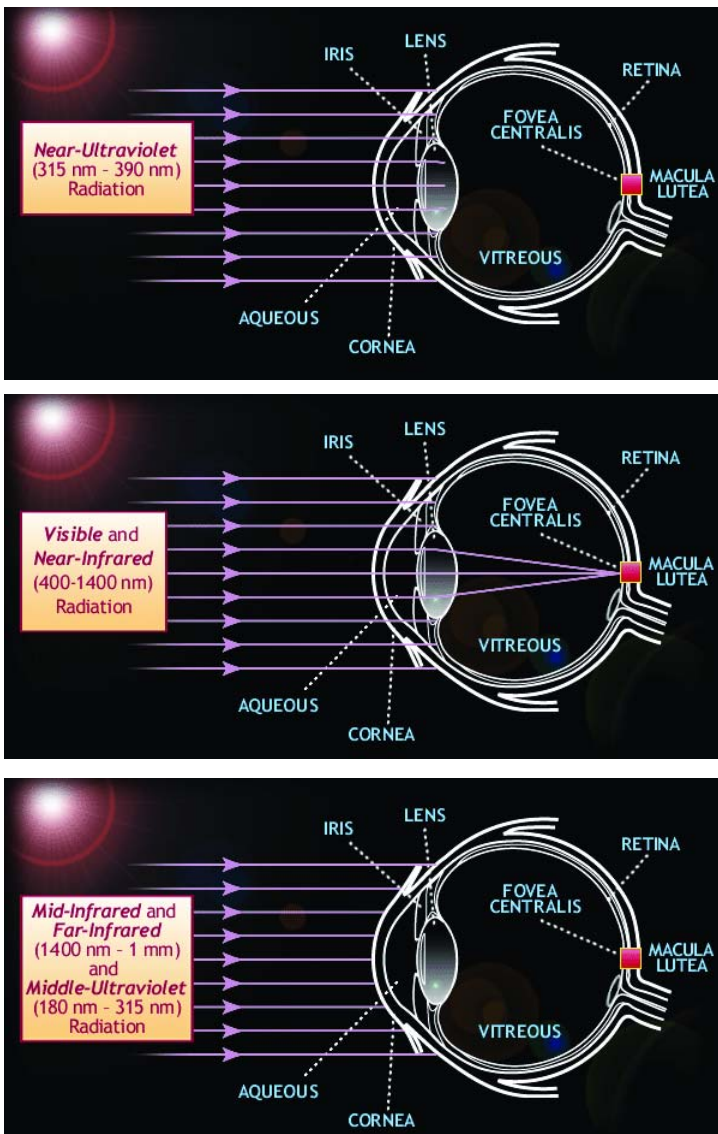
The human body is vulnerable to the output of certain lasers, and under certain circumstances, exposure can result in damage to the eye and skin. Research relating to injury thresholds of the eye and skin has been carried out in order to understand the biological hazards of laser radiation. It is now widely accepted that the human eye is almost always more vulnerable to injury than human skin. The cornea (the clear,



**Figure 1.** The optical spectrum. Laser light is non-ionizing and ranges from the ultraviolet (100-400 nm), visible (400-700 nm), and infrared (700 nm-1 mm).



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.



**Figure 2.** Absorption characteristics of the human eye.

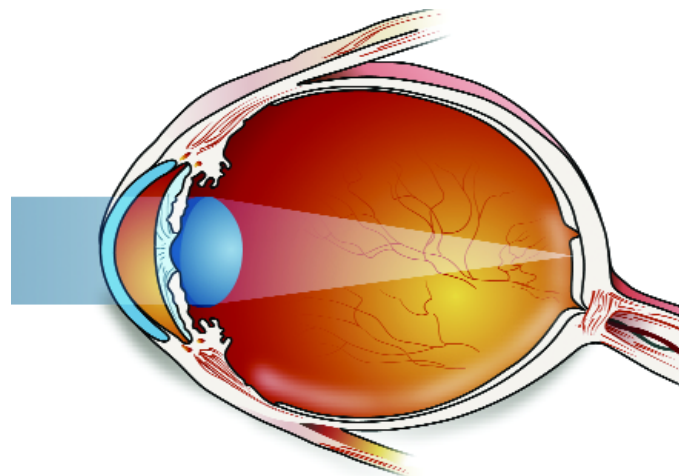
Within this spectral region collimated laser rays are brought to focus on a very tiny spot on the retina. This is illustrated in Figure 3.

