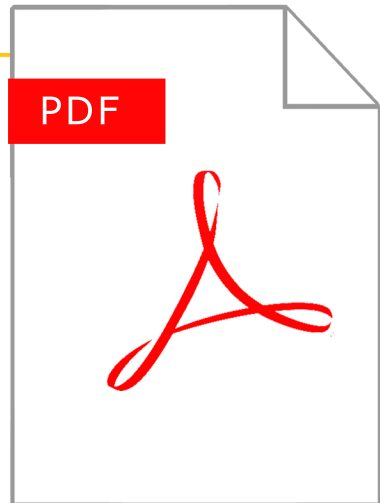


American National Standard

*American National Standard
for Safe Use of Lasers in
Manufacturing Environments*



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



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First Printing

**American National Standard
for Safe Use of Lasers in
Manufacturing Environments**

**Secretariat
Laser Institute of America**

**Approved: August 6, 2013
American National Standards Institute, Inc.**

**American
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American National Standard for Safe Use of Lasers in Manufacturing Environments

1. General

1.1 Scope.

This standard provides recommendations for the safe use of lasers and laser systems that operate at wavelengths between 180 nm and 1 mm.

Laser applications in the manufacturing environment include, but are not limited to, material processing, fabrication, laser alignment, leveling, inventory, metrology, and machine vision.

1.2 Application.

The objective of this standard is to provide reasonable and adequate guidance for the safe use of lasers and laser systems. A practical means for accomplishing this is first to (1) classify lasers and laser systems according to their relative hazards and then to (2) specify appropriate controls for each classification.

NOTE—Reference to an undated standard or code means reference to the latest revision of that standard.

1.2.1 Certified Laser Products. Normally, only certified laser products should be employed in the manufacturing environment. Certification requires meeting applicable local, state or federal requirements. These include:

- a) U.S. Food and Drug Administration, Code of Federal Regulations, Title 21, Volume 8, 1040 (21 CFR 1040), “Performance Standards for Light-Emitting Products”

NOTE—21 CFR 1040.10 and 21 CFR 1040.11 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.

- b) IEC 60825-1. “Safety of laser products – Part 1: Equipment classification and requirements”

However, a certified laser product may be modified by the end-user and additional hazard evaluation will be required. Compliance with the FLPPS (or IEC 60825-1) may require those modifying a certified laser product to re-certify the product.

1.2.2 Laser Classes.

1.2.2.1 Low-Risk Lasers (Class 1, 1M, 2, 2M and 3R). Class 1 and Class 1M lasers and laser systems are considered incapable of causing a hazard (except Class 1M if viewed with collecting optics such as eye loupe or telescope). The hazard risk associated with Class 2 and 2M (visible) is also very low and eye protection is normally afforded by the aversion response (except Class 2M when viewed with collecting optics). Class 3R is potentially hazardous under some direct and specular reflection viewing conditions if the eye is appropriately focused and stable, but the probability of an actual injury is small.

NOTE 1—For purposes of this standard, products which have been classified previously as Class IIa under the FLPPS should be treated the same as Class 1.

NOTE 2—For additional information about the subclasses 3R and 3B see ANSI Z136.1.

The low-risk lasers found in the manufacturing environment – often used in alignment, leveling, metrology and machine vision – generally pose no significant hazard and require precautions only if high-power embedded lasers are accessed during maintenance and/or service, or if not used in accordance with the manufacturer’s warning labels against intentional viewing. Therefore, most requirements in this standard apply to Class 3B and Class 4 lasers and laser systems.

1.2.2.2 Moderate to High-Risk Lasers (Class 3B and 4). A Class 3B laser system (medium-power) may be hazardous under direct and specular reflection viewing conditions, but is normally not a diffuse reflection or fire hazard. Environmental factors such as dust, aerosols, and oxidizing gases in the surrounding area can increase the hazard of Class 3B lasers particularly when their beams are focused.

A Class 4 laser system (high-power) is a hazard to the eye and/or skin from the direct beam, may pose a diffuse reflection or fire hazard and may also produce laser generated air contaminants (LGAC) and hazardous plasma radiation (see Section 7).

