

American National Standard

*American National Standard
for Safe Use of Lasers
in Educational Institutions*



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**American National Standard
for Safe Use of Lasers
in Educational Institutions**

Secretariat

Laser Institute of America

Approved May 19, 2020

American National Standards Institute, Inc.

**American
National
Standard**

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Foreword (This introduction is not a normative part of ANSI Z136.5-2020, *American National Standard for Safe Use of Lasers in Educational Institutions*.)

In 1968, the American National Standards Institute (ANSI) approved the initiation of the Safe Use of Lasers Standards Project under the sponsorship of the Telephone Group.

Prior to 1985, Z136 standards were developed by ANSI Committee Z136 and submitted for approval and issuance as ANSI Z136 standards. Since 1985, Z136 standards are developed by the ANSI Accredited Standards Committee (ASC) Z136 for Safe Use of Lasers. A copy of the procedures for development of these standards can be obtained from the secretariat, Laser Institute of America, 13501 Ingenuity Drive, Suite 128, Orlando, FL 32826 or viewed at www.z136.org.

The present scope of ASC Z136 is to protect against hazards associated with the use of lasers and optically radiating diodes.

ASC Z136 is responsible for the development and maintenance of this standard. In addition to the consensus body, ASC Z136 is composed of standards subcommittees (SSC) and technical subcommittees (TSC) involved in Z136 standards development and an editorial working group (EWG). At the time of this printing, the following standards and technical subcommittees were active:

SSC-1	Safe Use of Lasers (parent document)
SSC-2	Safe Use of Lasers and LEDs in Telecommunications Applications
SSC-3	Safe Use of Lasers in Health Care
SSC-4	Measurements and Instrumentation
SSC-5	Safe Use of Lasers in Educational Institutions
SSC-6	Safe Use of Lasers Outdoors
SSC-7	Eyewear and Protective Barriers
SSC-8	Safe Use of Lasers in Research, Development, and Testing
SSC-9	Safe Use of Lasers in Manufacturing Environments
SSC-10	Safe Use of Lasers in Entertainment, Displays, and Exhibitions
TSC-1	Biological Effects and Medical Surveillance
TSC-2	Hazard Evaluation and Classification
TSC-4	Control Measures, Training, and Laser Safety Programs
TSC-5	Non-Beam Hazards
TSC-7	Analysis and Applications
EWG	Editorial Working Group

The seven standards currently issued are:

ANSI Z136.1-2014, *American National Standard for Safe Use of Lasers*

ANSI Z136.2-2012, *American National Standard for Safe Use of Optical Fiber Communication Systems Utilizing Laser Diode and LED Sources*

ANSI Z136.3-2018, *American National Standard for Safe Use of Lasers in Health Care*

ANSI Z136.5-2020, *American National Standard for Safe Use of Lasers in Educational Institutions*

ANSI Z136.6-2015, *American National Standard for Safe Use of Lasers Outdoors*

ANSI Z136.8-2012, *American National Standard for Safe Use of Lasers in Research, Development, or Testing*

ANSI Z136.9-2013, *American National Standard for Safe Use of Lasers in Manufacturing Environments*

This American National Standard provides guidance for the safe use of lasers and laser systems in educational institutions. The provisions of this standard are applicable to educational facilities ranging from grade school through college and university. In general, the methodology used in this standard is based upon procedures previously established in ANSI Z136.1. General procedures have been adapted for the unique environment of educational institutions. Engineering and administrative control measures appropriate for typical educational activities associated with lasers are supplied to assist users in establishing a sound laser safety program in the educational environment.

This standard has been published as part of the ANSI Z136 series of laser safety standards. The basic document is the ANSI Z136.1, *American National Standard for Safe Use of Lasers*. For the most part, this standard may be used independently of ANSI Z136.1; however, the user should be familiar with and have access to ANSI Z136.1. Instances where additional guidance contained in ANSI Z136.1 is required are noted in this document.

It is expected that this standard will be periodically revised as new information and experience in the use of lasers is gained. Future revisions may have modified methodology, and use of the most current document is highly recommended.

While there is considerable compatibility among existing laser safety standards, some requirements differ among state, federal, and international standards and regulations. These differences may have an effect on the particulars of the applicable control measures.

Occasionally, questions may arise regarding the meaning or intent of portions of this standard as it relates to specific applications. When the need for an interpretation is brought to the attention of the secretariat, the secretariat will initiate action to prepare an appropriate response. Since ANSI-approved Z136 standards represent a consensus of concerned interests, it is important to ensure that any interpretation has also received formal consideration. Requests for interpretations and suggestions for improvements of the standard are welcome. They should be sent to ASC Z136 Secretariat, Laser Institute of America, 13501 Ingenuity Drive, Suite 128, Orlando, FL 32826.

This standard was developed by Standards Subcommittee 5 (SSC-5) “Safe Use of Lasers in Educational Institutions” and approved by ASC Z136. Committee approval of the standard does not necessarily imply that all members voted for its approval.

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C.D. Clark III, Committee Vice-Chair
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Notice

(This notice is not a normative part of ANSI Z136.5-2020, *American National Standard for Safe Use of Lasers in Educational Institutions*.)

Z136 standards and recommended practices are developed through a consensus standards development process approved by the American National Standards Institute. The process brings together volunteers representing varied viewpoints and interests to achieve consensus on laser safety related issues. As Accredited Standards Developer (ASD) and secretariat to ASC Z136, the Laser Institute of America (LIA) administers the process and provides financial and clerical support to the committee.

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American National Standard for Safe Use of Lasers in Educational Institutions

1. General

1.1 Scope.

This standard addresses laser safety concerns and situations that may occur in educational environments. This standard is not a substitute for ANSI Z136.1 (latest revision)¹ that is required for a full understanding of laser safety officer (LSO) duties and laser hazard evaluation. Environments characteristic of educational institutions, wherein lasers may be found, include teaching laboratories, classrooms, lecture halls, science fairs, museums, and student projects on-and-off campus. This standard is intended for faculty and students using lasers at primary, secondary, and college levels of education excluding graduate level research laboratories that are more comprehensively addressed by ANSI Z136.8 (latest revision) and Z136.1 (latest revision). The wavelength range of interest includes the ultraviolet (UV), visible, and infrared (IR) regions of the electromagnetic spectrum; specifically, the wavelength range from 180 nanometers (nm) to 1 millimeter (mm).

The LSO, or responsible person, for the educational institution shall assess if a specific laser safety standard, ANSI Z136.2, Z136.3, Z136.6, Z136.8 or Z136.9 (latest revisions), is to be consulted for additional safety control measures to complement the laser lesson plan.

1.2 Purpose and Application.

The purpose and application of this standard is to provide reasonable and adequate guidance for the safe use of lasers in educational environments by evaluating and minimizing hazards associated with laser radiation. The hazard evaluation procedure used in this standard is based on Class 1 through Class 4 classification of the laser or laser system that is related to the ability of the laser beam to cause physiological damage to the eye or skin and a fire hazard as an ignition source during intended use. The amount of laser radiation emitted from Class 1 lasers and laser systems is considered to be non-hazardous; Class 4 lasers and laser systems possess the highest potential hazard.

