American National Standard

ANSI Z136.8 – 2012

American National Standard for Safe Use of Lasers in Research, Development, or Testing

Laser Institute of America
Laser Applications and Safety

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First Printing

American National Standard for Safe Use of Lasers in Research, Development, or Testing

Secretariat
Laser Institute of America

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American National Standard

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Foreword

(This introduction is not a normative part of ANSI Z136.8-2012, *American National Standard for Safe Use of Lasers in Research, Development, or Testing.)*

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, or 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 and Training
TSC-5	Non-Beam Hazards
TSC-7	Analysis and Applications
EWG	Editorial Working Group

The seven standards currently issued are:

ANSI Z136.1-2007, *American National Standard for Safe Use of Lasers* (replaces ANSI Z136.1-2000)

ANSI Z136.3-2011, *American National Standard for Safe Use of Lasers in Health Care* (replaces ANSI Z136.3-2005 *American National Standard for Safe Use of Lasers in Health Care Facilities*)

ANSI Z136.4-2010, *American National Standard Recommended Practice for Laser Safety Measurements for Hazard Evaluation* (replaces ANSI Z136.4-2005)

ANSI Z136.5-2009, *American National Standard for Safe Use of Lasers in Educational Institutions* (replaces ANSI Z136.5-2000)

ANSI Z136.6-2005, *American National Standard for Safe Use of Lasers Outdoors* (replaces ANSI Z136.6-2000)

ANSI Z136.7-2008, *American National Standard for Testing and Labeling of Laser Protective Equipment* (first edition)

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

This American National Standard is intended to ensure the safe use of lasers in research, development, or testing environments, and has been published as part of the ANSI Z136 series of laser safety standards. The base document of the series is the American National Standard for Safe Use of Lasers, ANSI Z136.1. The procedures and methodologies described in this standard are based on requirements previously established in ANSI Z136.1 and are intended to give more specific processes for accomplishing laser safety in a research, development, or testing settings. The purpose of this standard is to give more specific user guidance for accomplishing laser safety for individuals with the potential for laser exposure in the research, development, or testing setting. It should be recognized that the scope of the ANSI Z136.8 includes all circumstances when people may be exposed to laser radiation as part of research, development, and testing applications. This standard includes policies and procedures to ensure laser safety in any area where research, development, and testing is performed, including Universities, product development labs, private and government research labs (e.g., National Laboratories), and product testing settings. In general, this standard may be used independently of ANSI Z136.1; however, instances where additional guidance contained in ANSI Z136.1 is required are noted in the text of this document. The body of this standard is a normative standard that applies to all research, development, and testing settings that use lasers. The appendices, excluding Appendix A, are informative providing examples and discipline specific supplementary information.

It is expected that this standard will be periodically revised as new information and experience in the use of lasers are gained. Future revisions may have modified content 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 Z136 standards represent a consensus of concerned interests, it is important to ensure that any interpretation has also received the concurrence of a balance of interests. For this reason, the secretariat is not able to provide an instant response to interpretation requests except in those cases where the matter has previously 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 processed and approved for submittal to ANSI by ASC Z136. Committee approval of the standard does not necessarily imply that all members voted for its approval.

Robert Thomas, Committee Chair
Sheldon Zimmerman, Committee Vice-Chair
Ben Edwards, Committee Secretary

Notice (This notice is not a normative part of ANSI Z136.8-2012, *American National Standard for Safe Use of Lasers in Research, Development, or Testing.)*

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 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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Contents

SECTION PAGE

Figures

SECTION PAGE

or a numbered capital letter. The laser classifications are Class 1, Class 1M, Class 2, Class 2M, Class 3R, Class 3B, and Class 4. In general, the potential beam hazard level increases in the same order.

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

laser personnel. Persons who routinely work around hazardous laser beams. This standard requires such persons to be protected by engineering controls and administrative procedures.

laser pointer. A laser product that is usually hand held that emits a low-divergence visible beam and is intended for designating specific objects or images during discussions, lectures, or presentations as well as for the aiming of firearms or other visual targeting practice. These products are normally Class 2 or Class 3R.

laser safety officer (LSO). One who has authority and responsibility to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards.