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, 1 milliwatt/cm<sup>2</sup> laser beam would result in a 100 watt/cm<sup>2</sup> 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.

### 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.



For wavelengths that focus on the retina (400 to 1400 nm) the optical concentration of the eye is about 100,000 times.
If the irradiance entering the eye is 1mW/cm <sup>2</sup> then the irradiance at the retina will be 100 W/cm <sup>2</sup> .

**Figure 3.** Focussing effects of the human eye.

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.

### OSHA Standards

The regulatory administration of the U.S. Department of Labor with the responsibility of assuring a safe work place is vested in the Occupational Safety and Health Administration (OSHA). At this time, OSHA does not have an all encompassing and comprehensive laser standard. There is an OSHA standard which covers the use of lasers in the construction field only (29 CFR 1926).

However, there have been OSHA citations issued relative to lasers using the authority vested under the "general duty clause" of Public Law 91-596; the Occupational Safety and Health Act of 1970. In these cases, the OSHA inspectors have asked the employers to revise their reportedly unsafe work-place using the recommendations and requirements of such industry consensus standards as the ANSI Z 136.1 Standard. For more information, see the Laser Safety and Health Topics Page at [www.osha.gov](http://www.osha.gov).

**Table 1 - Non-Beam Hazards Associated with Laser Use**

Noise  
 X-Radiation  
 Fire  
 Explosion  
 Electrical  
 Plasma Radiation  
 Compressed Gas  
 Laser Generated Airborne  
 Contaminants (LGAC)



**ANSI Z136.1  
 Safe Use of  
 Lasers Standard**

### ANSI Z136 Laser Safety Standards

The most important and most often quoted laser safety standard is the American National Standards Institute's Z136 series of laser safety standards. These are consensus standards that represent the standard of safety and are the foundation of laser safety programs in industry, medicine, research, and government. The ANSI Z136 series of laser safety standards are referenced by OSHA and many U.S. states as the basis of evaluating laser-related occupational safety issues. For example, OSHA may refer to ANSI Z136 standard when applying the "General Duty Clause."

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.

### FDA Standards

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 system is considered to be incapable of producing damaging radiation levels during operation, and exempt from any control measures or other forms of surveillance. Although some Class 1 lasers emit very weak, non-hazardous beams, most Class 1 laser systems incorporate "embedded" higher-power lasers, which can be accessed only if important safety features such as interlocks are defeated or deliberately bypassed as sometimes done during servicing. In this case, the system temporarily reverts back to the original laser classification (requiring special safety procedures).

*NOTE: Products which have been previously classified as Class 2a should be treated the same as Class 1.*

### Class 1M

A Class 1M laser system is considered to be incapable of producing hazardous exposure conditions during normal operation unless the beam is viewed with an optical instrument such as an eye-loupe (diverging beam) or a telescope (collimated beam), and is exempt from any control measures other than to prevent potentially hazardous optically aided viewing; and is exempt from other forms of surveillance.

### Class 2

A Class 2 laser system emits in the visible portion of the spectrum (400-700 nm), and eye protection is normally afforded by the human aversion response, which is .25 second.

### Class 2M

A Class 2M laser system emits in the visible portion of the spectrum (400-700 nm), and eye protection is normally afforded by the human aversion response for unaided viewing. However, Class 2M is potentially hazardous if viewed with certain optical aids.

### Class 3 (medium-power)

Class 3 laser systems may be hazardous under direct and specular reflection viewing conditions, but is normally not a diffuse reflection hazard or fire hazard. There are two subclasses, Class 3R and Class 3B. A Class 3R laser system is potentially hazardous under some direct and specular reflection viewing conditions if the eye is appropriately focused and stable, but the probability of an actual injury is small. This laser will not pose either a fire hazard or diffuse reflection hazard. A Class 3B laser system may be hazardous under direct and specular viewing conditions, but is normally not a diffuse reflection or fire hazard.

