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.

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An OSHA Cooperative Program

Laser Institute of America
Laser Applications and 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.

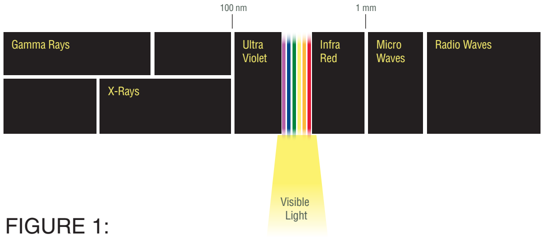


FIGURE 1:
The optical spectrum. Laser light is non-ionizing and ranges from the ultraviolet (100-400 nm), visible (400-700 nm) and infrared (700 nm-1 mm).

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.

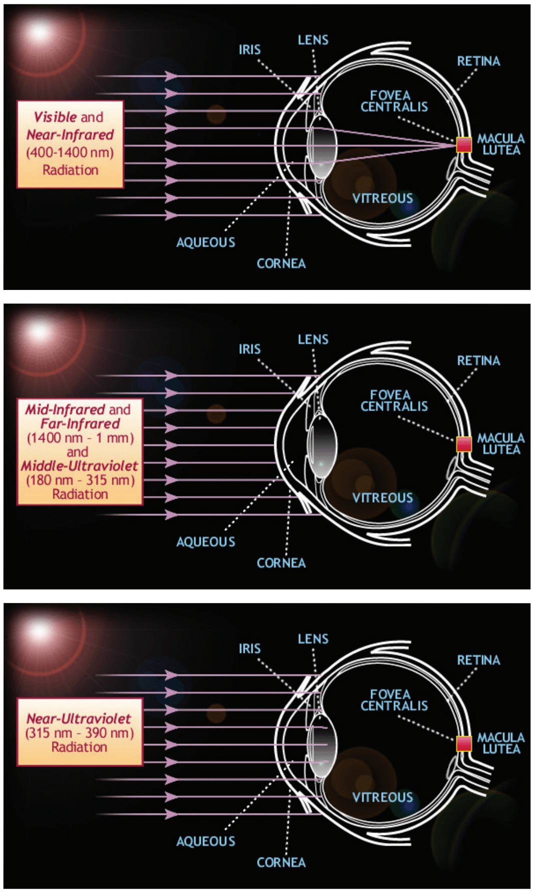


FIGURE 2:
Absorption characteristics of the human eye.

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 focused 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^2 laser beam would result in a 100 watt/cm^2 exposure to the retina, which is more than enough power density (irradiance) to cause damage.

If the eye is not focused 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 focusing effect does not apply to the skin, the skin is far less vulnerable to injury from these wavelengths.

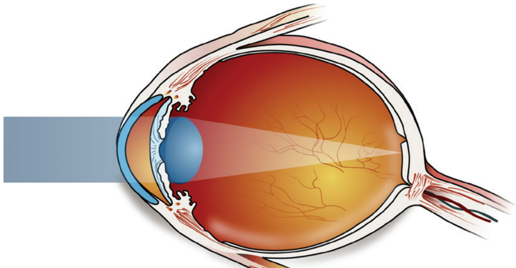


FIGURE 3:
Focusing effects of the human eye. For wavelengths that focus on the retina (400 to 1400 nm). The optical concentration of the eye is about 100,000 times If the irradiance entering the eye is 1mW/cm^2, then the irradiance at the retina will be 100 W/cm^2.

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.

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

TABLE 1:
Non-beam hazards associated with laser use.

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 US 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. Currently, only the use of lasers in the construction field is addressed within an OSHA standard (29 CFR 1926).

However, OSHA citations have been 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, OSHA inspectors have asked the employers to revise their reportedly unsafe workplace using the recommendations and requirements of such industry consensus standards as the ANSI Z136.1 standard. For more information, see the "Safety and Health Topics, Laser Hazards" page at www.osha.gov/SLTC/laserhazards/index.html.