1.2.1 Laser Classification. Laser and laser system hazard potential are generally described using a scheme of Class 1 (inherently safe) through Class 4 (most hazardous). Laser equipment manufacturers are subject to laser product performance standards and regulations that include build safety features and safeguards. Where lasers are deployed such as in a place of work or an educational setting, their safe use is addressed by the applicable consensus standards of Z136 (latest revisions).

¹ When a reference to a standard, regulation or order is followed by a date, e.g., Z136.1-2014, the reference is to that specific document. When a reference to a standard, regulation or order is not followed by a date, e.g., Z136.2, FAA order JO 7400.2, it means the latest revision of that document.

Within the U.S.A., those lasers, laser systems, and laser products placed into commerce after 1976 are classified by the manufacturer commensurate with their potential hazard in accordance with 21CFR1040.10 and 21CFR1040.11 that are commonly known, collectively, as the “Federal Laser Product Performance Standard” (FLPPS) and are currently referred to as such by the Occupational Safety & Health Administration (OSHA), and in other documents, regarding laser hazards and safety measures. Regulations and standards encompass equipment safety features appropriate for the inherent laser hazard. Proper owner manuals for such compliant equipment will identify the inherent hazard(s), the safeguards of the product, instructions on its safe use and recommendations for protection against any residual hazard(s) to the user. In many cases, recommendations noted may simply state to follow that of the respective Z136 standard.

For user safety, lasers and laser systems are classified according to their hazard potential using a scheme of Class 1 through Class 4 as outlined in Section 3 with commensurate safety control measures discussed in Section 4. More comprehensive information can be found in ANSI Z136.1 (latest revision).

For certified lasers or laser systems, that is those compliant with FLPPS, it is not necessary to re-classify according to this standard if it has not been modified. The LSO has the responsibility to determine the classification of those lasers or laser systems that have been developed (purpose built) or modified so that the original hazard classification may have changed. The LSO then has the responsibility to effect the appropriate safety control measures (see Section 4).

1.3 Laser Safety Officer (LSO).

The LSO is an individual designated by the administration of the educational institution to administer and manage the laser safety program. The LSO shall have the authority and responsibility to effect the knowledgeable evaluation and control of laser hazards, to monitor and enforce the control of such hazards, as well as to effect the training of individuals who are involved with the use of laser technology and applications. Since many persons under the direction of the LSO are encountering laser technology and applications for the first time, the person designated for this position shall possess a sense of duty to the “laser novices” under his or her administration. The LSO position may be a part-time appointment.

An LSO shall be designated in all educational institutions involved with the operation, maintenance, or service of Class 3B and 4 lasers or laser systems (see Section 3 for hazard class designation). Operation, maintenance, or service of Classes 1, 1M, 2, 2M, 3R and some former 3a lasers and laser systems normally does not require an LSO. For those Class 1, 1M, 2, 2M, or 3R systems with embedded Class 3B or 4 lasers, maintenance or service safety situations with exposed conditions shall have the appropriate control measures and safety protocols with responsible person(s) identified in the written laser safety plan. Although primary and secondary educational institutions using only laser systems below Class 3B normally do not require the designation of an LSO, when large groups of students are using lasers in an insufficiently controlled environment informed supervision may be required.

Table 1 summarizes when an LSO is required based on the highest-class laser or laser system present in an educational institution.

Table 1. Laser Safety Officer (LSO) Requirements for Laser Classes

Laser Class	Procedural & Administrative Controls	Training	Medical Surveillance	Laser Safety Officer	Laser Safety Program
1	Not Required	Not Required	Not Required	Not Required	Not Required
1M	Required	Application Dependent ^a	Application Dependent ^a	Application Dependent ^a	Application Dependent
2	Not Required ^b	Not Required ^b	Not Required	Not Required	Not Required
2M	Required	Application Dependent ^a	Application Dependent ^a	Application Dependent ^a	Application Dependent
3R	Not Required ^b	Not Required ^b	Not Required	Not Required ^b	Not Required
3B	Required	Required	Suggested	Required	Required
4	Required	Required	Suggested	Required	Required
NOTE—During maintenance and service, the classification associated with the maximum level of accessible laser radiation shall be used to determine the applicable control measures.					

^a Certain uses of Class 1M or 2M lasers or laser systems that exceed Class 1 or Class 2 because they do not satisfy Measurement Condition 1 may require hazard evaluation and/or manufacturer's information (see 4.1).

^b Not required except for conditions of intentional intrabeam exposure applications, which is prohibited in this standard.

^c Should be considered if containing an embedded Class 3B or 4 laser (see 1.3.1).

The administration shall have the authority to require the power level of a laser or laser system reduced if it is determined to be excessive for the intended purpose. For example, a Class 2 or 3R laser or laser system may be used instead of a visible or invisible Class 3B laser or laser system. In all instances, the lowest power level required for the project should be used.

In recognition of the fact that an LSO may not be present in primary and secondary schools where Class 3B or 4 lasers are absent, all lesson plans or demonstrations involving lasers should be reviewed by a knowledgeable individual for laser safety controls. These controls are a required part of the laser plan and demonstration.

In addition to the above responsibilities, the LSO has the following specific responsibilities where Class 3B or 4 lasers or laser systems are to be used.

1.3.1 Classification. The LSO shall be responsible for effecting the classification or verification of the classification of Class 3B and 4 lasers and laser systems used under the LSO's jurisdiction. Unmodified lasers or laser systems classified by the manufacturer in accordance with FLPPS may

be considered as fulfilling all classification requirements of this standard. In cases where the laser or laser system classification is not provided, or where classification may change due to the addition or deletion of engineering controls, the laser or laser system shall be classified in accordance with the procedures prescribed in ANSI Z136.1 (latest revision), FLPPS, or the International Electrotechnical Commission's "Safety of laser products - Part 1: Equipment classification and requirements" (IEC 60825-1), as applicable.

1.3.2 Hazard Evaluation. The LSO shall be responsible for the hazard evaluation of laser work areas, as prescribed in ANSI Z136.1 (latest revision). The hazard evaluation shall consider the level of maturity and ability of each person who is to be permitted within the nominal hazard zone (NHZ) (see Section 3). The LSO shall inspect all teaching setups involving the use of lasers and shall have the responsibility to immediately notify the teacher or administrator of a potentially hazardous condition to discontinue, cancel, or postpone a demonstration or research project until the condition has been rectified.

1.3.3 Controls. The LSO shall be responsible for ensuring that the prescribed controls are in effect (see Section 4), recommending or approving substitute or alternate controls when primary controls are not feasible or practical, and periodically auditing the functionality of the controls in use.

1.3.4 Procedural Approvals. The LSO shall approve a lesson plan involving the demonstration of a laser product. Once approved, this lesson plan can be re-used without review by the LSO, so long as two conditions are met. First, the control measures required in the plan shall be followed. Second, no changes to the laser system, including changes in output or collimation of the beam, may be made that would result in an increased hazard.

