

American National Standard

*American National Standard
for Safe Use of Lasers*



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



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ANSI Z136.1-2007

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

Secretariat
Laser Institute of America

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**American
National
Standard**

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American National Standard for Safe Use of Lasers

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 1000 μm .

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 to (1) classify lasers and laser systems according to their relative hazards and to (2) specify appropriate controls for each classification.

Other special application standards within the Z136 series may deviate from the requirements of this standard. Each deviation is valid only for applications within the scope of the standard in which it appears. Guidance in specialized standards (e.g., Z136.3 and Z136.4)¹ that appears to conflict with the requirements of this standard shall have precedence within the scope of that standard. The laser safety officer (LSO) shall determine which, if any, of the specialized Z136 laser safety standards are applicable. The complete record of current Z136 standards is listed in the Foreword and Section 10 of this document.

The basis of the hazard classification scheme in Section 3 of this standard is the ability of the laser beam to cause biological damage to the eye or skin during use. For example:

a) **Class 1 Laser System:**

Considered to be incapable of producing damaging radiation levels during operation, and exempt from any control measures.

NOTE 1—For the purposes of this standard, products that have been classified previously as Class IIa under the Federal Laser Product Performance Standard (FLPPS) should be treated the same as those in Class 1 (see Appendix J).²

NOTE 2—A common example of a Class 1 laser system is one that includes an embedded higher class laser, but during normal operation presents no laser radiation hazard to the user.

b) **Class 1M Laser System:**

Considered to be incapable of producing hazardous exposure conditions during normal operation unless the beam is viewed with collecting optics (e.g., telescope) and is exempt from any control measures other than to prevent potentially hazardous optically aided viewing.

¹ When reference to a standard, regulation or order is followed by a date (e.g., Z136.1-2007), the reference is to that specific document. When the 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.

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

NOTE—The additional hazard from the use of eye loupes within 10 cm of the source will not increase the hazard classification to Class 1M in this standard. In the International Electrotechnical Commission (IEC) 60825-1 (2007) standard, the additional hazard resulting from the use of eye loupes within 10 cm of the source can result in an increase in the hazard class to Class 1M.

c) **Class 2 laser system:**

Emits in the visible portion of the spectrum (400 nm to 700 nm) and eye protection is normally afforded by the aversion response.

d) **Class 2M laser system:**

Emits in the visible portion of the spectrum (400 nm to 700 nm) and eye protection is normally afforded by the aversion response for unaided viewing.

However, Class 2M is potentially hazardous if viewed with collecting optics (e.g., telescope).

NOTE—The additional hazard from the use of eye loupes within 10 cm of the source will not increase the hazard classification to Class 2M in this standard. In IEC 60825-1, the additional hazard resulting from the use of eye loupes within 10 cm of the source can result in an increase in the hazard class to Class 2M.

e) **Class 3R laser system:**

Has reduced control requirements and is potentially hazardous under some direct and specular reflection viewing conditions if the eye is appropriately focused and stable, but the probability of an actual injury is small. This laser will not pose either a fire hazard or diffuse reflection hazard.

NOTE— See Appendix J for guidance on lasers classified Class IIIa.

f) **Class 3B laser system:**

May be hazardous under direct and specular reflection viewing conditions, but is normally not a fire hazard, diffuse reflection hazard, nor a laser generated air contaminant (LGAC) production hazard.

g) **Class 4 laser system:**

Is a hazard to the eye or skin from the direct beam, may pose a fire hazard or diffuse reflection hazard, and may also produce LGAC and hazardous plasma radiation (see Section 7).

Lasers or laser systems designated for a specific class by a manufacturer in accordance with the FLPPS or IEC 60825-1 may be considered as fulfilling all classification requirements of this standard (see Appendix J). 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 optical elements and/or engineering control measures (see 4.3 and 4.4.2), the laser or laser system shall be classified by the LSO in accordance with the descriptions given in Section 3, the methods described in Section 9, or both (see also ANSI Z136.4).