*NOTE: Products which have been previously classified as Class 3a should be treated the same as Class 3R.*

### Class 4 (high-power)

A Class 4 laser system is a hazard to the eye and skin from the direct beam, and may pose a diffuse reflection or fire hazard, and may also produce laser generated airborne contaminants and hazardous plasma radiation.

## The Laser Safety Officer (LSO)

ANSI Z136.1 specifies there shall be a designated LSO for all circumstances of operation, maintenance, and service for a Class 3B or Class 4 laser or laser system.

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.



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## For Class 3B and 4 lasers, a Laser Safety Officer shall be designated to oversee safety

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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 (SOP's) 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.

## Z136 Recommendations for Controlling Laser Hazards

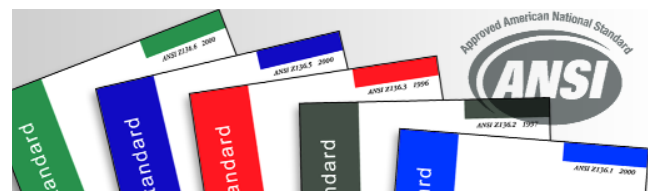
Like any other potentially hazardous operation, lasers can be used safely through the use of suitable facilities, equipment, and well trained personnel. The ANSI Z136.1 *Safe Use of Lasers* standard provides a detailed description of control measures which can be put into place to protect against potential 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 including laser eyewear. 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 required for those working with Class 3 or Class 4 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 *Safe Use of Lasers* 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.** Other standards in the ANSI Z136 series include:



- ANSI Z136.2 - *Safe Use of Optical Fiber Communication Systems Utilizing Laser Diode and LED Sources*
- ANSI Z136.3 - *Safe Use of Lasers in Health Care Facilities*
- ANSI Z136.4 - *Recommended Practice for Laser Safety Measurements for Hazard Evaluation*
- ANSI Z136.5 - *Safe Use of Lasers in Educational Institutions*
- ANSI Z136.6 - *Safe Use of Lasers Outdoors*

# alliance

An OSHA Cooperative Program

LIA is committed to keeping the workplace safe from hazards associated with lasers. On August 9, 2005 LIA formed an Alliance with the Occupational Safety and Health Administration (OSHA) to help achieve these goals.

OSHA and LIA recognize the value of establishing a collaborative relationship to foster safer and more healthful American workplaces. The Alliance will provide LIA's members and others, including small businesses with information, guidance, and access to training resources that will help them protect employees' health and safety, particularly in reducing and preventing exposure to laser beam and non-beam hazards in industrial and medical workplaces. In addition, the organizations will focus on sharing information on laser regulations and standards, bioeffects lasers have on the eyes and skin, laser control measures and laser safety program administration. In developing this Alliance, OSHA and LIA recognize that OSHA's State Plan and Consultation Project partners are an integral part of the OSHA national effort.

OSHA and LIA will work together to achieve the following training and education goals:

- ❖ Work with OSHA to provide expertise to develop training and education programs for OSHA staff, laser manufacturers and laser users of Class 3a, 3b and 4 lasers regarding laser program administration information to employers and employees.
- ❖ Deliver or arrange for the delivery of laser-related safety courses.

OSHA and LIA will work together to achieve the following outreach and communication goals:

- ❖ Work with OSHA to provide expertise in developing information on the recognition and prevention of laser hazards in the workplace, and to provide expertise in developing ways of communicating such information (e.g. print and electronic media, electronic assistance tools and OSHA's and the LIA's Web site) to employers and employees in medical, industrial, military, research & development, and optical fiber communications industries.
- ❖ Speak, exhibit, or appear at OSHA's or LIA's conferences, local meetings, or other laser safety training events such as, LIA's International Laser Safety Conference.
- ❖ Share information among OSHA personnel and industry safety and health professionals regarding LIA's best practices or effective approaches and publicize results through outreach by LIA and through OSHA- or LIA-developed materials, training programs, workshops, seminars, and lectures (or any other applicable forum).
- ❖ Work with other Alliance participants on specific issues and projects on laser safety that are addressed and developed through the Alliance Program.

The OSHA/LIA Alliance details and specific items that are currently in progress can be seen at [www.Laserinstitute.org](http://www.Laserinstitute.org) and [www.osha.gov](http://www.osha.gov).



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