

American National Standard

*American National Standard
for Safe Use of Lasers Outdoors*



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



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Revision of
ANSI Z136.6-2005

**American National Standard
for Safe Use of Lasers Outdoors**

Secretariat
Laser Institute of America

Approved October 5, 2015
American National Standards Institute, Inc.

**American
National
Standard**

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American National Standard for Safe Use of Lasers Outdoors

1. General

1.1 Scope.

This standard provides guidance for the safe use of potentially hazardous lasers and laser systems (180 nm to 1 mm), in outdoor environments. It also provides guidance for controlling disability glare from exposure to non-injurious levels of visible laser light (see Appendix D), which might interfere with sensitive or critical tasks, and guidance for the manufacturers of these open-beam laser systems. Lasers used for fixed, terrestrial point-to-point free-space optical telecommunications are not covered in this document.

1.1.1 Visual Interference. Visible laser beams used outdoors, especially at night, for display and other purposes may need additional control measures to protect persons potentially exposed to hazards associated with bright light. These hazards include transient visual and psychological effects of laser beams such as afterimage, glare, and startle. These effects can produce indirect safety hazards when people are performing critical visual tasks. Examples of critical tasks include, but are not limited to, operating heavy equipment or motor vehicles, piloting aircraft, or facilitating control tower activities. The FAA Modernization and Reform Act of 2012 made it a federal felony to knowingly point the beam of a laser pointer at an aircraft. Illumination of an aircraft by a visible laser beam may cause interference with the flight crew, which is in violation of federal and/or state law. Therefore, as a general policy, it is recommended never to point or direct visible laser beams at aircraft that may exceed the visual interference levels defined in Table 4¹ and/or the respective Class 1 MPE found in ANSI Z136.1.

For purposes of this standard, visible radiation effects are assumed to occur in the spectral region from 380 nm to 780 nm. The exact divisions between visible and invisible radiation depend on the spectral sensitivity of the individual and other considerations (see Appendix H). Spectral ranges such as 400 nm to 700 nm or 380 nm to 780 nm are defined for convenience and should not be considered as precise delineations between visible and invisible. This standard addresses biological effects, both on vision impairment and on actual injury potential from optical radiation. For the consideration of temporary visual effects, the spectrum of 380 nm to 780 nm is used.

1.1.2 Product Performance Standards. Laser systems, which may be used outdoors, that meet the U.S. Federal Laser Product Performance Standard, Title 21 Code of Federal Regulations 1040 (21 CFR 1040), herein referred to as the FLPPS, can be considered as meeting the product performance requirements of this standard. The Food and Drug Administration's Center for Devices and Radiological Health (FDA/CDRH), which administers the FLPPS, has issued a guidance document, Laser Notice 50, that describes the conditions under which laser product manufacturers may introduce into United States commerce laser products that comply with the

¹ There are a few legitimate applications where aircraft may be targeted with visible laser light that exceeds the levels defined in Table 4, such as rescue operations.

International Electrotechnical Commission (IEC) standards 60825-1, as amended, and 60601-2-22. The FDA/CDRH may require additional or alternate safety control measures in the variance or exemption. This Standard identifies such alternate measures in 4.3.4.

1.1.3 Federal Variance or Exemption. Provisions are provided in the FLPPS (21 CFR 1010.4) which give the FDA/CDRH authority to grant variances and exemptions from specific parts or all of the requirements of the standard. Variances and exemptions can only be granted when specific alternative conditions are met and can only be used after the FDA/CDRH has approved them. This standard provides guidance for those systems that have received a variance or an exemption from some of the product performance requirements of the FLPPS. Alternate safety features are provided in this standard. Some additional product performance safety features for outdoor laser systems that could be required by the LSO are included in 4.3.4. This standard also addresses outdoor laser applications that do not require an FDA/CDRH variance and the outdoor use of lasers that may not have been originally intended for outdoor use.

1.1.4 U.S. Department of Defense (DoD) Laser Purchases. A laser hazard evaluation approved by the appropriate authority for each purchasing Service is required for all DoD laser systems intended for outdoor use. The DoD purchasing authority may apply the DoD exemption to the federal requirements of FLPPS if the intended use meets appropriate criteria (see Section 6 for alternate criteria).

