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American National Standard

ANSI Z136.1—2007

*American National Standard
for Safe Use of Lasers*



**Laser Institute
of America**

Laser Applications and Safety



ANSI®
Z136.1 – 2007
Revision of
ANSI Z136.1-2000

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

**Secretariat
Laser Institute of America**

**Approved March 16, 2007
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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 0.18 μm and 1 mm.

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.

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.

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 is:

- Considered to be incapable of producing damaging radiation levels during operation, and
- Exempt from any control measures or other forms of surveillance.

Note: For the purposes of this standard, products which have been classified previously as Class IIa under the Federal Laser Product Performance Standard (FLPPS) should be treated the same as Class 1.

A Class 1M laser system is:

- Considered to be incapable of producing hazardous exposure conditions during normal operation unless the beam is viewed with an optical instrument such as an eye-loupe (diverging beam) or a telescope (collimated beam), and
- Exempt from any control measures other than to prevent potentially hazardous optically aided viewing; and is exempt from other forms of surveillance.

A Class 2 laser system:

- Emits in the visible portion of the spectrum (0.4 to 0.7 μm), and
- Eye protection is normally afforded by the aversion response.

A Class 2M laser system:

- Emits in the visible portion of the spectrum (0.4 to 0.7 μm), and

- Eye protection is normally afforded by the aversion response for unaided viewing.
- However, Class 2M is potentially hazardous if viewed with certain optical aids.

A Class 3 laser system (medium-power):

- May be hazardous under direct and specular reflection viewing conditions, but is normally not a diffuse reflection or fire hazard.

There are two subclasses:

- A Class 3R laser system is potentially hazardous under some direct and specular reflection viewing condition 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.
- A Class 3B laser system may be hazardous under direct and specular reflection viewing conditions, but is normally not a diffuse reflection or fire hazard.

Note: For lasers classified as Class IIIa see Appendix H for guidance.

A Class 4 laser system (high-power):

- Is a hazard to the eye or skin from the direct beam, and
- May pose a diffuse reflection or fire hazard
- 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 manufacturer in accordance with the Federal Laser Product Performance Standard (FLLPS) (or latest revision thereof) or International Electrotechnical Commission (IEC) 60825-1 (or latest revision thereof) 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 Section 4.3), the laser or laser system shall be classified by the Laser Safety Officer (LSO) in accordance with the descriptions given in Section 3, the methods described in Section 9, or both.

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

- 1) Determine the appropriate class of the laser or laser system.
- 2) Comply with the measures specified for that class of laser or laser system, using Table 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 Tables 5a and 5b of this standard.

Table 1. Requirements by Laser Classification

Class	Procedural & Administrative Controls	Training	Medical Surveillance	LSO
1	Not Required	Not Required	Not Required	Not Required
1M	Required	Application Dependent (2)	Application Dependent (2)	Application Dependent (2)
2	Not Required (1)	Not Required (1)	Not Required	Not Required
2M	Required	Application Dependent (2)	Application Dependent (2)	Application Dependent (2)
3R	Not Required (1)	Not Required (1)	Not Required	Not Required (1)
3B	Required	Required	Suggested	Required
4	Required	Required	Suggested	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.

- 1) *Not required except for conditions of intentional intrabeam exposure applications.*
- 2) *Certain uses of Class 1M or 2M lasers or laser systems that exceed Class 1 or Class 2 because they do not satisfy Measurement Condition 1 may require hazard evaluation and/or manufacturer's information (see Section 4.1.1.3).*

Sections 8 and 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 Tables 5a and 5b), determine whether the source is a point source or whether extended source viewing conditions apply (see Figures B1, B3, and B4 in Appendix B for illustrated viewing conditions).

For the purposes of this standard, except for short-distance viewing of small diameter or focused Class 3B lasers (see Section 3.3.3), only Class 4 lasers are capable of producing hazardous diffuse reflections; hence calculations for viewing diffuse reflections are normally only necessary for 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 for the assurance of the safe use of lasers owned 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. Employer and/or facility safety programs and employee training should be provided for laser systems containing embedded Class 3B and Class 4 lasers. 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 3.1 and Table 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 would 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 to be 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 assure the safe use of lasers for a specific application.

1.3.2 Laser Safety Program Provisions. The laser safety program established by the employer shall include provisions for the following:

- 1) Designation of an individual as the Laser Safety Officer (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. (*Note: A normative appendix is an extension of the standard, and as such is an integral part of the standard.*) 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 assures that the task is performed by qualified individual(s).
- 2) 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 D).
- 3) Application of adequate protective measures for the control of laser hazards as required in Section 4.
- 4) 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.
- 5) An appropriate medical examination and medical surveillance program in accordance with Section 6.