1.3.5 Personal Protective Equipment (PPE). The LSO shall recommend or approve required PPE, for example, laser protective eyewear (LPE), and protective clothing and gloves, to ensure protection from laser beam hazards. The LSO shall be responsible for inspections and periodic audits of protective equipment to ensure that it is in proper working order. The LSO can defer to industrial hygiene and/or safety professionals for recommendation or approval of non-beam hazard PPE.

1.3.6 Signs and Labels. The LSO shall approve wording on area signs and equipment labels. The LSO shall be responsible for appropriate wording and labels on lasers or laser systems that are constructed at the institution or on any altered commercially manufactured device that emits laser radiation (see Section 4). It is critical that the LSO check warning signs and labels to see that the information is current for the laser activity.

1.3.7 Facility and Equipment. The LSO shall approve laser installations and laser equipment prior to initial use. This also applies to the modification of existing facilities or equipment. See Appendix H for examples of how laboratories may be designed for different laser classifications.

1.3.8 Safety Features Audits. The LSO shall be responsible for periodic examination of the safety features of laser equipment, installations, and laser facilities to ensure their safe operation and usage.

1.3.9 Training. The LSO shall ensure that adequate safety training is provided to staff, students, and authorized personnel using Class 3B and 4 lasers and laser systems (see 4.6.3 and Section 5). The LSO shall maintain records for each of these persons, indicating that appropriate training has been provided (see Appendix F).

1.3.10 Medical Examination. When necessary, the LSO shall effect medical examinations of affected personnel (see Section 6 and Appendix G). These personnel shall include anyone who is suspected of having received a laser injury or eye exposure exceeding the applicable MPE, and shall include, but are not restricted to administration, faculty, staff, and students who work with Class 3B and 4 lasers or laser systems. If an injury or accidental exposure exceeding the applicable MPE is suspected, urgent medical attention shall be provided. The LSO shall ensure that applicable medical examinations are scheduled and performed and shall maintain records of these examinations (see Section 6 and Appendix G for further information on medical surveillance).

1.3.11 Accidents. Upon notification of a known or suspected accident resulting from the operation of a laser or laser system, the LSO or designate for those facilities with Class 1 through 3R lasers shall perform an investigation of the accident and initiate appropriate action. This may include preparation of reports for submission to appropriate agencies. Federal reporting requirements can be found in the US Code of Federal Regulations, 21 CFR Subchapter J, Part 1002.20.

1.3.12 Additional Duties. Additional recommended duties of the LSO are included in ANSI Z136.1-2014, Appendix A, a normative appendix.

2. Acronyms and Definitions

2.1 Abbreviations and Acronyms.

Refer to 2.2 for definitions of these acronyms

AEL – accessible emission limit
 ANSI – American National Standards Institute (USA)
 ArF – argon fluoride (laser)
 CDRH – Center for Devices and Radiological Health (USA)
 CO₂ – carbon dioxide (laser)
 CW – continuous wave
 GaAs – gallium arsenide (laser), a family of solid-state semiconductor lasers
 HeNe – helium-neon (laser)
 Hz – hertz
 IEC – International Electrotechnical Commission
 IR – infrared
 J – joule
 LASER – light amplification by stimulated emission of radiation
 LCA – laser-controlled area
 LGAC – laser generated airborne contaminants
 LPE – laser protective eyewear
 LSO – laser safety officer

MPE – maximum permissible exposure
Nd:YAG – neodymium-doped YAG (yttrium aluminum garnet) host medium (laser)
NHZ – nominal hazard zone
NOHD – nominal ocular hazard distance
OD – optical density
OSHA – Occupational Safety and Health Administration (USA)
PPE – personal protective equipment
SOP – standard operating procedure
YAG – yttrium-aluminum garnet (crystal), serving as host element to lasing dopant
Yb:Fiber – ytterbium-doped fiber host medium (laser)
Yb:YAG – ytterbium-doped YAG (yttrium aluminum garnet) host medium (laser)

2.2 Definitions.

The definitions of the terms listed below are based on a pragmatic approach. The terms defined are limited to those used in this standard and its appendices and are intended to be a reference for the reader.

absorption. The transformation of radiant energy to a different form of energy by interaction with matter.

accessible emission limit (AEL). The maximum accessible emission level permitted within a particular laser hazard class; see the latest version of ANSI Z136.1 for detailed examples.

accessible optical radiation. Optical radiation to which the human eye or skin may be exposed for the condition, for example, operation, maintenance, or service specified.

administrative control measure. Control measures incorporating administrative means, for example, training, safety approvals, laser safety officer (LSO) designation, and standard operating procedures (SOP), to mitigate the potential hazards associated with laser use. The objective of such is for laser hazard risk management and/or containment, for the protection and safety of the operator(s) and/or other personnel.

aperture. An opening, window, or lens through which optical radiation can pass. The aperture limits the energy or power for measurement or exposure.

attenuation. The decrease in the power or energy as it passes through an absorbing and/or scattering medium.

attenuator. A device for achieving attenuation, for example, a beam stop, that reduces the laser power or energy to or below a specific level or by a specific fraction.

average power. The total energy in an exposure or emission divided by the duration of that exposure or emission.

aversion response. Closure of the eyelid, eye movement, pupillary constriction, or movement of the head to avoid an exposure to a noxious or bright light stimulant. In this standard, the aversion

response to an exposure from a bright, visible, laser source is assumed to limit the exposure of a specific retinal area to 0.25 s or less.

beam. A collection of light/photonic rays characterized by direction, diameter (or dimensions), and divergence (or convergence).

beam attenuation. The reduction of beam intensity (irradiance). Beam attenuation can be accomplished in at least two ways: placing a filter in the path of the beam or the use of a system of lenses or mirrors to expand the beam.

beam diameter. The distance between diametrically opposed points in that cross-section of a circular beam where the intensity is $1/e$ (~ 0.368) times that of the peak level. The value is normally chosen at $1/e^2$ (0.135) of the peak level for manufacturing specifications. *Unit:* centimeter (cm).

beam divergence (Φ). For purposes of this standard, divergence is the increase in the diameter of the laser beam with distance from the beam waist, based on the full angle at the point where the irradiance (or radiant exposure for pulsed lasers) is $1/e$ times the maximum value. *Unit:* radians (rad).

beam stop. An opaque device used to absorb the laser beam at a predetermined location. The beam stop must be robust enough to absorb the laser beam without damage to itself. Examples of beam stops include shutters or stops that permit operators to block the laser beam without actually turning off the laser. Shutters or stops may be simple mechanical devices such as an output aperture cover of non-transparent, non-reflective material that can be placed over the beam exit aperture. Other shutters or stops may be placed within the laser enclosure but are controlled from outside the enclosure.

classroom environment. A classroom or a closed room in which most, if not all students, are seated and one or more instructors are present to provide supervision.