Lasers or laser systems designated for a specific class by a laser manufacturer in accordance with the FLPPS or IEC 60825-1 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 the class level may change because of the addition or deletion of engineering control measures (see 4.3), the laser or laser system shall be classified by the Laser Safety Officer (LSO) in accordance with the descriptions provided in Section 3, the methods described in Section 9, or both.

1.2.3 Step-by-Step Procedure. The recommended step by step procedure for using this standard is as follows:

- a) Determine the appropriate class of the laser or laser system.
- b) Comply with the control measures specified for that class of laser or laser system, using Table 1.1 as a guide. This procedure will in most cases eliminate the need for measurement of laser radiation, quantitative analysis of hazard potential, or use of the Maximum Permissible Exposures (MPEs) as given in Section 8 and Table 5 of this standard.

1.3 Laser Safety Programs.

1.3.1 General. Management (employer) has the fundamental responsibility to ensure the safe use of lasers owned and/or operated in facilities under its control. Management shall establish and maintain an adequate program for the control of laser hazards. Employer and/or facility safety programs and employee training programs shall be provided for Class 3B or Class 4 lasers and laser systems. Employer and/or facility safety programs and employee training should be provided for laser systems containing embedded Class 3B and Class 4 lasers, if accessed by employer's staff. Service of such systems (embedded Class 3B and Class 4 lasers) by outside vendors does not require employer staff laser safety training. The LSO shall approve safety procedures implemented at times when such systems are accessed and no longer in a Class 1 configuration. Employer and/or facility safety programs and employee training programs are not required for Class 1 lasers and laser systems that do not contain embedded Class 3B and Class 4 lasers (see Section 5 and Table 1.1).

The following guidelines for laser safety programs contain requirements (designated by *shall*) and recommendations (designated by *should*). In the case of a recommendation it may be useful for the employer to review Section 3 of this standard and perform a hazard evaluation, with particular emphasis on the total foreseen risk based on consideration of the laser, laser system and application, as well as the environment in which it is used and the personnel using the laser. The evaluation should include considerations such as the likelihood of the use of viewing optics, and the intentional or unintentional misuse of a laser that, under normal conditions, would not be considered hazardous. In many situations the implementation of a recommendation may not be necessary; in other situations, it may be useful or prudent to implement the recommendation in order to ensure the safe use of lasers for a specific application.

1.3.2 Laser Safety Program Provisions. When identified as necessary, the laser safety program established by the employer (see Table 1.1) shall include provisions for the following:

- a) Designation of an individual as the LSO with the authority and responsibility to effect the knowledgeable evaluation and control of laser hazards, and the implementation of appropriate control measures, as well as to monitor and enforce compliance with required standards and regulations. The specific duties and responsibilities of the LSO are designated in normative Appendix A.¹ Throughout the body of this standard, it shall be understood that wherever duties or responsibilities of the LSO are specified, it will mean that the LSO either performs the stated task or ensures that the task is performed by a qualified individual(s).
- b) Education of authorized personnel (e.g., LSOs, operators, in-house and/or vendor service personnel) in the safe use of lasers and laser systems and, as applicable, the assessment and control of laser hazards. This may be accomplished through training programs. Employers should consider the benefits of initiating awareness training for employees working with and around lasers and laser systems greater than Class 1. If

¹ A normative appendix contains information that is required to implement the standard and is therefore, officially part of the standard.

training is warranted for embedded lasers, it shall extend to those routinely around the systems who will be present when maintenance requiring beam access or service occurs (see Section 5 and Appendix E). When service is conducted by an outside firm/vendor, supporting documentation of appropriate laser safety training should be presented to the employer and meet to the approval of the employer's Health & Safety Committee and/or the employer's LSO.

- c) Application of adequate control measures for the mitigation of laser hazards as required in Section 4.
- d) Incident investigation, including reporting of alleged accidents to the LSO, and preparation of action plans for the prevention of future accidents following a known or suspected incident.
- e) An appropriate medical examination is considered in accordance with Section 6.
- f) Formation of a Laser Safety Committee when the number, hazards, complexity and/or diversity of laser activities warrants. The structure and responsibilities for a Laser Safety Committee are presented in Appendix A.

1.3.3 Personnel Responsibilities. Employees who work with lasers or laser systems and their supervisors have responsibilities for establishing their safe use. Suggested responsibilities for these individuals are provided in Appendix A.