1.2 Intended Use of this Standard.

This standard is intended as a guide for designers, users, and operators of lasers or laser systems that are used outdoors. It provides specific information for hazard evaluation, implementation of control measures, and education. It also provides uniform guidance for users and managers of laser systems in establishing standard operating procedures (SOPs) and protocols for Class 3B and Class 4 lasers (see Appendix A for sample SOPs). General guidelines for laser safety and hazard assessment can be found in ANSI Z136.1.²

Differences in sensitivity to optical radiation among individuals and anticipation of unusual situations are recognized in this standard. Hazard evaluation is based on the potential of the laser to produce injury or adverse effects. Control measures are intended to help prevent hazardous exposures to people through recognized and accepted safety practices, and are not usually based on the probability of exposure or injury.

1.3 Coordination.

1.3.1 FDA. Laser product manufacturers are required by federal law to report and certify their products with the FDA. Laser products that comply with the FLPPS and are not used for display do not require an FDA/CDRH variance to be used outdoors. However, a variance is required for all Class 3B and Class 4 outdoor laser demonstration products. Some government agencies have exemption agreements with FDA that require independent design, labeling, and reporting requirements (see 1.1.3). For further information, visit <http://www.fda.gov>.

² When the year of publication is shown (e.g., ANSI Z136.1-2014), the reference is to that specific standard; when the year of publication is not shown, the reference is to the latest revision of that standard.

1.3.2 FAA. Users of Class 3B and Class 4 lasers used for demonstration purposes are required to obtain a letter of non-objection from the Federal Aviation Administration (FAA) as a condition of compliance with their FDA variance. Additionally, the FAA requests the operators of other Class 3B and Class 4 lasers with beams that could enter navigable airspace to coordinate with them at least 90 days prior to laser operations, when feasible. These steps are intended to reduce the likelihood that people are exposed to hazardous laser radiation and that the laser energy will not interfere with FAA approved flight operations (see 4.5, and Appendixes A, E, and F). For further information, see Advisory Circular, AC 70-1 available at <http://www.faa.gov>.

1.3.3 Laser Clearinghouse. When operating uninterminated lasers that have a very small divergence and can pose high irradiance or fluence values at high altitudes, it may be necessary to deconflict potential issues with satellites by contacting the U.S. Strategic Command Laser Clearinghouse at (805) 606-1282.

1.3.4 Military/Department of Energy. Users of Class 3B and Class 4 lasers operating through special use airspace, as designated by the FAA for DoD or Department of Energy (DOE) use, even if the maximum permissible exposure (MPE) is not exceeded in that area, shall contact the local military authorities to ensure that the use will not interfere with military or DOE operations. These authorities should also be contacted when propagating all other lasers through their airspace.

1.3.5 Federal/State/Local Authorities. Federal, state, and local law may require special coordination or registration. Laws are currently in place and more are being considered that would further restrict the use of lasers outdoors, particularly when used in the navigable airspace. When propagating laser beams through special use airspace, the user should coordinate with the appropriate airspace controlling agency.

1.3.6 Others. When laser beams cross property lines, the property owner should be notified if human exposure in excess of the MPE is possible. However, positive beam control shall be in place to ensure that unintentional exposures above the MPE do not occur. See Sections 4.3.4 and 4.4.3.

1.4 Laser Safety Officer (LSO).

For Class 3B and Class 4 outdoor operations, an individual shall be designated as the LSO by the employer, system owner, and/or property owner as necessary. The LSO shall have both the authority and the responsibility to effect the knowledgeable evaluation of laser hazards and to monitor and enforce their control. The LSO duties may include:

- a) classifying or verifying classification of laser systems under the LSO's jurisdiction
- b) performing a hazard analysis of laser work areas including establishment of hazard zones
- c) ensuring that the prescribed control measures are in effect
- d) recommending or approving substitute or alternate control measures when the primary ones are not feasible or practical
- e) periodically auditing the functionality of the control measures in use
- f) approving SOPs

5.3 Training.

Laser safety education and training commensurate with the hazards shall be provided to supervisors and users. The exact amount and depth of detail should be tailored to each situation. Generally, LSOs in a management capacity should receive training as outlined in ANSI Z136.1. (See Appendix G of this standard for training of laser workers, Laser Safety Specialists, Laser Systems Management Organization LSO, Site LSO, Authorized Laser Operators, Personnel in the Target Area of a Laser, and Safety Observers.)