The recommended step-by-step procedure for using this standard is as follows:

- a) Determine the appropriate class of the laser or laser system. For example, refer to label, operator's manual or perform hazard classification analysis. In most cases, use of the manufacturer certified classification will eliminate the need for measurement of laser radiation, quantitative analysis of hazard potential, or use of the Maximum

Permissible Exposure (MPE) values given in Section 8 and Table 5a, Table 5b, Table 5c, Table 5d, and Table 5f of this standard. Section 8 and Section 9 should be consulted for quantitative evaluation of the hazard associated with a given laser or laser system. To use the ocular MPEs for the retinal hazard region (provided in Table 5a, Table 5b, Table 5c, Table 5d, and Table 5f), determine whether the source is a point source or whether extended source viewing conditions apply (see Figure B1, Figure B3, and Figure B4 in Appendix B for illustrated viewing conditions).

- b) Comply with the requirements specified for that class of laser or laser system, using Table 1-1 as a guide.

Table 1-1. Requirements by Laser Class

Class	Control Measures	Training	LSO	Engineering Controls
1	Not Required	Not Required	Not Required	Not Required
1M	Required	Application Dependent ^a	Application Dependent ^a	Application Dependent ^a
2	Not Required ^b	Not Required ^b	Not Required	Not Required ^b
2M	Required	Application Dependent ^a	Application Dependent ^a	Application Dependent ^a
3R	Not Required ^b	Not Required ^b	Not Required ^b	Not Required ^b
3B	Required	Required	Required	Required
4	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 control measures.				

^a Certain uses of Class 1M or Class 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.

For the purposes of this standard, except for short-distance viewing (typically within 1 m) of small diameter or focused Class 3B lasers, only Class 4 lasers are capable of producing hazardous diffuse reflections; hence, calculations for viewing diffuse reflections are normally only necessary for accessible Class 4 lasers.

The laser hazard classification system is based entirely on the laser radiation emission. Non-beam hazards must be dealt with separately and are addressed in Section 7.

1.3 Laser Safety Programs.

1.3.1 General. Management (employer) has the fundamental responsibility to ensure the safe use of lasers owned by and/or operated in facilities under its control. Management (employer) 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, as well as for those laser systems with embedded Class 3B or Class 4 lasers where beam access by employees is required during maintenance and/or service. Employer and/or facility safety programs and employee training programs are not required for Class 1 lasers or Class 1 laser systems that do not contain embedded Class 3B or 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 possibility of the use of viewing optics, and the intentional or unintentional misuse of a laser. 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. 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.³

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 (LSOs, operators, service personnel and others) 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 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).
- c) Application of adequate control measures for the mitigation of laser hazards as required in Section 4.

³ A normative appendix is an extension of the standard, and as such is an integral part of the standard.

- d) Incident investigation, including reporting of alleged accidents to or by the LSO, and preparation of action plans for the prevention of future accidents following a known or suspected incident.
- e) Appropriate medical examinations are considered in accordance with Section 6 and Appendix F.
- 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 the safe use of those lasers within their purview. Suggested responsibilities for these individuals are provided in Appendix A3.

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

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

2. Acronyms and Definitions

2.1 Acronyms and Abbreviations Used in this Standard.

AEL – accessible emission limit
 ANSI – American National Standards Institute
 ASC – accredited standards committee
 CDRH – Center for Devices and Radiological Health (USA)
 CFR – Code of Federal Regulations
 CPR – cardio-pulmonary resuscitation
 CW – continuous wave
 DLSO – deputy laser safety officer
 EWG – editorial working group
 FAA – Federal Aviation Administration
 FDA – Food and Drug Administration
 FLPPS – Federal Laser Product Performance Standard
 Hz – hertz
 IEC – International Electrotechnical Commission
 IEEE – Institute of Electrical and Electronics Engineers
 IR – infrared
 J – joules
 JO – joint order
 Laser – light amplification by stimulated emission of radiation
 LCA – laser controlled area
 LEP – laser eye protection
 LGAC – laser generated air contaminants

LIDT – laser-induced damage threshold
 LSO – laser safety officer
 LTIR – laser-target interaction radiation
 MPE – maximum permissible exposure
 MSDS – material safety data sheet
 NBH – non-beam hazard
 Nd:YAG – neodymium doped yttrium-aluminum-garnet
 NEC – National Electrical Code
 NFPA – National Fire Protection Association
 NHZ – nominal hazard zone
 NLR – non-laser radiation
 NOHD – nominal ocular hazard distance
 OD – optical density
 OFCS – optical fiber communication system
 OSHA – Occupational Safety and Health Administration
 PPE – personal protective equipment
 PRF – pulse repetition frequency
 SOP – standard operating procedure
 SSC – standards subcommittee
 TL – threshold limit
 TSC – technical subcommittee
 UV – ultraviolet
 VLT – visible luminous transmission