collateral radiation. Any electromagnetic radiation, except laser radiation, emitted by a laser or laser system. This does not include laser target interaction radiation (re-radiation).

college. A post-secondary educational institution or establishment, in particular one providing higher education or specialized professional or vocational training. A college can be a stand-alone institution or a division within a university.

collimated beam. Effectively, a “parallel” beam of light with very low divergence or convergence.

conduit. A pipe or hollow cable through which laser energy passes.

continuous wave (CW). In this standard, a laser operating with or modeled as having a continuous output for a period greater than or equal to 0.25 s ($t \geq 0.25$ s) is regarded as a CW laser.

control measure. A means to mitigate potential hazards associated with the use of lasers. Control measures can be divided into three groups: engineering, procedural (administrative), and personal protective equipment (PPE).

controlled area. An area where the occupancy and activity of those within are subject to control and supervision for the purpose of protection from laser hazards. *See also:* **laser-controlled area.**

cornea. The transparent outer layer of the human eye that covers the iris and the crystalline lens. The cornea is the main refracting element of the eye.

diffraction. Deviation of part of a beam determined by the wave nature of radiation. Diffraction can occur when radiation passes through an aperture or passes by the edge of an opaque object.

diffuse reflection. A reflection from a “rough” surface that causes incident radiation to reflect randomly in all directions. It is a change in the spatial distribution of a beam.

educational research laboratories. For purposes of this standard educational research laboratories means laboratories at colleges and universities primarily devoted to continuing research projects using Class 3B and 4 lasers or laser systems.

electromagnetic radiation. The flow of energy consisting of orthogonally vibrating electric and magnetic fields lying transverse to the direction of propagation. Gamma rays, x-rays, ultraviolet (UV), visible, and infrared (IR) radiation, and radio waves occupy various portions of the electromagnetic spectrum and differ only in frequency, wavelength, and photon energy.

embedded laser. An enclosed laser that has a higher classification than that of the laser system in which it is incorporated, where the system’s lower class is appropriate due to the engineering features that limit accessible emission.

enclosed laser. A laser that is contained within a protective housing of itself or of the laser or laser system in which it is incorporated. Opening or removal of the protective housing provides additional access to laser radiation above the applicable MPE than possible with the protective housing in place. An embedded laser is an example of one type of enclosed laser.

energy. The capacity for doing work. Energy content is commonly used to characterize the output from pulsed lasers. *Unit:* joules (J).

engineering control measure. Control measures designed or incorporated into the laser or laser system (e.g., interlocks, shutters, watch-dog timers) or its application.

extended source. A source of radiation that can be resolved by the eye into a geometrical image, in contrast to a point source of radiation, which cannot be resolved into a geometrical image.

eye-safe laser. A misnomer for a Class 1 laser product. Because of the frequent misuse of the term *eye-safe laser* to refer to a laser emitting at wavelengths outside the retinal-hazard region, the term *eye-safe* can be misunderstood. If in the visible spectrum and below the MPE, there can be

transient effects such as dazzle, flash-blindness, or after-images that may result from intra-beam viewing. Hence, the use of the term *eye-safe laser* is discouraged and is not employed in this standard.

fail-safe interlock. An interlock where the failure of a single mechanical or electrical component of the interlock will cause the system to go into, or remain in, a safe mode.

focal length. The distance from the secondary nodal point of a lens to the secondary focal point. For a thin lens imaging a distant source, the focal length is the distance between the lens and the focal point. *Unit:* meter (m).

Typical units:

millimeter (mm) = 10^{-3} m

centimeter (cm) = 10^{-2} m

focal point. The point toward which radiation converges or from which radiation diverges or appears to diverge.

hertz (Hz). The unit which expresses the frequency of a periodic oscillation in cycles per second. The unit is also used to express the number of repetitive laser pulses occurring per second. 1 hertz = 1 cycle per second.

high school. Typically refers to grades nine through twelve.

infrared radiation (IR). For purposes of this standard, the region of the electromagnetic spectrum between the long-wavelength extreme of the visible spectrum (700 nm) and the shortest microwaves (1000 μ m).

intrabeam viewing. The viewing condition whereby the eye is exposed to all or part of a laser beam.

installation. Placement and connection of laser equipment to enable intended operation.

ionizing radiation. Electromagnetic radiation having sufficiently large photon energy to directly ionize atomic or molecular systems with a single quantum event. Electromagnetic radiation at wavelengths shorter than approximately 100 nm is considered ionizing radiation.

irradiance (E). Radiant power incident per unit area upon a surface, expressed in watts-per-centimeter squared ($\text{W} \cdot \text{cm}^{-2}$).

joule. A unit of energy. 1 joule = 1 watt · second ($\text{W} \cdot \text{s}$).

laser. A device that produces radiant energy predominantly by stimulated emission. Laser radiation may be highly coherent temporally, spatially, or both. An acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation.

laser classification. An indication of the beam hazard level of a laser or laser system during normal operation, or the determination thereof. The hazard level of a laser or laser system is represented

by a number or a numbered capital letter. The laser classifications are Class 1, 1M, 2, 2M, 3R, 3B, and 4.

laser-controlled area (LCA). A laser use area where the occupancy and activity of those within is controlled and supervised. This area may be defined by walls, barriers, or other means. Within this area, potentially hazardous exposure is possible.

laser diode. A laser employing a forward-biased semiconductor junction as the active medium.

laser demonstration. A display using a laser or a laser system for teaching purposes or concept development.

laser electro-optic training program. A two-year associate degree program usually taught at a community college or vocational technical school.

laser generated airborne contaminants (LGAC). Airborne contaminants generated when a laser beam of sufficient irradiance or radiant exposure interacts with target materials. The materials include, but are not limited to plastics, metals, ceramics, glasses, wood, and tissue. LGAC may be in the form of gases, vapors, or aerosols and often are a complex mixture of substances in all three states.

laser pointer. A laser or laser system designed or used to specify a discrete point or location such as those lasers used in classroom lectures or for the aiming of firearms. These products are usually Class 1, 2, or 3R.

laser protective barrier. A device used to block or attenuate incident direct or diffuse laser radiation. Laser protective barriers are frequently used during times of service to the laser system when it is desirable to establish a boundary for a controlled laser area.

laser radiation. Highly coherent and, most often, highly collimated radiation emitted by a laser. This should not be confused with ionizing radiation.

laser safety officer (LSO). One who has the authority and responsibility to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards. This individual has the training and experience to administer a laser safety program.

laser system. An assembly of electrical, mechanical, and optical components that includes a laser.

laser teaching laboratory. A laboratory at the high school, undergraduate, or graduate school level devoted to teaching students concepts and techniques using laser or laser systems as the primary tool of instruction.

lecture hall environment. A large room in which there is a well-defined student seating area and a separate demonstration area where an instructor has control of any demonstration that may be presented.