- 6) 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

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.

alpha max. The angular subtense of an extended source beyond which additional subtense does not contribute to the hazard and need not be considered. This value is 100 mrad for retinal thermal effects and 110 mrad for the retinal photochemical effects. Symbol: α_{\max}

alpha min. The angular subtense of a source below which the source can be effectively considered as a point source. The value of alpha min is 1.5 mrad. Symbol: α_{\min}

aperture. An opening, window, or lens through which optical radiation can pass.

apparent visual angle. The angular subtense (α) of the source as calculated from source size and distance from the eye. It is not the beam divergence of the source (see Section 8.1 and Figure B4 for criteria).

attenuation. The decrease in the radiant flux as it passes through an absorbing or scattering medium.

Table 10. Control Measures for the Seven Laser Classes

Engineering Control Measures	Classification						
	1	1M	2	2M	3R	3B	4
Protective Housing (4.3.1)	X	X	X	X	X	X	X
Without Protective Housing (4.3.1.1)	LSO shall establish Alternative Controls						
Interlocks on Removable Protective Housings (4.3.2)	∇	∇	∇	∇	∇	X	X
Service Access Panel (4.3.3)	∇	∇	∇	∇	∇	X	X
Key Control (4.3.4)	—	—	—	—	—	•	X
Viewing Windows, Display Screens and Collecting Optics(4.3.5.1)	Assure viewing limited < MPE						
Collecting Optics (4.3.5.2)							
Fully Open Beam Path (4.3.6.1)	—	—	—	—	—	X NHZ	X NHZ
Limited Open Beam Path (4.3.6.2)	—	—	—	—	—	X NHZ	X NHZ
Enclosed Beam Path (4.3.6.3)	None is required if 4.3.1 and 4.3.2 fulfilled						
Remote Interlock Connector (4.3.7)	—	—	—	—	—	•	X
Beam Stop or Attenuator (4.3.8)	—	—	—	—	—	•	X
Activation Warning Systems (4.3.9.4)	—	—	—	—	—	•	X
Indoor Laser Controlled Area (4.3.10)	—	*	—	*	—	X NHZ	X NHZ
Class 3B Indoor Laser Controlled Area (4.3.10.1)	—	—	—	—	—	X	—
Class 4 Laser Controlled Area (4.3.10.2)	—	—	—	—	—	—	X
Outdoor Control Measures (4.3.11)	X	* NHZ	X NHZ	* NHZ	X NHZ	X NHZ	X NHZ
Laser in Navigable Airspace (4.3.11.2)	X	* NHZ	X NHZ	* NHZ	X NHZ	X NHZ	X NHZ
Temporary Laser Controlled Area (4.3.12)	∇ MPE	∇ MPE	∇ MPE	∇ MPE	∇ MPE	—	—
Controlled Operation (4.3.13)	—	—	—	—	—	—	•
Equipment Labels (4.3.14 and 4.7)	X	X	X	X	X	X	X
Laser Area Warning Signs and Activation Warnings (4.3.9)	—	—	—	—	•	X NHZ	X NHZ

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

Administrative and Procedural Control Measures	Classification						
	1	1M	2	2M	3R	3B	4
Standard Operating Procedures (4.4.1)	—	—	—	—	—	•	X
Output Emission Limitations (4.4.2)	—	—	—	—	LSO Determination		
Education and Training (4.4.3)	—	•	•	•	•	X	X
Authorized Personnel (4.4.4)	—	*	—	*	—	X	X
Alignment Procedures (4.4.5)	∇	∇	∇	∇	∇	X	X
Protective Equipment (4.6)	—	*	—	*	—	•	X
Spectators (4.4.6)	—	*	—	*	—	•	X
Service Personnel (4.4.7)	∇	∇	∇	∇	∇	X	X
Demonstration with General Public (4.5.1)	—	*	X	*	X	X	X
Laser Optical Fiber Transmission Systems (4.5.2)	MPE	MPE	MPE	MPE	MPE	X	X
Laser Robotic Installations (4.5.3)	—	—	—	—	—	X NHZ	X NHZ
Protective Eyewear (4.6.2)	—	—	—	—	—	•	X
Window Protection (4.6.3)	—	—	—	—	—	X	X NHZ
Protective Barriers and Curtains (4.6.4)	—	—	—	—	—	•	•
Skin Protection (4.6.6)	—	—	—	—	—	X	X NHZ
Other Protective Equipment (4.6.7)	Use may be required						
Warning Signs and Labels (4.7) (Design Requirements)	—	—	•	•	•	X NHZ	X NHZ
Service Personnel (4.4.7)	LSO Determination						
Laser System Modifications (4.1.2)	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

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