Individuals involved in purchasing lasers and laser systems should contact the LSO to aid in the implementation of the laser safety program. Suggested actions are provided in Appendix A, Section A3.

Individuals fabricating, altering or installing a Class 3B or 4 laser or laser system should contact the LSO to aid in the implementation of the laser safety program.

2. Definitions

2.1 Definitions as Used in this Standard.

The definitions of the terms listed below are based on a pragmatic rather than a basic approach. Therefore, the terms defined are limited to those actually used in this standard and its appendixes and are in no way intended to constitute a dictionary of terms used in the laser field as a whole.

absorption. 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.

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

administrative (procedural) control measure. Administrative and procedural controls are methods or instructions that specify rules, or work practices, or both, which implement or supplement engineering controls and which may specify the use of personal protective

- g) Other hazards not due to laser radiation that may cause the individuals to react unexpectedly or influence the choice of personal protective equipment

4. Control Measures

4.1 General Considerations.

No one shall be exposed to laser radiation exceeding the applicable MPEs under any reasonably foreseeable conditions of operation. Therefore, control measures, commensurate with the hazards, shall be devised to reduce the possibility of exposure of the eyes or skin to hazardous levels of laser radiation and to mitigate indirect hazards due to visual interference effects. These measures also include other hazards associated with the use of laser devices during operation and maintenance. For all uses of lasers and laser systems, the minimum laser radiation necessary for the intended application should be used.

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 information may be 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.

- a) Class 1 lasers or laser systems are exempt from any laser control measures.

NOTE—A Class 1 laser system may contain a higher class laser, even a Class 4 laser. However, as the beam is inaccessible in a Class 1 laser system during normal operations, no beam control measures are required.

- b) Class 1M lasers or laser systems are exempt from any control measures or other forms of surveillance except when optically aided direct viewing of the beam is expected and/or during 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.
- c) Class 2 lasers or laser systems are exempt from any control measures except when intentional direct viewing of the beam is possible.
- d) Class 2M lasers or laser systems are exempt from any control measures or other forms of surveillance except when intentional direct viewing of the beam and/or potentially hazardous optically aided viewing is possible.
- e) Class 3R lasers or laser systems are exempt from any control measures or other forms of surveillance except when direct viewing of the beam or its specular reflection is possible, or during 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.
- f) Class 3B lasers or laser systems require the approval of appropriate control measures by the LSO in order to reduce the risk of a hazardous exposure to the eye from a

7. Non-Beam Hazards

7.1 General.

Non-beam hazards (NBH) are a class of hazards that do not result from direct human exposure to a laser beam. NBH include physical, chemical, and biological agents, as well as work place ergonomics issues. In some cases, these hazards can be life threatening (e.g., electrocution). As a result, the hazards discussed in this section require use of control measures different from those discussed in Section 4. Also, all written SOPs shall address NBH as well as beam hazards.

Because of the diversity of NBH, the LSO may employ safety and/or industrial hygiene personnel to ensure non-beam hazard evaluation(s) are completed. Appendix G provides additional background material on NBH to assist the LSO in recognizing potential hazards.

7.2 Physical Agents.

7.2.1 Electrical Hazards. Electrical equipment in general presents potential hazards including shock, electrocution, resistive heating, and ignition of flammable materials.

7.2.1.1 Shock. This may occur from contact with energized electrical conductors contained in device control systems, power supplies, and other devices that operate at potentials of 50 volts and above.

The effect upon those who accidentally come into contact with energized conductors can range from a minor “tingle,” to startle reaction, to serious personal injury, or death via electrocution.

7.2.1.2 Resistive Heating. Heating of a conductor due to electric current flow increases with the conductor’s resistance. Unchecked and increasing resistive heating can produce excessive heat buildup and potentially damage/corrode system components. While laser system designers generally provide sufficient cooling for routine operations, it is important that this equipment be regularly checked for excessive resistive heating symptoms, such as component warping, discoloration, or corrosion, and repaired as needed.

7.2.1.3 Electric Spark Ignition of Flammable Materials. Equipment malfunctions can lead to electrical fires. In addition, electrical sparks can serve as an ignition source in the presence of a flammable vapor.