ANSI Z136 LASER SAFETY STANDARDS

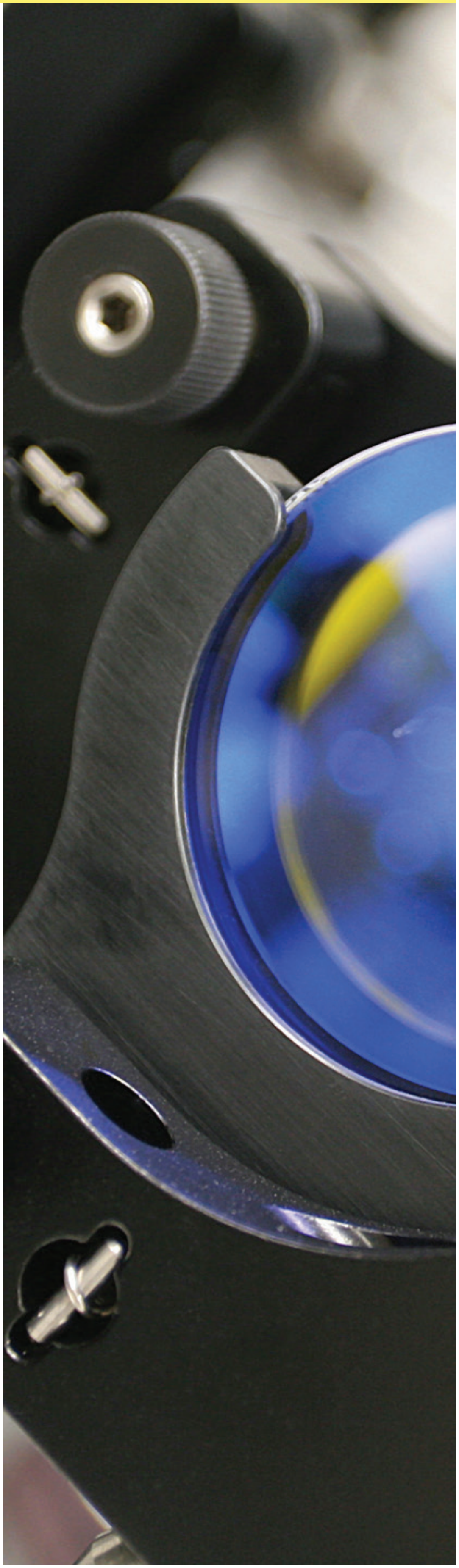
The most important and most often quoted laser safety standards are the American National Standards Institute (ANSI) Z136 series of laser safety standards. These are consensus documents that represent the standard of safety and are the foundation of laser safety programs in industry, medicine, research and government. The ANSI Z136 series of laser safety standards are referenced by OSHA and many US states as the basis of evaluating laser-related occupational safety issues. For example, OSHA may refer to ANSI Z136.1 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, conduct laser safety calculations and measurements, evaluate and assign laser hazard control measures and provides guidance 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 US 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, manmade 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 (MPEs) by laser safety professionals. In many cases it is unnecessary to make use of MPEs 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 AND CLASS 1M

A Class 1 laser system is considered to be incapable of producing damaging radiation levels during operation, and is 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).

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.

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

CLASS 2 AND CLASS 2M

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 0.25 second.

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.

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 (SOPs) 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.

FOR CLASS 3B AND 4 LASERS, A LASER SAFETY OFFICER SHALL BE DESIGNATED TO OVERSEE SAFETY.

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 that 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 is 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 (2012) – *Safe Use of Optical Fiber Communication Systems Utilizing Laser Diode and LED Sources*
- ANSI Z136.3 (2011) – *Safe Use of Lasers in Health Care*
- ANSI Z136.4 (2010) – *Recommended Practice for Laser Safety Measurements for Hazard Evaluation*
- ANSI Z136.5 (2009) – *Safe Use of Lasers in Educational Institutions*
- ANSI Z136.6 (2015) – *Safe Use of Lasers Outdoors*
- ANSI Z136.7 (2008) – *Testing and Labeling of Laser Protective Equipment*
- ANSI Z136.8 (2012) – *Safe Use of Lasers in Research, Development, or Testing*
- ANSI Z136.9 (2013) – *Safe Use of Lasers in Manufacturing Environments*

LIA & OSHA

alliance

An OSHA Cooperative Program

The U.S. Department of Labor's Occupational Safety and Health Administration (OSHA) and Laser Institute of America (LIA) continue to recognize the value of maintaining a collaborative relationship to foster safer and more healthful American workplaces. To that end, OSHA and LIA hereby renew in part the Alliance signed August 9, 2005, and renewed August 22, 2007 and May 8, 2012, with a continued emphasis on Laser Safety. Specifically, both organizations are committed to providing LIA members and others with information, guidance, and access to training resources that will help them protect the health and safety of workers and understand the rights of workers and the responsibilities of employers under the Occupational Safety and Health Act (OSH Act). Through the Alliance, the organizations will continue to address preventing exposure to beam and non-beam hazards in industrial, medical, and research workplaces. In renewing this Alliance, OSHA and LIA recognize that OSHA's State Plan and On-site Consultation Project partners are an integral part of the OSHA national effort.

Outreach and Communication

The Participants intend to work together to achieve the following outreach and communication goals:

- To develop information on the recognition and prevention of workplace hazards, and to develop ways of communicating such information (e.g., print and electronic media, electronic assistance tools, and OSHA's and the LIA's Web sites) to OSHA staff, employers and workers in the industry.

- To 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.

- To share information among OSHA personnel and industry safety and health professionals regarding LIA's good practices or effective approaches through training programs, workshops, seminars, and lectures (or any other applicable forum) developed by the participants.

- To work with other Alliance participants on specific issues and projects on laser safety that are addressed and developed through the Alliance Program.

OSHA's Alliances provide parties an opportunity to participate in a voluntary cooperative relationship with OSHA for purposes such as raising awareness of OSHA's rulemaking and enforcement initiatives, training and education, and outreach and communication. These Alliances have proved to be valuable tools for both OSHA and its Alliance participants. By entering into an Alliance with a party, OSHA is not endorsing or promoting, nor does it intend to endorse or promote, any of that party's products or services.

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Laser Applications and Safety

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