

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
American National Standards Institute, Inc.**

**American
National
Standard**

An American National Standard implies a consensus of those substantially concerned with its scope and provisions. An American National Standard is intended as a guide to aid the manufacturer, the consumer and the general public. The existence of an American National Standard does not in any respect preclude anyone, whether he or she has approved the standard or not, from manufacturing, marketing, purchasing, or using products, processes or procedures not conforming to the standard. American National Standards are subject to periodic review and users are cautioned to obtain the latest editions.

CAUTION NOTICE: This American National Standard may be revised or withdrawn at any time. The procedures of the American National Standards Institute require that action be taken periodically to reaffirm, revise, or withdraw this standard no later than five years from the date of publication. Purchasers of American National Standards may receive current information on all standards by calling or writing the American National Standards Institute.

Published by

**Laser Institute of America
13501 Ingenuity Drive, Suite 128
Orlando, FL 32826**

ISBN-13: 978-0-912035-65-9 & ISBN-10: 0-912035-65-X

Copyright © 2007 by Laser Institute of America.
All rights reserved.

No part of this publication may be copied or reproduced in any form, including an electronic retrieval system or be made available on the Internet, a public network, by satellite or otherwise, without the prior written permission of the publisher.

Printed in the United States of America

CONTENTS

| SECTION | PAGE |
|--|------|
| 1. General..... | 1 |
| 1.1 Scope..... | 1 |
| 1.2 Application..... | 1 |
| 1.3 Laser Safety Programs..... | 3 |
| 2. Definitions..... | 5 |
| 3. Hazard Evaluation and Classification..... | 15 |
| 3.1 General..... | 15 |
| 3.2 Laser Considerations..... | 16 |
| 3.3 Laser and Laser System Hazard Classification Definitions..... | 18 |
| 3.4 Environment in Which the Laser is Used..... | 20 |
| 3.5 Personnel..... | 22 |
| 4. Control Measures..... | 23 |
| 4.1 General Considerations..... | 23 |
| 4.2 Substitution of Alternate Control Measures (Class 3B or Class 4)..... | 27 |
| 4.3 Engineering Controls..... | 27 |
| 4.4 Administrative and Procedural Controls (Class 3B and Class 4)..... | 36 |
| 4.5 Special Considerations..... | 39 |
| 4.6 Protective Equipment..... | 42 |
| 4.7 Area Warning Signs and Labels..... | 48 |
| 5. Education and Training..... | 51 |
| 5.1 General..... | 51 |
| 5.2 Refresher Training..... | 52 |
| 5.3 Trainer Qualifications..... | 52 |
| 5.4 LSO Training..... | 52 |
| 5.5 User Training..... | 53 |
| 6. Medical Examinations..... | 53 |
| 6.1 Examinations Following a Suspected or Actual Laser-Induced Injury..... | 53 |
| 6.2 Medical Surveillance..... | 53 |
| 6.3 General Procedures..... | 54 |
| 6.4 Frequency of Medical Examinations..... | 54 |
| 7. Non-Beam Hazards..... | 54 |
| 7.1 General..... | 54 |
| 7.2 Physical Agents..... | 55 |
| 7.3 Chemical Agents..... | 58 |
| 7.4 Biological Agents..... | 60 |
| 7.5 Human Factors..... | 61 |
| 8. Criteria for Exposures of Eye and Skin..... | 62 |
| 8.1 Ocular Exposures From Point Sources and Extended Sources..... | 62 |
| 8.2 MPE for Ocular Exposures..... | 63 |