7.2.1.4 Electrical Hazard Control Measures. Electrical safety requirements are published by organizations including, but not limited to OSHA, the National Electrical Code (NFPA 70 & 79), and ANSI (B11.x series), and related state and local laws and regulations. These requirements govern equipment connection to the electrical utilization system, electrical protection parameters, and specific safety training. These requirements shall be observed with all laser installations.

Protection against accidental contact with energized conductors (shock) by means of a barrier system is the primary methodology to prevent electric shock accidents with laser equipment.

In addition, it is recommended that fire extinguishers designed for electrical fires are available in proximity of the laser systems.

Table 10a. Control Measures for the Seven Laser Classes

Engineering Control Measures	Classification						
	1	1M	2	2M	3R	3B	4
Protective Housing (4.4.2.1)	X	X	X	X	X	X	X
Without Protective Housing (4.4.2.1.1)	LSO shall establish Alternative Controls						
Interlocks on Removable Protective Housings (4.4.2.1.3)	∇	∇	∇	∇	∇	X	X
Service Access Panel (4.4.2.1.4)	∇	∇	∇	∇	∇	X	X
Key Control (4.4.2.2)	—	—	—	—	—	•	•
Viewing Windows, Display Screens and Diffuse Display Screens (4.4.2.3)	Assure viewing limited < MPE						
Collecting Optics (4.4.2.6)	X	X	X	X	X	X	X
Fully Open Beam Path (4.4.2.7.1)	—	—	—	—	—	X NHZ	X NHZ
Limited Open Beam Path (4.4.2.7.2)	—	—	—	—	—	X NHZ	X NHZ
Enclosed Beam Path (4.4.2.7.3)	None is required if 4.4.2.1 and 4.4.4.1.3 are fulfilled						
Remote Interlock Connector (4.4.2.7.4)	—	—	—	—	—	•	X
Beam Stop or Attenuator (4.4.2.7.5)	—	—	—	—	—	•	X
Area Warning Device (4.4.2.8)	—	—	—	—	—	•	X
Class 4 Laser Controlled Area (4.4.2.9 and 4.4.3.5)	—	—	—	—	—	—	X
Protective Barriers and Curtains (4.4.2.5)	—	—	—	—	—	•	•

- LEGEND:
- X Shall
 - Should
 - No requirement
 - ∇ Shall if enclosed Class 3B or Class 4
 - MPE Shall if MPE is exceeded
 - NHZ Nominal Hazard Zone analysis required
 - * May apply with use of optical aids

Table 11a. Summary of Area Warning Devices and Signs

Clause	Title	Classification					Required Statement or Comment
		2	2M	3R	3B	4	
3.5.1	Personnel	✓	✓	✓	✓	✓	Some individuals may be unable to read or understand signs
4.4.2.8.1	Visible Warning Devices	-	-	-	✓	✓	Visible warning should be required for Class 3B and shall for Class 4
4.4.2.8.2	Audible Warning Devices	-	-	-	✓	✓	Audible warning should be required for Class 3B and shall for Class 4
4.6.1	Design of Signs	✓	✓	✓	✓	✓	Per ANSI Z535 requirements
4.6.1.1	Safety Alert Symbol	✓	✓	✓	✓	✓	The alert symbol is required on all Caution, Warning and Danger signs
4.6.1.2	Laser Radiation Hazard Safety Symbol	✓	✓	✓	✓	✓	The laser sunburst is required on all signs per ANSI Z535
4.6.1.3	Laser Warning Sign Posting	-	-	✓	✓	✓	Specifies posting requirements of Class 3R, Class 3B and Class 4
4.6.1.4	Laser Warning Sign Purpose	-	-	-	✓	✓	States the four purposes of area warning signs
4.6.2	Area Warning Sign Signal Words	✓	✓	✓	✓	✓	Specifies which sign is required: Danger, Warning, or Caution
4.6.2.1	Signal Word “Danger”	-	-	-	-	✓	Specifies when to use the word “Danger” and format
4.6.2.2	Signal Word “Warning”	-	-	-	✓	✓	Specifies when to use the word “Warning” and format
4.6.2.3	Signal Word “Caution”	✓	✓	✓	-	-	Specifies when to use the word “Caution” and format
4.6.3	Pertinent Sign Information	✓	✓	✓	✓	✓	Specifies the format of signs
4.6.3.4	Message Panel Information	✓	✓	✓	✓	✓	Specifies the wording of message panel
4.6.4	Location of Signs	✓	✓	✓	✓	✓	Specifies the location of signs
NOTE—Signs and labels prepared in accordance with Z136.1-2007 (and prior editions) are considered to fulfill the requirement of the standard.							
LEGEND— ✓ denotes that the section applies to the applicable Class of laser.							