lesson plan. A form of standard operating procedure for the educational environment centered about a learning objective. It is a teacher's detailed description of the sequence of instructions for achieving the desired learning experience, transfer of knowledge, or understanding of the stated objective. A lesson plan is the teacher's guide for running a particular lesson, and it may include the goal (what the students are supposed to learn), how the goal will be reached (the method, procedure) and a way of measuring how well the goal was reached (test, worksheet, or homework). Details will vary depending on the preference of the teacher, subject being covered, and the needs of the students. There may be requirements mandated by the school system regarding the plan, such as safety policies and protocols.

macula. The small uniquely pigmented specialized area of the retina of the eye, which, in normal individuals, is predominantly employed for acute central vision, that is, the area of the best visual acuity.

maintenance. Performance of those adjustments or procedures (specified in the user information provided by the manufacturer, and considered preventative, to maintain optimal performance of the laser system), that are to be carried out by the user to ensure the intended performance of the product. Maintenance does not include *operation* or *service* as defined in this section.

maximum permissible exposure (MPE). The level of laser radiation to which an unprotected person may be exposed without adverse biological changes in the eye or skin.

meter. A unit of length in the International System of Units (SI), defined as the length of a path traversed in vacuum by light during a period of $1/299,792,458$ of a second. A meter is approximately 39.37 inches. Typically, the meter is subdivided into the following units:

- a) centimeter (cm) = 10^{-2} m
- b) millimeter (mm) = 10^{-3} m
- c) micrometer (μm) = 10^{-6} m
- d) nanometer (nm) = 10^{-9} m

monochromatic radiation. Electromagnetic radiation that contains only one or a very narrow range of wavelengths.

nominal hazard zone (NHZ). The space within which the level of the direct, reflected, or scattered radiation may exceed the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the applicable MPE.

nominal ocular hazard distance (NOHD). The distance along the axis of the unobstructed beam from a laser, fiber end, or connector to the human eye beyond which the irradiance or radiant exposure is not expected to exceed the applicable MPE.

non-beam hazards (NBHs). All hazards arising from the presence of a laser system, excluding direct human exposure to direct or scattered laser radiation.

operating instructions. Instructions for the safe use of lasers or laser systems. Such may be supplied by the manufacturer in the user manual, part of a lesson plan with laser safety instructions for an

educational laboratory or included in a demonstration provided by the laser safety officer or the teacher/administrator in charge. Used for all classes of lasers and laser systems.

operation. The performance of the laser or laser system over the full range of its intended functions (normal operation). Operation does not include *maintenance* or *service* as defined in this section.

optical density ($D(\lambda)$ or OD). The logarithm to the base ten of the reciprocal of the transmittance at a particular wavelength: $OD = \log_{10} [1/\tau(\lambda)]$, where $\tau(\lambda)$ is the transmittance at the wavelength of interest. The optical density, attenuation, at a specific wavelength(s) shall be specified for laser protective eyewear (LPE).

optical fiber. Any filament or fiber made of dielectric materials that guides optical radiation, whether or not it is used to transmit signals.

personal protective equipment (PPE). Personal safety protective devices used to mitigate hazards associated with laser use, for example, laser protective eyewear (LPE), protective clothing, and gloves.

point source. For purposes of this standard, a source with an apparent visual angle equal to or less than alpha min ($\alpha_{\min}$), for example, ≤ 1.5 mrad.

power (Φ). The rate at which energy is emitted, transferred, or received.
Unit: watt (W), ($1W=1J\cdot s^{-1}$).

primary school. A school with grades from kindergarten to fifth or sixth grade, depending on the jurisdiction.

procedural control measure. *See:* **administrative control measure.**

protective housing. An enclosure that surrounds the laser or laser system and prevents access to laser radiation above the applicable MPE. The aperture through which the useful beam is emitted is not part of the protective housing. The protective housing limits access to other associated radiant energy emissions and to electrical hazards associated with components and terminals and may enclose associated optics and a workstation.

pulse duration (t). The duration of a laser pulse usually measured as the time interval between the half-power points on the leading and trailing edges of the pulse. *Units:* seconds (s).
Typical units:

- a) microsecond (μs) = 10^{-6} s
- b) nanosecond (ns) = 10^{-9} s
- c) picosecond ps = 10^{-12} s
- d) femtosecond (fs) = 10^{-15} s

pulsed laser. A laser that delivers its energy in the form of a single pulse or a train of pulses. For purposes of this standard, the duration of a pulse is less than 0.25 s.

pupil. The variable aperture in the iris through which light travels to the interior of the eye.

Q-switch. A device for producing very short (~ 10 to 250 ns) intense laser pulses by enhancing the storage and dumping of optical energy in and out of the lasing medium, respectively. The noted pulse durations are nominal, for reference purposes only. The physical construct of the laser can achieve pulse durations slightly outside of these bounds.

Q-switched laser. A laser that emits very short (~ 10 to 250 ns), high peak-power pulses by means of a Q-switch. *See also* *Q-switch*.

radian (rad). A unit of angular measure equal to the angle subtended at the center of a circle by an arc whose length is equal to the radius of the circle. $1 \text{ radian} \sim 57.3 \text{ degrees}$; $2\pi \text{ radians} = 360 \text{ degrees}$.

radiance (L). Power output per unit solid angle per unit area, expressed in watts-per-centimeter squared per-steradian. *Unit:* ($\text{W} \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}$).

radiant energy (Q). Energy emitted, transferred, or received in the form of radiation. *Unit:* joules (J).

radiant exposure (H). Surface density of the radiant energy received, expressed in units of joules-per-square centimeter. *Unit:* ($\text{J} \cdot \text{cm}^{-2}$).

radiant flux. *Syn:* **radiant power**.

radiant power (Φ). Power emitted, transferred, or received in the form of radiation, expressed in watts. *Unit:* (W). *Syn:* **radiant flux**.

reflectance (p). The ratio of total reflected radiant power to total incident power. *Unit:* (dimensionless). *Syn:* **reflectivity**.

reflection. Deviation of radiation back into the original medium following incidence on a surface. The angle of reflection equals the angle of incidence.

refraction. The bending of a beam of light in transmission through an interface between two dissimilar media or in a medium whose refractive index is a continuous function of position (graded index medium).

refractive index (of a medium) (n). The ratio of the velocity of light in a vacuum to the velocity of light in the medium. *Symbol:* n . *Syn:* **index of refraction**.

repetitive pulse laser. A laser with multiple pulses of radiant energy occurring in a sequence.

science fair projects. Projects wherein students use lasers in a generally unsupervised environment and may involve public exposition.

science museums. A public learning environment dedicated to the concept of using hands-on demonstrations, projects, or other learning situations to teach scientific concepts. May also be called halls of science, exploratoriums, or museums of science.

secondary school. A school including grades seven through twelve, including high school grades.

service. The performance of procedures, typically defined as repair, to bring the laser, laser system, or laser product back to full and normal operational status. Service does not include *operation* or *maintenance* as defined in this standard.

shall. The word *shall* is to be understood as mandatory.

should. The word *should* is to be understood as advisory.

source. A laser or a laser-illuminated reflecting surface.

spectator. An individual who observes a laser or laser system in operation, and who may lack the appropriate laser safety training.