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

lesion. An abnormal change in the structure of an organ or part due to injury or disease.

limiting angular subtense. See *alpha min*.

limiting aperture diameter. The diameter of a circle over which irradiance or radiant exposure is averaged for purposes of hazard evaluation and classification. Symbol: D_f

limiting cone angle. The cone angle through which radiance or integrated radiance is averaged when photochemical effects are considered in hazard evaluation and classification. Symbol: γ

limiting exposure duration. An exposure duration that is specifically limited by the design or intended use(s). Symbol: T_{max}

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

magnified viewing. Viewing a small object through an optical system that increases the apparent object size. This type of optical system can make a diverging laser beam more hazardous (e.g., using a magnifying optic to view an optical fiber emitting a laser beam).

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. It 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.

measurement aperture. The aperture used for classification of a laser to determine the effective power or energy that is compared with the AEL for each laser hazard class.

meter. A unit of length in the international system of units; currently defined as the length of a path traversed in a vacuum by light during a period of 1/299792458 seconds. Typically, the meter is subdivided into the following units:

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

minimum viewing distance. The minimum distance at which the eye can produce a focused image of a diffuse source, usually assumed to be 10 cm.

monochromatic light. Having or consisting of one color or wavelength.

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 appropriate 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 hazard. A class of hazards that result from factors other than direct human exposure to a laser beam.

normative appendix. An appendix that contains information required to implement the standard and is therefore officially part of the standard. Normative appendixes are placed after the body of the standard for reasons of convenience or to create a hierarchical distinction.

ocular fundus. The concave interior of the eye consisting of the retina, the choroid, the sclera, the optic disk, and blood vessels as seen upon ophthalmoscopic examination.

OEM. Original equipment manufacturer.

open beam path. A laser beam path where any portion of the beam is accessible without defeating an engineering control.

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

ophthalmoscope (funduscope). An instrument for examining the interior of the eye.

optically aided viewing. Viewing with a telescopic (binocular) or magnifying optic. Under certain circumstances, viewing with an optical aid can increase the hazard from a laser beam. See *magnified viewing* and *telescopic viewing*.

optical density. The logarithm to the base ten of the reciprocal of the transmittance at a particular wavelength:

$$OD = \log_{10} (1/\tau_\lambda)$$

where τ_λ is the transmittance at the wavelength of interest. Symbol: OD, $D(\lambda)$, or D_λ

photochemical effect. A biological effect produced by a chemical action brought about by the absorption of photons by molecules that directly alter the molecule.

photosensitizers. Substances that increase the sensitivity of a material to exposure by optical radiation.

pigment epithelium (of the retina). The layer of cells that contain brown or black pigment granules next to and behind the rods and cones.

plasma radiation. Black-body radiation generated by luminescence of matter in a laser generated plume.

point source. For purposes of this standard, a source with an angular subtense at the cornea equal to or less than alpha-min (α_{min}), i.e., ≤ 1.5 mrad.

point source viewing. The viewing condition whereby the angular subtense of the source, α, is equal to or less than the limiting angular subtense, α_{min}.

power. The rate at which energy is emitted, transferred, or received. Unit: watts (W); 1 watt = 1 joule-per-second.

procedural controls. Methods or instructions that specify rules, or work practices, or both, that implement or supplement engineering controls and which may specify the use of personal protective equipment.

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. 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. Typical units:

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

Symbol: t

pulse-repetition frequency (PRF). The number of pulses occurring per second, expressed in hertz. Symbol: F

pulsed laser. A laser that delivers its energy in the form of a single pulse or a train of pulses. In 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 (~10-250 ns), intense laser pulses by enhancing the storage and dumping of energy in and out of the lasing medium, respectively.

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

radian (rad). A unit of angular measure equal to the angle subtended at the center of the circle by an arc whose length is equal to the radius of the circle (sr). 1 radian ~ 57.3 degrees; 2π radians = 360 degrees.

radiance. Radiant flux or power output per unit area per unit solid angle expressed in watts-per-centimeter squared per-steradian ($W \cdot cm^{-2} \cdot sr^{-1}$). Symbol: L

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

radiant exposure. Surface density of the radiant energy received. Unit: joules-per-centimeter squared ($J \cdot cm^{-2}$). Symbol: H

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

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

radiometry. For the purposes of this standard, the measurement of infrared, visible, and ultraviolet radiation.

reflectance. The ratio of total reflected radiant power to total incident power. Also called "reflectivity."

reflection. Deviation of radiation following incidence on a surface.