6. Requirements for Military Specific Lasers

6.1 General.

The requirements in this section apply to military specific lasers and may be used as guidance for other organizations having a variance or exemption from the FLPPS. Lasers used by the military that are not exempted will be classified according to the FLPPS. DODI 3100.11 requires that all uninterminated laser emissions be coordinated with the U.S. Strategic Command Laser Clearinghouse, regardless of hazard class or military exemption status. The Laser Clearinghouse may provide a provisional 1-year waiver if they determine that the laser is not capable of interfering with the mission of satellites, or they may provide geometric and/or temporal limits as to when the laser can be used. (See Appendix A for examples of Laser Clearinghouse reporting forms and associated authorization letters.)

6.1.1 Basic Policy. Military lasers shall be designed to the lowest output power or energy consistent with reliable mission accomplishment. Laser systems and their support equipment shall be designed to minimize accessibility to hazardous emissions during maintenance activities.

6.1.2 Training Modes and Direct Fire Simulators. Class 1 emissions are a goal for all lasers used in a training environment. Force-on-force training lasers shall not exceed the Class 3R AEL (with or without the use of viewing aids). Other training lasers or lasers in training mode should not exceed the Class 3R AEL (with or without the use of viewing aids).

6.2 Designated Service Laser Hazard Agency (DSLHA).

Regardless of class or exemption status, military specific lasers are required to have approval for use by their Service. Each Service has a DSLHA that should be contacted for Service-specific procedures.

To ensure an independent evaluation of laser hazards, the appropriate DSLHA(s) shall be contacted prior to the procurement or use of these lasers or upon change in their output, design, or application. This should be done with sufficient lead-time so that a hazard analysis can be performed. The need for a full hazard evaluation is contingent upon the results of this analysis as well as Service-specific regulations. Control measures shall be implemented as directed by Service-specific requirements.

6.2.1 DSLHAs Contact Information. For the U.S. Army, contact the Nonionizing Radiation Program of the Army Public Health Center, 5158 Blackhawk Rd, Bldg. E1950, Aberdeen Proving Ground, MD 21010-5403. E-mail: usarmy.apg.medcom-phc.mbx.nonionizing@mail.mil. Telephone: (410) 436-3932.

For the U.S. Navy and Marine Corps, contact Code G-73 of the Dahlgren Division of the Naval Surface Warfare Center Dahlgren Division (NSWCDD), 6078 Norc Ave, Suite 309, Dahlgren, VA 22448-5131. E-mail: lasersafety@navy.mil. Telephone: (540) 653-1060. The Navy Laser Safety Review Board (LSRB) authorizes the conditions under which the equipment can be used.

For the U.S. Air Force, contact the Air Force Research Laboratory, 711th HPW/RHDO, 4141 Petroleum Rd., Fort Sam Houston, TX 78234. E-mail: 711hpw.rhdo.usaflasersafety@us.af.mil. Telephone: (210) 539-8175. The Air Force Laser System Safety Review Board (LSSRB) authorizes the conditions under which the equipment can be used.

Upon review by the DSLHA, the control measures specified in this section may be substituted by other controls, which provide equivalent protection. If alternate control measures are used, all personnel directly affected shall be provided appropriate operational and laser safety training. Documentation of alternate control measures and training is recommended.

6.3 FLPPS/Military (DoD) Exemption Requirements and Considerations.

It is the responsibility of the manufacturer to comply with all requirements of the FLPPS, except for those that interfere with the intended use of the device. The manufacturer is required by federal law to have written notification of military exemption qualification from a DoD authority prior to delivery of any laser product not fully compliant with the FLPPS. The DSLHA determines whether a laser system meets the FLPPS and can aid the user in determining if use of the DoD exemption is necessary.