specular reflection. A mirror-like reflection.

standard operating procedure (SOP). Formal written description of the safety and administrative procedures to be followed in performing a specific task.

teacher. Any faculty member, instructor, or teaching assistant responsible for the operation of a laser or laser system.

transmission. Passage of radiation through a medium.

transmittance (τ). The ratio of transmitted power (energy) to incident power (energy).
Unit: (dimensionless).

ultraviolet radiation (UV). Electromagnetic radiation with wavelengths between 180 nm and 400 nm (0.18 to 0.4 μm).

university. An institution of higher learning providing facilities for teaching and research and authorized to grant undergraduate and/or graduate degrees.

visible radiation (light). In this standard, the term is used to describe electromagnetic radiation which can be detected by the human eye and lies in the range 400 nm to 700 nm (0.4 to 0.7 μm).

vocational technical school. An institution that provides instruction in a skill or trade that can be used to pursue a career.

watt (W). The unit of power providing the rate of delivery of energy. 1 watt = 1 joule/second.
See: **power.**

wavelength (λ). The distance in the line of advance of a sinusoidal wave from any one point to the next point of corresponding phase, for example, the distance from one peak to the next.

Unit: meter (m).

Typical units:

micrometer (μm) = 10^{-6} m

nanometer (nm) = 10^{-9} m

3. Hazard Evaluation and Classification

3.1 General.

Many lasers and laser systems are used in universities, colleges, secondary, and primary schools for teaching, research, laboratory experiments, demonstrations, and projects/science fairs. Often large numbers of students work in laboratory groups in confined areas, and frequently, different departments share laser systems and installations. It is common to find a variety of lasers of different classes and wavelengths in a single laboratory. Open laser cavities, unrestricted beam paths, and possible specular reflections are also common in these environments. Many of the installations are also capable of producing non-beam hazards, NBHs, such as exposure to chemical, electrical, as well as, optical and plasma radiation hazards (see Section 7).

The following four aspects of the application of a laser or laser system influence the total hazard evaluation and the application of appropriate controls:

- a) The capability of the laser or laser system to injure personnel.
- b) The environment in which the laser is used, including access to the beam path taking under consideration enclosures, baffles, and beam.
- c) The personnel who may use the laser or be exposed to laser radiation.
- d) The interaction of the beam with its intended target.

3.2 Laser and Laser System Hazard Classification.

Lasers and laser systems are classified by the manufacturer in accordance with the FLPPS, 21 CFR Part 1040.10 and 1040.11 as applicable, but may be re-classified in accordance with ANSI Z136.1 (latest revision) when modified. The LSO should ensure that the laser or laser system used in an experimental setting is properly classified; see ANSI Z136.1 for a complete discussion of laser hazard classification. The following is an abbreviated explanation.

Laser hazard classification is based on the accessible laser emission during normal operation. A laser system may contain an embedded laser of a higher class than that of the system, for example, when sufficient engineering controls are in place to reduce the accessible emission and therefore, the class of the system. If it is possible during maintenance or service for the accessible emission to exceed the system class, then controls appropriate for the higher class shall be implemented. If any laser system is modified, the laser safety officer, LSO, shall evaluate the new configuration

and, if necessary, effect the reclassification of the system in accordance with ANSI Z136.1 (latest revision). If a new laser system is constructed, the LSO shall effect an evaluation and classification of the system.

The hazard classes of lasers and laser systems are described below.

3.2.1 Class 1 Lasers or Laser Systems. Class 1 lasers or laser systems are considered incapable of producing damaging laser exposure during operation and are, therefore, exempt from any control measures or other forms of surveillance.

NOTE—A common example of a Class 1 laser system is one that contains an embedded higher-class laser, but during normal operation does not present a laser radiation hazard to the user.

- a) **Class 1M lasers or laser systems** are considered 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). It is, therefore, exempt from any control measures other than to prevent potentially hazardous optically aided viewing.
- b) **Class 1 Conditions:** Frequently, the hazard analysis will define an extremely limited nominal hazard zone, NHZ, and procedural controls can provide adequate protection. Class 1 conditions shall be considered as fulfilled for those limited open beam path lasers or laser systems where analysis, including measurements when necessary, confirms that the accessible levels during operation are at or below applicable maximum permissible exposure, MPE, levels.

3.2.2 Class 2 Lasers or Laser Systems. Class 2 lasers or laser systems (low power) emit in the visible portion of the spectrum, from 400 nm to 700 nm, and eye protection is normally afforded by the aversion response, for example, blinking, pupillary contraction, and moving head. The accessible emission limit, AEL, of a CW Class 2 laser does not exceed 1 mW.

- a) **Class 2M lasers or laser systems** emit in the visible portion of the spectrum, from 400 nm to 700 nm, and eye protection is normally afforded by the aversion response for unaided viewing, but is potentially hazardous if viewed with certain optical aids such as an eye-loupe or a telescope.

3.2.3 Class 3 Lasers or Laser Systems. Class 3 lasers or laser systems (medium power) are divided into two subclasses, Class 3R and Class 3B. A Class 3 laser system may be hazardous to the eye under direct and specular reflection viewing conditions, but the diffuse reflection is usually not a hazard and it is not a hazard to the skin. A Class 3 laser system is normally not a fire hazard.

- a) **Class 3R lasers or laser systems** produce moderate levels of visible or invisible laser radiation and require more stringent controls than Class 1 and 2 lasers. The original intent of this hazard classification was for a semi-controlled environment with a responsible operator for laser emission and the NHZ having restricted access, such as with surveying, leveling and alignment lasers for the construction industry. However, under some direct and specular viewing conditions an individual can sustain an injury if the eye is focused and stable or if optical aids are used. The accessible emission limit of a CW Class 3R visible laser is a factor of 5 greater than for Class 2, equating to 5 mW AEL for a visible

CW laser. For invisible lasers, the accessible emission limit is a factor 5 greater than for Class 1.

- b) **Class 3B lasers or laser systems** may be hazardous under direct and specular viewing conditions but is not normally a diffuse reflection or fire hazard. The AEL of a CW Class 3B visible or invisible laser is nominally 500 mW.

3.2.4 Class 4 Lasers or Laser Systems. Class 4 lasers or laser systems (high power) are a hazard to the eye or skin from the direct beam, and sometimes from a diffuse reflection, and can also be a fire hazard. A Class 4 laser system may also produce laser generated air contaminants, LGACs, and hazardous plasma radiation (see Section 7). Class 4 lasers are those with accessible emission of CW, average power greater than 0.5 W, or visible pulsed lasers that emit more than 30 mJ.

Educational institutions are likely to have lasers and laser systems classified under the former ANSI Z136.1-2000 standard. Table 2 compares the former standard with the current ANSI Z136.1-2014 standard.