2.2 Definitions.

The definitions of the terms listed below are based on a pragmatic rather than a rigorous 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 laser radiation. Laser radiation emitted from a laser that is compared with the AEL to determine its hazard class. Includes accessible radiant energy and power. *See also: effective energy; effective power.*

administrative control measure. Control measures incorporating administrative means [e.g., training, safety approvals, LSO designation, and standard operating procedures (SOP)] to mitigate the potential hazards associated with laser use.

alpha max. The angular subtense of an extended-source beyond which additional subtense does not contribute to the hazard and need not be considered. *Symbol:* α_{\max} .

4.6.6.2 Location of Equipment Labels. All equipment warning labels shall be conspicuously displayed in locations on the equipment where they best will serve to warn onlookers (see 4.4.2.1.5).

5. Education and Training

5.1 General.

Training shall be provided to each LSO and employee routinely working with or potentially exposed to Class 3B or Class 4 laser radiation. Training should be provided to employees working with or potentially exposed to Class 1M, Class 2, Class 2M or Class 3R laser radiation (see Appendix E). The level of training shall be commensurate with the degree of potential laser hazards, both from the laser radiation and non-beam hazards. The course topics selected from Appendix E, and the depth and skill level of content, shall largely be determined based on the results from a complete hazard evaluation as detailed in Section 3.

The employer should address the recommendations in Appendix E when determining the requirements for a laser safety training program. The laser safety program includes provisions for training the LSO and users.

5.2 Refresher Training.

The employer shall address the needs for maintaining the appropriate level of laser safety proficiency through the use of periodic training.

The implementation and frequency of refresher training shall be considered on the basis of the total hazard evaluation criteria presented in Section 3 of this standard. The evaluation of personnel working with lasers and the amount of time they spend working with lasers are equally important considerations as the potential hazards from a laser. Occasional work with lasers may be a stronger justification for refresher or more frequent laser safety training than working daily with lasers. The reason is that the occasional user's degree of familiarity is usually less than those who work daily with lasers or laser systems. On the other hand, those persons working frequently with lasers and laser systems may become complacent about safety. The level of education of the user is another major point for consideration.

Refresher training may be an abbreviated version of the original training, or it may simply be a generic overview of laser safety. Whatever form refresher training takes, the end result should be that the users have the necessary laser safety awareness and knowledge to continue to work safely with their lasers.

5.3 Trainer Qualifications.

Education and training programs shall be conducted by individuals with training skills adequate and appropriate to the subject matter being taught. For example, this would include but not be limited to knowledge of lasers, laser safety concepts, and laser safety standards.

NOTE—Experience has shown that the important factors are experience with lasers, good presentation skills, and a thorough knowledge of the applicable standards.

5.4 LSO Training.

Management (employer) shall provide for LSO training on the potential hazards (including bioeffects), control measures, applicable standards, medical examinations (if applicable), and any other pertinent information pertaining to laser safety and applicable standards, or provide to the LSO adequate consultative services. The training shall be commensurate to at least the highest class of laser under the jurisdiction of the LSO. The training shall also include consideration for the evaluation and control of any non-beam hazards associated with the lasers and the laser systems under the jurisdiction of the LSO.

5.5 User Training.

Laser safety training shall be provided to the users of Class 3B or Class 4 lasers and laser systems. Laser safety training should be provided to users of Class 1M, Class 2, Class 2M and Class 3R lasers. Laser safety training shall include warnings against the misuse of lasers.

Users shall include operators, technicians, engineers, maintenance and service personnel, and any other persons working with or potentially exposed to laser radiation in excess of Class 1. The training shall ensure that the users are knowledgeable of the potential hazards and the control measures for laser equipment they may have occasion to use. All training shall be commensurate with the greatest potential for hazards associated with each laser operation, and shall be consistent with the results of the completed hazard evaluation as performed in accordance with Section 3 of this standard, which considers the laser and its application, the environment, and the personnel.

Where appropriate, training shall include cardiopulmonary resuscitation (CPR) and safety procedures for applicable non-beam hazards associated with laser systems in use.