Military exemption notifications should list items of non-compliance from the FLPPS and limit both the number of units exempted and the date range for which the exemption is necessary. As all issues of non-compliance to the FLPPS may not be known for early engineering and developmental systems, all military exemption notifications that do not limit both the date of delivery and number of units shall itemize all requirements of the FLPPS that are not in compliance. Additionally, all military exemption notifications shall include the qualification for exemption (combat, combat training, or classified in the interest of national security), and should define the scope to which it may be used. Scope limitations might include military Service or group, numbers of systems, serial numbers, timeframe, configuration, or specification variability. Additional exemption notifications may be required for the same laser system if being procured outside the scope of the original exemption notification. The DoD does not accept FDA/CDRH variances for military specific lasers in lieu of the application of the DoD exemption from the FLPPS.

The procuring agent shall provide a copy of the exemption notification to all applicable DSLHA(s) and shall control the inventory and demilitarization of delivered systems. An exempted laser shall not be transferred, either temporarily or permanently, to an individual or to a non-DoD organization unless it is brought into full compliance with the FLPPS, is destroyed beyond repair, or is transferred by other legal means. Transfer of a military exempted laser system to another DoD agency requires the transfer of inventory and demilitarization responsibilities to that agency.

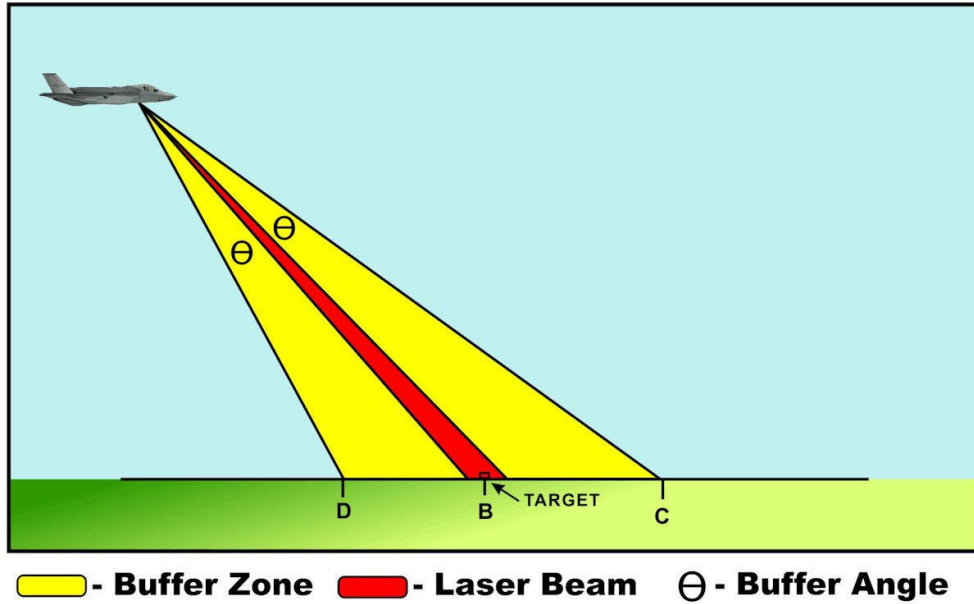


Figure 3b. Buffer Zone for Aircraft-based Laser

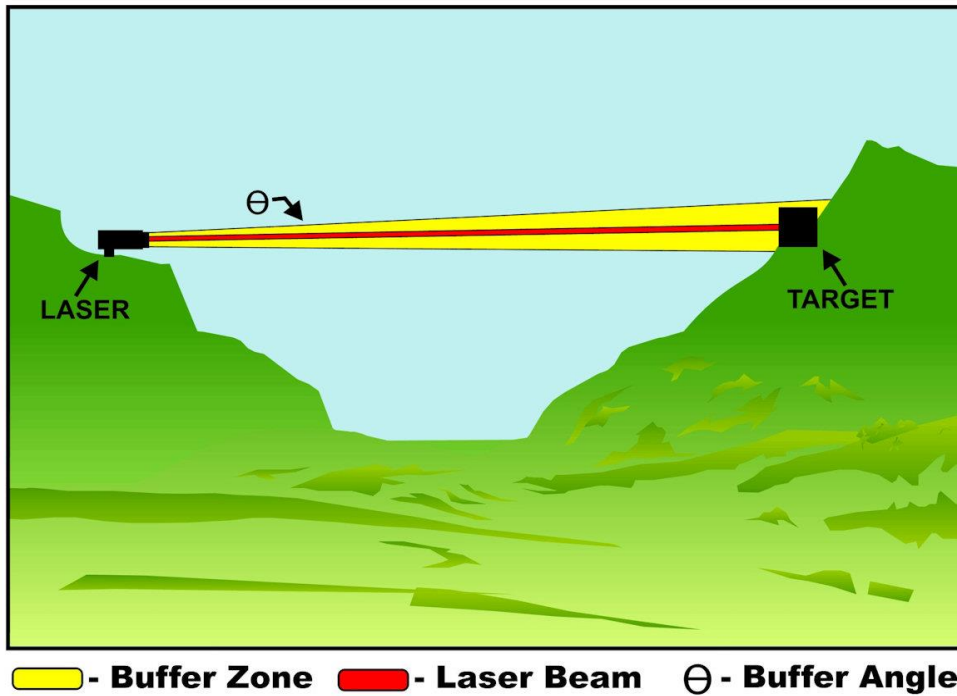


Figure 3c. Buffer Zone for Ground-based Laser

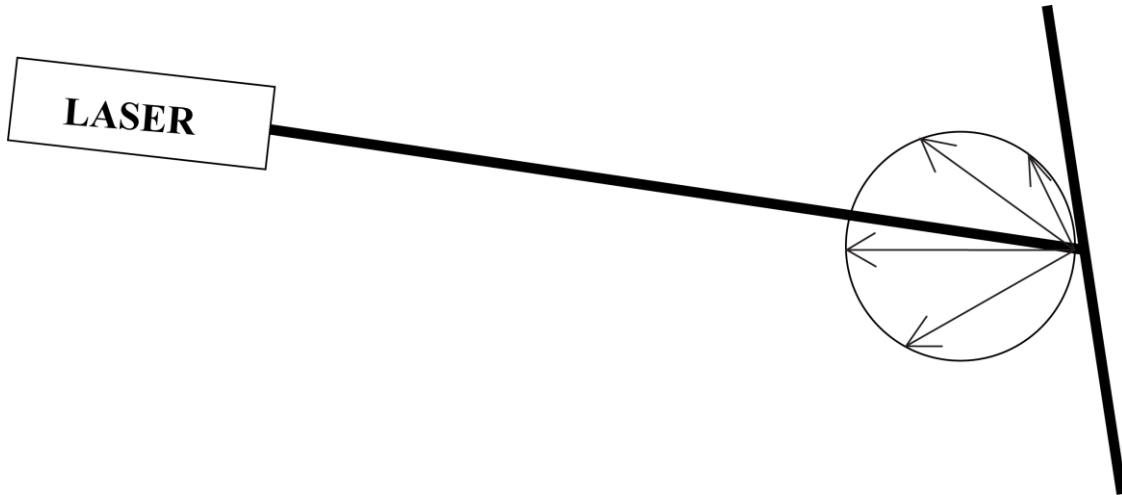


Figure B8. Diffuse Reflection of Laser Beam

NOTE—The reflected laser energy is spread over a large area from a matte surface.