Table 2. Comparison of Laser Classifications

ANSI Z136.1 (2000 and prior)	ANSI Z136.1 (2007 and later)	U.S. FDA/CDRH	IEC 60825-1 (2001 and later)
Class 1	Class 1	Class I	Class 1
-	Class 1M	-	Class 1M
Class 2	Class 2	Class II	Class 2
-	Class 2M	-	Class 2M
Class 3a	Class 3R	Class IIIa	Class 3R
Class 3b	Class 3B	Class IIIb	Class 3B
Class 4	Class 4	Class IV	Class 4
NOTE—Hazard classification among these standards is not equivalent in all cases. This table is provided for reference purposes only. ²			

² Notes in text and figures of this standard are given for information only and do not contain requirements needed to implement the standard.

3.3 Optical Fibers.

Optical fibers can be used to transmit laser power to remote or otherwise inaccessible locations. Laser transmission systems that employ optical cables shall be considered enclosed systems with the optical fiber sheath forming part of the enclosure. The beam emerging from an optical fiber usually diverges rapidly. Depending on the power at close range, the output from the end of a fiber may be hazardous. Therefore, the LSO shall determine the conditions under which a hazard could exist. As a general rule, the beam emerging from the fiber should be treated with the same caution as the direct beam from a laser. Because the optical fiber may terminate at some distance from the laser source, the terminal or active end of the fiber optic should be labeled to indicate laser radiation may be present.

NOTE—The requirements and nomenclature for optical fiber systems used for telecommunications, optical fiber communication systems, may differ from those pertaining to laser optical fiber transmission systems used for other purposes, for example, optical power delivery. See ANSI Z136.2 (latest revision) or IEC 60825-2 (latest revision) as applicable for user safety requirements specific to optical fiber systems used for telecommunications.

3.4 Environment in Which the Laser is Used.

In the typical educational institution utilizing lasers, there is often a significant turnover in students and faculty involved with various experiments requiring new and/or modified configurations of the laser system and laboratory. Care must be taken to ensure modified or new laser setups are installed according to the safety requirements indicated in this standard and ANSI Z136.1 (latest revision).

Environments common to educational settings include:

- a) Classrooms.
- b) High school, undergraduate and graduate teaching laser laboratories.
- c) Student projects on-and-off campus such as science fairs, science projects and museums.
- d) Auditorium and lecture hall demonstrations.
- e) Outdoors.
- f) Entertainment activities.

3.4.1 Classroom Environments. Classroom teaching demonstrations incorporating lasers shall be conducted so that the persons in the classroom are not exposed to laser radiation exceeding the MPE as described in Appendix A and ANSI Z136.1 (latest revision). See Section 4.2 regarding control and laser hazard class limits by grade level. Classroom demonstrations/student experiments shall follow an approved laser lesson plan.

3.4.2 Laboratory Environments. There are several distinct laser laboratory environments, each with its own potential laser hazards. These are described below in 3.3.2.1 and 3.3.2.2.

3.4.2.1 Laser Teaching Laboratories. Teaching laboratories are primarily devoted to teaching students new concepts or techniques. Visible lasers should be used exclusively when possible. If invisible lasers are necessary to accomplish the goal of the demonstration/experiment, a visible laser should be used first to assess the setup. In this standard, teaching laboratories that use lasers are grouped into three broad categories:

- a) Undergraduate teaching laboratories are where high-power lasers and many lasers of different wavelengths and classes may be utilized to teach subjects such as photochemistry, materials processing, and biomedicine.
- b) Laser training laboratories are where the focus is on the laser rather than its use as a tool, with the emphasis on operation, alignment, repair, and beam manipulation. These laboratories are commonly found in laser electro-optic technical colleges and schools.
- c) Introductory teaching laboratories are typically where large numbers of students perform standard experiments during a fixed time period. Examples include high school science, physics, chemistry laboratories, and/or college physics including fundamental optics as well as photonics laboratories. Lasers are usually used as measurement tools, as light sources for optical experiments, or in communication experiments.

Occasionally, a laser teaching laboratory does not fit into one of these broad categories. In such cases, the LSO shall evaluate the environment on an individual basis and determine safe operating procedures. When used as laser pointers, additional cautionary instructions should be provided.

Where the senior grades of secondary schools have experimental goals necessitating the use of a Class 3B laser, the lesson plan shall include appropriate control measures, approved by the LSO, so that exposure conditions are below the applicable MPE.

A Class 4 laser, typically used for industrial, scientific, military, and medical applications, can cause permanent eye damage and can burn skin. Given the serious risk posed, engineering control measures are typically required to provide safe conditions for affected persons.

3.4.2.2 Graduate Teaching Laser Laboratories. The typical graduate teaching laboratory using lasers or laser systems poses many challenges to the LSO and area personnel that may not be present in other laser teaching laboratories. They should follow the requirements of ANSI Z136.8 (latest revision). The following are some situations one might observe in such an environment and their related safety implications:

- a) Some teaching laboratories have student desks and workstations near the laser equipment.
- b) The personnel may be students or staff with no experience with the kinds of lasers they are expected to operate.
- c) Graduate teaching laboratories often have visitors and visiting faculty who may not be familiar with lasers and laser equipment.
- d) The laser and other equipment may be shared, that is, several persons may operate a single laser on a “time share” basis. There are usually no guidelines on how a system should be transferred to another teacher, professor, or student.
- e) There are often several types of lasers situated in one laboratory, each of which may pose different safety concerns. One might find, for example, an argon laser, mode-locked Nd:YAG, dye laser system, and an excimer laser in use in a single laboratory.

3.4.3 Lecture Hall Environments. Lecture halls usually have a well-defined demonstration area where the teacher has control. The seating area is separate from the demonstration area and observers remain in their seats (see Figures E1 through E6 in Appendix E). Potential hazards in

this environment include the entry of observers into the demonstration area and the misdirection or reflection of the beam.

3.4.4 Science Fair and Projects. Science fairs, technical challenges, science expositions, and other types of competitions present environments in which lasers used in student projects may create serious hazards because the audience is largely unsupervised. These events and projects should normally be limited to lasers that have emissions in the visible wavelength range of 400 nm to 700 nm. Because of the nature of such events, the lack of experience or training dictates that Class 3B and 4 lasers or laser systems shall not be operated during the public phases where outside spectators are present. Lasers should only be used when their unique properties are necessary to demonstrate an objective or learned principle. The beam(s) shall be terminated within the exhibit booth. Even Class 1 beams may be dazzling and create unwarranted fears.

An LSO from the students' educational institution shall be appointed before work has begun for the event and shall be available to answer questions about laser safety and ensure that proper controls are used by the students during the development of the project. The educational institution sponsoring the event shall appoint an LSO who is familiar with the controls specified in Section 4, can answer safety questions while the students are working on their projects during the event, and can review each setup that involves lasers.

3.4.4.1 Construction and Testing of a Project Containing a Laser. Potential hazards to the student, and any associates who may be present, may exist during the construction phase of the laser project. Therefore, the project, if under the sponsorship of an educational institution, shall be reviewed by the LSO of the institution. Individual projects shall be incorporated into the general safety program of the school and, if possible, only Class 1, 1M, 2, 2M, and/or 3R lasers should be used for projects. Class 3B and 4 lasers should only be used if the increased power is essential for the projects.