6. Medical Examinations

6.1 Examinations Following a Suspected or Actual Laser-Induced Injury.

Medical examinations shall be performed as soon as practical (usually within 48 hours) when a suspected injury or adverse effect from a laser exposure occurs. In addition to the acute symptoms, consideration shall be given to the exposure wavelength, emission characteristics and exposure situation to ensure appropriate medical referral. See Appendix F for recommended examination protocol commensurate with the observed symptoms and laser system. For injury to the eye from lasers operating in the retinal hazard region, examinations shall be performed by an ophthalmologist.

6.2 Rationale for Other Medical Examinations.

The rationale for providing a medical surveillance program for personnel working in a laser environment and specific information of value to examining or attending physicians are included in Appendix F. Medical surveillance should be considered for those who are clearly known to be at risk from particular kinds of laser radiation. Medical surveillance is not recommended for personnel using Class 1, Class 1M, Class 2, Class 2M or Class 3R lasers

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)	Ensure 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)	Further controls not required if 4.4.2.1 and 4.4.2.1.3 fulfilled						
Area Warning Device (4.4.2.8)	—	—	—	—	—	•	X
Laser Radiation Emission Warning (4.4.2.9)	—	—	—	—	—	•	X
Class 4 Laser Controlled Area (4.4.2.10 and 4.4.3.5)	—	—	—	—	—	—	X
Entryway Controls (4.4.2.10.3)	—	—	—	—	—	—	X
Protective Barriers and Curtains (4.4.2.5)	—	—	—	—	—	•	•

LEGEND: X Shall
 • Should
 — No requirement
 ∇ Shall if enclosed Class 3B or Class 4
 NHZ Nominal Hazard Zone analysis required

Table 10b. Control Measures for the Seven Laser Classes (cont.)

Administrative (and Procedural) Control Measures	Classification						
	1	1M	2	2M	3R	3B	4
Standard Operating Procedures (4.4.3.1)	—	—	—	—	—	•	X
Output Emission Limitations (4.4.3.2)	—	—	—	—	LSO Determination		
Education and Training (4.4.3.3)	—	•	•	•	•	X	X
Authorized Personnel (4.4.3.4)	—	—	—	—	—	X	X
Indoor Laser Controlled Area (4.4.3.5)	—	◦	—	◦	—	X NHZ	X NHZ
Class 4 Laser Controlled Area (4.4.2.9 and 4.4.3.5)	—	—	—	—	—	—	X
Temporary Laser Controlled Area (4.4.3.5)	∇ MPE	∇ MPE	∇ MPE	∇ MPE	∇ MPE	—	—
Controlled Operation (4.4.3.5.2.1)	—	—	—	—	—	—	•
Outdoor Control Measures (4.4.3.6)	X	◦ NHZ	X NHZ	◦ NHZ	X NHZ	X NHZ	X NHZ
Laser in Navigable Airspace (4.4.3.6.2)	•	•	•	•	•	•	•
Alignment Procedures (4.4.3.8)	∇	X	X	X	X	X	X
Spectators (4.4.3.7)	—	◦	—	◦	—	•	X
Service Personnel (4.4.3.9)	LSO Determination						

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 10c. Control Measures for the Seven Laser Classes (cont.)

Personal Protective Equipment PPE	Classification						
	1	1M	2	2M	3R	3B	4
Laser Eye Protection (4.4.4.1)	—	—	—	—	—	X	X
Skin Protection (4.4.4.3)	—	—	—	—	—	•	•
Protective Clothing (4.4.4.1 and 4.4.4.3.1)	—	—	—	—	—	•	•

LEGEND: X Shall
 • Should
 — No requirement

Table 10d. Control Measures for the Seven Laser Classes (cont.)

Control Measures: Special Considerations and Warning Signs	Classification						
	1	1M	2	2M	3R	3B	4
Laser Optical Fiber Transmission Systems (4.5.2)	MPE	MPE	MPE	MPE	MPE	X	X
Laser Robotic Automated Installations (4.5.3)	—	—	—	—	—	X NHZ	X NHZ
Laser Controlled Area Warning Signs (4.6)	—	—	—	—	—	X	X

LEGEND: X Shall
 — No requirement
 MPE Shall if MPE is exceeded
 NHZ Nominal Hazard Zone analysis required

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