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). The ratio of the velocity of light in a vacuum to the phase velocity in the medium. Symbol: n

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

restricted location. An area where access is granted for authorized people and limited for the general public through administrative and engineering control measures. Laser radiation hazards at Class 3B levels or greater may be present and control measures are required. Administrative controls include posted warning signs, attending training, and following established standard operating procedures (SOPs) for laser system(s). Engineering controls include access control measures such as lockable doors, barriers, defeatable interlocks, and curtains to prevent laser radiation from leaving the restricted location.

retina. The sensory tissue that receives the incident image formed by the cornea and lens of the human eye.

retinal hazard region. Optical radiation with wavelengths between 400 and 1400 nm, where the principal hazard is usually to the retina.

safety latch. A mechanical device designed to require a conscious decision to override to gain entry into a controlled area.

scanning laser. A laser having a time-varying direction, origin, or pattern of propagation with respect to a stationary frame of reference.

scintillation. The rapid changes in irradiance levels in a cross-section of a laser beam.

secured enclosure. An enclosure to which casual access is impeded by an appropriate means, e.g., a door secured by a magnetically or electrically operated lock or latch, or by fasteners that need a tool to remove.

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

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

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

solid angle. The three-dimensional angular spread at the vertex of a cone measured by the area intercepted by the cone on a unit sphere whose center is the vertex of the cone. Unit: steradian (sr).

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

spectator. An individual who wishes to observe or watch a laser or laser system in operation, and who may lack the appropriate laser safety training.

specular reflection. A mirror-like reflection.

steradian (sr). The unit of measure for a solid angle. There are 4π steradians about any point in space.

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

T_1. The exposure duration (time) at which MPEs based upon thermal injury are replaced by MPEs based upon photochemical injury to the retina.

T_2. The exposure duration (time) beyond which extended source MPEs based upon thermal injury are expressed as a constant irradiance.

T_{max}. The total expected or anticipated exposure duration. T_{max} may differ depending upon its use.

telescopic viewing. Viewing an object from a long distance with the aid of an optical system that increases the visual size of the image. The system (e.g., binoculars) generally collects light through a large aperture thus magnifying hazards from large-beam, collimated lasers.

testing. The act of measurement, evaluation, verification or assessment of any properties or parameters of a laser or laser system, i.e., life time test or beam specifications.

thermal effect. An effect brought about by the temperature elevation of a substance due to laser exposure.

threshold limit (TL). An expression of the "resistance factor" for beam penetration of a laser protective device, i.e., the maximum average irradiance or radiant exposure at a given beam diameter for which a laser protective device provides adequate beam resistance. Thus, laser exposures delivered on the protective device (e.g., laser protective eyewear filters, protective windows, and barriers) at or below the TL will limit beam penetration to levels at or below the applicable MPE. Unit: $W \cdot cm^{-2}$ or $J \cdot cm^{-2}$.

t_{min}. For a pulsed laser, the maximum duration for which the MPE is the same as the MPE for a 1 ns exposure. For thermal biological effects, this corresponds to the "thermal confinement duration" during which heat flow does not significantly change the absorbed energy content of the thermal relaxation volume of the irradiated tissue.

transmission. Passage of radiation through a medium.

transmittance. The ratio of transmitted power (energy) to incident power (energy).

ultraviolet radiation. In this standard, electromagnetic radiation with wavelengths between 180 and 400 nm (wavelengths shorter than those of visible radiation).

uncontrolled area. An area where the occupancy and activity of those within is not subject to control and supervision for the purpose of protection from radiation hazards.

unrestricted location. An area where access is not limited. By default, no laser radiation hazards exist (Class 1), and these locations can be occupied by the general public, visitors, and spectators without implementing control measures (administrative, engineering, and personal protective equipment).

viewing window. A visually transparent part of an enclosure that contains a laser process. It may be possible to observe the laser processes through the viewing window(s).

visible radiation (light). The term is used to describe electromagnetic radiation that can be detected by the human eye. In this standard, this term is used to describe wavelengths that lie in the range 400 to 700 nm. Derivative standards may legitimately use 380 – 780 nm for the visible radiation range.

watt (W). The unit of power or radiant flux. 1 watt = 1 joule-per-second.

wavelength. The distance in the line of advance of a sinusoidal wave from any one point to the next point of corresponding phase (e.g., the distance from crest to crest or trough to trough).

work practices. Procedure(s) used to accomplish one or more tasks.