3.4.4.2 Public Demonstration of Projects. Projects using Class 3B and 4 lasers shall meet the requirements of the Center for Devices and Radiological Health, CDRH, for public laser displays. Projects using Class 1, 1M, 2, 2M, and 3R lasers may be operated under the continuous supervision of the students if the operation does not conflict with the instructions mandated for the event by the LSO.

3.5 Laser Pointers.

Laser pointers are very popular and inexpensive. These 1 mW to 5 mW visible lasers, usually labeled with a danger label, can present an eye hazard when used as an instrument of harassment. Laser pointers are intended only for educational purposes, for example, in lectures and demonstrations. These devices shall only be used for their intended purpose by individuals who are aware of the safety hazards. The LSO should be aware that some laser pointers exceed 5 mW Class 3R limits and might be mislabeled as Class 2 or 3R laser products.

NOTE—Many municipalities have either banned, or have considered banning, the sale of laser pointers to minors or have considered the levying of fines when they are used for other than their intended purpose.

3.6 Common Causes of Laser Accidents.

Laser safety training should inform regarding the most common causes of laser accidents, which are:

- a) Unanticipated eye and skin exposure during alignment.
- b) Misaligned optics and misdirected beams.
- c) Laser protective eyewear, LPE, not used or not available.
- d) Equipment malfunction.
- e) Intentional exposure of unprotected personnel.
- f) Operators unfamiliar with laser equipment.
- g) Lack of protection for ancillary, non-beam, hazards, NBHs.
- h) Improper restoration of equipment following service.
- i) Failure to have or follow Standard Operating Procedures, SOPs.
- j) Improper methods of handling high voltage.
- k) Incorrect eyewear worn for the lasers in use.
- l) Inhalation of laser generated air contaminants, LGACs.
- m) Unprotected viewing of laser generated plasmas.
- n) Fires resulting from the ignition of materials.
- o) Eye or skin injury of photochemical origin.
- p) Unanticipated exposure during usage.

4. Control Measures

4.1 General Considerations.

Control measures shall be implemented to minimize the possibility of exposure of the eye and skin to hazardous levels of laser radiation, and to minimize other hazards associated with laser devices during operation, maintenance, and service (see Tables 3, 4, 5, and Appendix B for a summary of control measures).

4.1.1 Overview of Control Measure Requirements. In most cases, the requirements for control measures can be specified based on the hazard classification of the laser radiation that is accessible during the operation, maintenance, or service of the laser product. However, in specific cases, additional laser information is needed to effectively specify the performance or effectiveness of certain control measures. The list below briefly describes what control measures are required and when additional information may be needed.

4.1.1.1 Class 1 Laser System. This system is exempt from any control measures for laser radiation except for conditions of an embedded Class 3B or Class 4 laser.

4.1.1.2 Class 1M Laser System. This system is exempt from any control measures except for conditions of:

- a) Optically aided direct viewing of the beam, and/or
- b) Unattended operation where the beam is directed into a location where it can be directly viewed by the general public and/or personnel that may be uninformed about the hazards.

4.1.1.3 Class 2 Laser System. This system requires an equipment label, but is exempt from any control measures except for conditions of:

- a) Intentional direct viewing of the beam that is prohibited in this standard,
- b) When there is a need to mitigate visual interference effects, and
- c) Unattended operation with the beam directed into a location where it can be directly viewed either by the general public or other personnel who may be uninformed about its hazards.

4.1.1.4 Class 2M Laser System. This system requires an equipment label, but is exempt from any control measures except for conditions of:

- a) Intentional direct viewing of the beam, and/or
- b) Potentially hazardous optically aided viewing,
- c) When there is a need to mitigate visual interference effects, and
- d) Unattended operation with the beam directed into a location where it can be directly viewed either by the general public or other personnel who may be uninformed about its hazards.

4.1.1.5 Class 3R Laser System. This system requires an equipment label, but is exempt from any control measures or other forms of surveillance except for conditions of:

- a) Direct viewing of the beam or its specular reflection,
- b) When there is a need to mitigate visual interference effects, and
- c) Unattended operation with the beam directed into a location where it can be directly viewed either by the general public or other personnel who may be uninformed about its hazards

4.1.1.6 Class 3B Laser System. This system requires the approval of appropriate control measures by the LSO to reduce the risk of hazardous exposure to the eye from a direct or specularly reflected beam. In some cases, control measures may also be required to prevent access to hazards from a diffuse reflection or fire hazard.

4.1.1.7 Class 4 Laser System. This system requires the approval of appropriate control measures by the LSO to reduce the risk of a hazardous exposure to the eye or skin from a direct, specularly reflected, or diffusely reflected beam. Control measures may also be required for potential fire hazards and other NBHs such as LGAC and hazardous plasma radiation (see Section 7).

Table 3 summarizes when additional control measures are necessary for the laser hazard class exposure condition.

Table 3. Controls Requirements

Laser Class	Engineering Controls	Procedural & Administrative Controls	Personal Protective Equipment	Training	Laser Safety Officer
1	Not Required ^a	Not Required ^a	Not Required ^a	Not Required ^a	Not Required ^a
1M	Application Dependent ^b	Required	Not Required	Application Dependent ^b	Application Dependent ^b
2	Not Required ^c	Not Required ^c	Not Required ^c	Not Required ^c	Not Required ^c
2M	Application Dependent ^b	Required	Not Required	Application Dependent ^b	Application Dependent ^b
3R	Not Required ^c	Not Required ^c	Not Required ^c	Not Required ^c	Not Required ^c
3B	Required	Required	Required	Required	Required
4	Required	Required	Required	Required	Required
NOTE—During maintenance and service, the classification associated with the maximum level of accessible laser radiation shall be used to determine the applicable safety control measures.					

^a Control measures are not required during operation and maintenance of a Class 1 laser system with the protective housings and interlocks in place. However, alignment and service procedures of an embedded Class 1M, 2, 2M, 3R, 3B, or 4 lasers shall require controls or administrative procedures appropriate to the laser class during these functions if the higher-class laser radiation is accessible.

^b Certain uses of Class 1M or 2M lasers or laser systems that exceed Class 1 or 2, because they do not satisfy measurement Condition 1, may require hazard evaluation and/or manufacturer's information (see Z136.1-2014, Section 3.2.3).

^c This standard does not permit conditions of intentional intra-beam exposure applications. Additional control measures may be required to mitigate visual interference effects.

Additional control and regulatory compliance measures may be required for unattended operation with the beam directed into a location where it can be directly viewed either by the general public or other personnel who may be uninformed about the hazard potential.

The LSO shall have the authority to effect the knowledgeable evaluation and control of laser hazards, to monitor and enforce the control of laser hazards, and to audit the appropriate controls summarized in Tables B1 and B2 in Appendix B.

For all uses of lasers and laser systems, the minimum laser radiation required for the application should be used. The laser beam height should also be maintained at a level other than the normal position of the eye of a person in the standing or seated position.