Appendix A

Supplement to Section 1 – Laser Safety Programs

NOTE—The following material is an extension of sub-section 1.3 and as a normative Appendix is an integral part of the standard.

A1. Laser Safety Officer (LSO)

A1.1 General. The LSO is an individual designated by the employer with the authority and responsibility to effect the knowledgeable evaluation and control of laser hazards, and to monitor and enforce the control of such hazards. The LSO shall have authority to suspend, restrict, or terminate the operation of a laser system if he/she deems that laser hazard controls are inadequate. For the laser safety program to be effective, the LSO must have sufficient authority to accompany the responsibility. In organizations that do not permit authority to reside with non-management personnel and the LSO is a non-management position, the management shall provide protocols and reporting structure to ensure adequate enforcement authority.

The LSO may be designated from among personnel such as the radiation safety officer, industrial hygienist, safety engineer, laser specialist, laser operator or user. The LSO may be a part-time position when the workload for an LSO does not require a full-time effort. In some instances, the designation of an LSO may not be required. Operation and maintenance of Class 1, Class 1M, Class 2, Class 2M and Class 3R lasers and laser systems normally do not require the designation of an LSO. However, under some circumstances, it may be desirable to designate an LSO, for example, if service is performed on a laser system having an embedded Class 3B or Class 4 laser or laser system. In such instances, management may designate the service person requiring access to the embedded laser as the LSO. In any case, there shall be a designated LSO for all circumstances of operation, maintenance, and service of a Class 3B or Class 4 laser or laser system.

If necessary, a Deputy Laser Safety Officer (DLSO) shall be appointed by management or the LSO. The DLSO shall perform the functions of the LSO when the latter is not available. For institutions with multiple divisions or plant locations, a system of DLSOs may be required.

A1.2 LSO Specific Duties and Responsibilities.

- a) **Safety Program.** The LSO shall establish and maintain adequate policies and procedures for the control of laser hazards. These policies and procedures shall comply with applicable requirements, including federal, state and local regulations.
- b) **Classification.** The LSO shall classify or verify classifications of lasers and laser systems used under the LSO's jurisdiction. Classifications shall be consistent with classifications listed in Section 3 of this standard.

Appendix B

Calculations for Hazard Evaluation and Classification

B1. General

Calculations are not necessary for hazard evaluation and classification in many applications; however, in outdoor applications and other specialized uses where eye exposure is contemplated, several types of calculations permit the important quantitative study of potential hazards.

The following sections are provided in this Appendix:

- a) B2: Definition of mathematical symbols used in this Appendix
- b) B3: Examples of MPE determinations
- c) B4: Discussion of hazard classification methods
- d) B5: Formulae for computing beam irradiance and radiant exposure
- e) B6: Formulae useful in hazard evaluation and calculating nominal ocular hazard distance and nominal hazard zone
- f) B7: Methods for determining MPEs based on retinal hazards from both photochemical and thermal effects for extended visible laser sources
- g) B8: Formulae useful in determining adequate protective eyewear or laser barriers
- h) B9: Applicable references

Figures B1 through B7 illustrate conditions of ocular exposure to laser radiation.

B1.1 Industrial Considerations. Laser machines in most industrial operations are required to be Class 1 due to floor space utilization (constraining the Nominal Hazard Zone) and for the safety of operators and nearby employees. Class 1 laser systems containing an embedded Class 3B or Class 4 laser generally do not require a hazard evaluation provided that the safety enclosure, engineering controls and procedural controls are unmodified.

B2. Symbols

The following symbols are used in the formulae of this Appendix:

a = Diameter of emergent laser beam (cm).

α = Apparent angle subtended by a source at the location of the viewer (rad).

α_{\max} = Apparent angle subtended by a source above which the thermal hazard is proportional to the radiance of the source (100 mrad).

American National Standard

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