3. Hazard Evaluation and Classification

3.1 General.

A laser controlled area (LCA) is any area, permanent or temporary, that contains hazardous laser operations. Hazards associated with the laser operation must be evaluated and mitigated by the use of appropriate control measures at the boundaries of and within the LCA. Several aspects of the laser or laser system application influence the total laser hazard evaluation and the application of control measures to the laser, the equipment, and the people. In research, development, or testing environments, these aspects consist of:

a) The capability of the laser or laser system to injure people.

b) The beam path (e.g., in air or vacuum), its configuration (e.g., open beam, fiber optic, level of enclosure) and the factors applied to beam (e.g., non-linear optics, pulse compression, or amplification).

c) Process interactions between the beam and materials during operation, e.g., rapid oxidation, ionizing radiation or laser generated air contaminants (LGACs).

d) The location in which the laser is used (i.e., unrestricted, restricted, controlled, inaccessible, or exclusion).

e) The personnel who may use or be exposed to laser radiation.

3.2 Laser Beam Path.

In the research, development, or testing setting, the parameters of the laser beam may change along its beam path. Therefore, any hazard evaluation will need to consider such changes. This can include changes in wavelength, pulse duration and accessibility to the beam.

3.2.1 Nominal Hazard Zones. The nominal hazard zone (NHZ) is that region identified and confined within the LCA in which the irradiance or radiant exposure of the laser beam may exceed the MPE. The NHZ may be the entire LCA. Every effort should be made to contain the NHZ to a smaller sub-area within the LCA using engineering controls, such as perimeter guards, enclosures, beam blocks, barriers, and curtains. When the NHZ is smaller than the LCA, the NHZ should be clearly identified and have appropriate labels or signs. The LSO may specify the implementation of control measures to protect personnel from exposure to laser radiation above the MPE within the NHZ. Calculations may indicate the NHZ is either smaller or larger than the actual LCA; for ease of operation the LSO can then define the LCA as the NHZ. The LSO shall use one of the following methods to define the NHZ:

3.2.1.1 If the laser radiation is contained within a specific location, then the specific location is defined as the NHZ.

3.2.1.2 Based upon calculations utilizing: 1) the appropriate laser range equations, and 2) the performance specifications provided by the laser or laser system manufacturer, the NHZ can be defined.

3.2.1.3 Declare the entire use area and all locations contained within as the NHZ. Control measures are required within the NHZ, which may include fully enclosing the NHZ when this area is limited in size (see Section 4.3.10 of ANSI Z136.1-2007). Viewing the main beam or a specular laser target with an optical instrument is potentially hazardous due to the instrument's light-gathering capability (see Appendixes B4.2, B6.4.3, and B6.6.3; and Examples 22-24, 45, and 53 in ANSI Z136.1-2007). Therefore, the use of such optical systems may effectively increase the NHZ boundaries and must be considered in the overall hazard analysis.

3.2.2 Indoor Laser Operations. The laser and beam path are considered when evaluating an indoor laser operation whether the beam is enclosed or operated in a restricted or controlled location. Consider all optics (e.g., lenses, mirrors, fiber optics) that are a permanent part of the beam path in this evaluation. The LSO in conjunction with the user should follow the step-by-step procedure described below when evaluating the NHZ for indoor use:

Step 1. Determine and evaluate all possible beam paths and reflections. Include multiple beam paths due to lack of fixed positioning and unintended beam paths due to unstable mounts, bearing wear, vibration and re-alignment, for example.

Step 2. Check for and contain stray reflections.

Step 3. Determine the likelihood for operation or maintenance personnel being within the LCA during operation.

Step 4. Determine whether optical aids such as eye loupes or hand magnifiers will be used within 10 cm of a highly diverging beam.

Step 5. Determine whether non-beam hazards exist.

3.2.3 Outdoor Laser Operations. Define the extent of several potentially hazardous conditions by considering all optics that are a permanent part of the beam path. The LSO should consider the guidance found in ANSI Z136.6 and follow the step-by-step procedures given below in steps 1 through 8.

Step 1. Determine the NHZ of the laser. Calculations of radiant exposure or beam irradiance as a function of range can be made with the range equation (an example can be found in Appendix B of ANSI Z136.1).