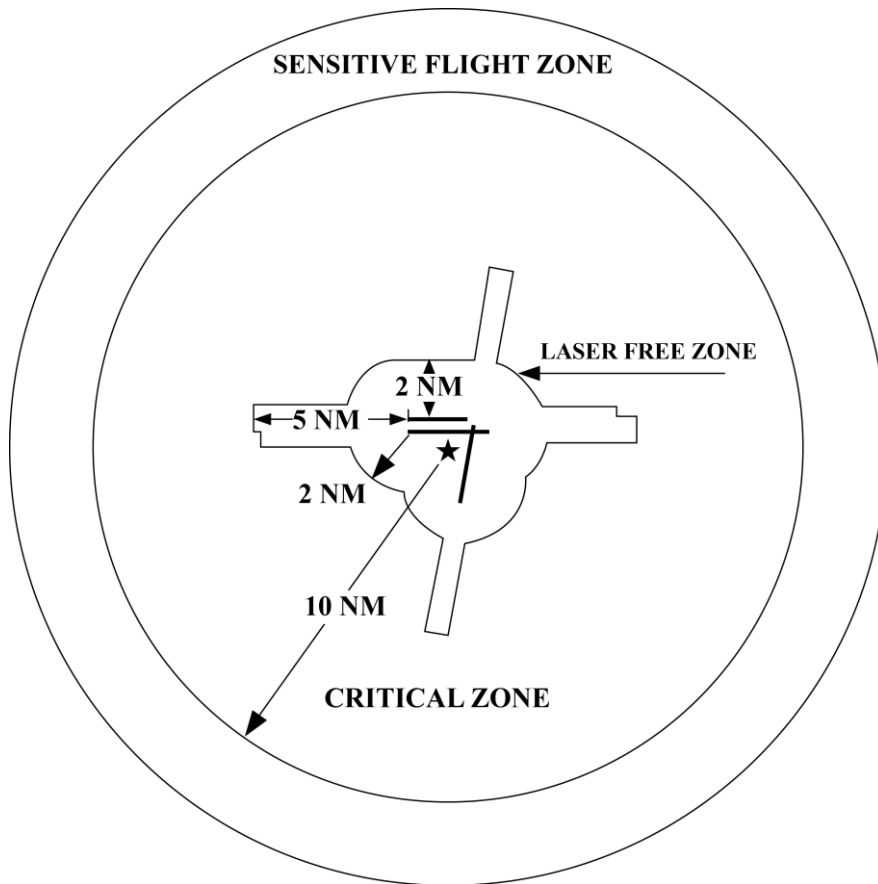


Figure B9. Rough Drawing of Local Airport

Appendix C

Atmospheric Effects

C1. Introduction

There are two main atmospheric effects that need to be addressed when assessing the hazard distance from a laser source: attenuation and scintillation. Attenuation is caused by absorption and scattering, and depends on the laser wavelength and atmospheric constituents (e.g., water vapor, smoke and aerosols). Scintillation is a random phenomenon that is caused by local temperature variations in the atmosphere. These variations cause local increases and decreases in the beam energy distribution. These changes do not pose a notable increase in risk of injury and therefore, the hazard evaluation is not affected.

C2. Atmospheric Scattering and Absorption

A laser beam that propagates through a vacuum will not be attenuated as it passes through space. However, under normal atmospheric conditions, the effect of atmospheric attenuation may become a major factor in evaluating the radiant exposure or irradiance at distances greater than a few kilometers from a laser. This attenuation consists of three effects: Mie scattering, Rayleigh scattering and molecular absorption. Mie (or large particle) scattering occurs where the particle size is greater than the wavelength of the optical radiation, and is normally the greatest contributor in the visible and near infrared. Rayleigh (or molecular) scattering occurs where particle size is much less than the wavelength, is reasonably constant for a given wavelength, and is the greatest contributor in the ultraviolet. Except in the infrared, absorption by gas molecules is normally insignificant in comparison to scattering.

Rayleigh scattering, which is proportional to λ^{-4} , is significantly more pronounced at shorter wavelengths; thus a laser with a long wavelength (up to 2000 nm) is attenuated less than a laser that operates in short wavelengths (down to 400 nm). A clear atmosphere may, therefore, be expected to be relatively transparent to visible and near infrared wavelengths. If the effects of atmospheric attenuation are to be considered, knowing the meteorological range V (km) is necessary. The attenuation is usually based upon a V of 60 km or “Exceptionally Clear Atmosphere” since the visibility may not be known during an outdoor operation.

C3. Atmospheric Scintillation

Scintillation is a complex phenomenon that is dependent upon laser beam and atmospheric characteristics. As a laser beam passes through the atmosphere, it may undergo localized changes in irradiance or radiant exposure. “Turbulons” are created when local temperature gradients produce variations in air density perpendicular to the beam propagation direction. These “turbulons” are expressed as local variations in the air index of refraction. Passing through a portion of the atmosphere where “turbulons” are present causes different areas of the beam to focus or defocus. Scintillation effects are most prominent close to the surface of the earth.

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