These calculated ranges are only estimates beyond a few hundred meters, since uncertainties arise from atmospheric effects (for example, scintillation due to turbulence).

Step 2. Evaluate potential hazards from transmission through windows and specular reflections. Specular surfaces ordinarily encountered (for example, windows and mirrors in vehicles and windows in buildings) are oriented vertically and will usually reflect a horizontal beam in a horizontal plane.

NOTE—As much as 8% of the beam's original irradiance or radiant exposure can be reflected toward the laser from a clear glass window that is oriented perpendicular to the beam. If the beam strikes a flat, specular surface at an angle, a much greater percentage of the beam can be reflected beyond, or to the side of, the target area. If the beam strikes a still pond or other similar surface at a grazing angle, effective reflectivity also may approach 100%. Specular reflective surfaces, such as raindrops, wet leaves, and most other shiny natural objects, seldom reflect hazardous radiant intensities beyond one meter from these reflectors.

Step 3. Determine whether hazardous diffuse reflections exist (see Table 3 and Examples 47 - 55 in Appendix B6.6 in ANSI Z136.1-2007). Determine the corresponding NHZ.

Step 4. Determine whether the beam will visually interfere with critical tasks. Refer to ANSI Z136.6 for more information on operation of visible laser systems outdoors at night.

Step 5. Evaluate the stability of the laser platform to determine the extent of lateral range control and the lateral constraints that should be placed on the beam traverse. Determine the corresponding NHZ during operation.

Step 6. Consider the likelihood of people being in the NHZ.

Step 7. Determine whether optical aids such as telescopes or binoculars could be used within or near the beam path.

Step 8. Determine if visible lasers will be used near airports at night. Levels of laser irradiance as low as 50 $nW \cdot cm^{-2}$ may be of concern. Refer to ANSI Z136.6 for the most complete guidance or the latest revision of FAA Order 7400.2 for additional guidance.

3.3 Laser Process Interactions.

In research, development, or testing, the target of laser radiation may produce non-beam hazards (ionizing radiation, LGAC). These hazards may be contained in an experimental chamber or extend beyond the target area. Awareness of such hazards and their appropriate controls shall be implemented. See section 7 – non-beam hazards for details.

3.4 Laser Use Location.

The decision by the LSO to employ additional control measures not specifically required in Section 4 of this standard, or to eliminate some that are, is influenced by location considerations for Class 3B and Class 4 lasers or laser systems. The following defines the terms and conditions for each Class 3B or Class 4 laser location:

a) Unrestricted location: Access is not limited. By default, no laser radiation hazards exist (Class 1), and these locations can be occupied by the general public, visitors, and spectators without implementing administrative or engineering control measures, and personal protective equipment (PPE).

   Example: A hallway in a building containing Class 3B and/or Class 4 lasers.

b) Restricted location: Access is granted for authorized people and limited for the general public through administrative and engineering control measures. Laser radiation hazards at Class 3B levels or greater may be present and control measures are required. Administrative controls include posted warning signs, attending training, and following established SOPs for laser system(s). Engineering controls include access control measures such as lockable doors, barriers, defeatable interlocks, and curtains to prevent laser radiation from leaving the restricted location.

   Example: A research laboratory containing Class 3B and/or Class 4 lasers.

c) Controlled location: Access, occupancy, and activities of people within are subject to strict control and supervision. By inference, controlled locations are restricted locations with laser radiation hazards at Class 4 with additional control measures specified by the laser operator, the LSO, and the employer management.

   Example: A R&D area with positive access control and video surveillance.

d) Exclusion location: Occupancy by people is possible, but is denied by the LSO during the operation of the laser system.

   Example: A free electron laser machine room or beam path.

e) Inaccessible location: Occupancy is not possible due to its dimensions.

   Example: An enclosed beam path on an optical table.

An evaluation at each location should consider the probability of personnel exposure to hazardous laser radiation and each may be influenced by whether the laser is used indoors or outdoors. If exposure of unprotected personnel from the primary beam or from specular reflections of the beam is possible, then the LSO shall determine the irradiance or radiant exposure for the primary beam, or specular reflection of the beam as an extended source, at the location(s) of possible exposure (see Appendix B in ANSI Z136.1).

3.5 Personnel.

The LSO must consider the people who may be in the vicinity of the laser and its emitted beams, and whether or not to adopt additional control measures.