| SECTION | PAGE |
|---|------|
| 8.3 Special Qualifications for Ocular Exposures..... | 66 |
| 8.4 MPE for Skin Exposure to a Laser Beam..... | 66 |
| 9. Measurements..... | 67 |
| 9.1 General..... | 67 |
| 9.2 Point Source and Extended Source Measurements..... | 68 |
| 9.3 Instruments..... | 69 |
| 10. Revision of Standards Referred to in this Document..... | 69 |
| 10.1 ANSI Standards..... | 69 |
| 10.2 Other Standards and Codes..... | 69 |
| Tables | |
| Table 1. Requirements by Laser Classification..... | 3 |
| Table 2. Recommended Limiting Exposure Durations for CW and Repetitive-Pulse MPE Calculations..... | 71 |
| Table 3. Diffusely Reflected Beam Energy in Joules that does not Exceed the MPE .. | 72 |
| Table 4. Simplified Method for Selecting Laser Eye Protection for Point Source Viewing (Wavelengths Between 0.400 and 1.400 μm)..... | 73 |
| Table 5a. Maximum Permissible Exposure (MPE) for Point Source Ocular Exposure to a Laser Beam..... | 74 |
| Table 5b. Maximum Permissible Exposure (MPE) for Extended Source Ocular Exposure..... | 75 |
| Table 6. Parameters and Correction Factors..... | 76 |
| Table 7. Maximum Permissible Exposure (MPE) for Skin Exposure to a Laser Beam..... | 77 |
| Table 8a. Limiting Apertures (Irradiance and Radiant Exposure) and Limiting Cone Angles γ (Radiance and Integrated Radiance) for Hazard Evaluation..... | 78 |
| Table 8b. Limiting Apertures for AEL Determination..... | 78 |
| Table 9. Measurement Apertures for Laser Classification..... | 79 |
| Table 10. Control Measures for the Seven Laser Classes..... | 80 |
| Table 11a. Summary of Area Warning Signs..... | 82 |
| Table 11b. Summary of Labeling Requirements..... | 83 |
| Table 11c. Summary of Protective Equipment Labeling..... | 83 |
| Figures | |
| Figure 1a. Sample Warning Sign for Class 2 and Class 2M Lasers..... | 84 |
| Figure 1b. Sample Warning Sign for Class 3R, Class 3B, and Class 4 Lasers..... | 85 |
| Figure 1c. IEC Warning Logo and Information Label..... | 86 |
| Figure 1d. Sample Warning Sign for Facility Policy, for example, Outside a Temporary Laser Controlled Area During Periods of Service..... | 87 |
| Figure 2a. Area/Entryway Safety Controls for Class 4 Lasers Utilizing Entryway Interlocks..... | 88 |
| Figure 2b. Entryway Safety Controls for Class 4 Lasers without Entryway Interlocks... | 89 |
| Figure 2c. Unsupervised Laser Installation for Demonstration Laser..... | 90 |
| Figure 2d. Supervised Laser Installation for Demonstration Laser..... | 91 |
| Figure 2e. Supervised Laser Installation for Demonstration Laser..... | 92 |

| SECTION | PAGE |
|--|------|
| Figure 3. Limiting Cone Angle γ , Photochemical MPEs..... | 93 |
| Figure 4. Point Source MPEs for Visible and Near Infrared Pulsed Sources (Wavelengths from 0.400 to 1.400 μm) | 94 |
| Figure 5. MPE for Ultraviolet Radiation (Small and Extended Sources) for Exposure Duration from 10^{-9} to 3×10^4 s for Ocular Exposure and 10^{-9} to 10^3 s for Skin Exposure..... | 95 |
| Figure 6. MPE for Ultraviolet (Wavelengths from 0.315 to 0.400 μm) and Infrared Radiation (Wavelengths from 1.400 μm to 1mm) for Single Pulses or Continuous Exposure (Small or Extended Sources) | 96 |
| Figure 7. MPE for Ocular Exposure to Visible Laser Radiation (Wavelengths from 0.400 to 0.700 μm) for Single Pulses or Continuous Exposure (Small or Extended Sources)..... | 97 |
| Figure 8a. Correction Factor C_A used to Determine the MPE for Wavelengths from 0.400 to 1.400 μm | 98 |
| Figure 8b. Correction Factor C_C used to Determine the MPE for Wavelengths from 1.050 to 1.400 μm | 99 |
| Figure 8c. Correction Factor C_B used to Determine the MPE for Wavelengths from 0.400 to 0.600 μm | 100 |
| Figure 9a. Correction Factor T_1 Beyond which Photochemical (Rather than Thermal) Effects Determine the MPE for Point Sources for Wavelengths from 0.450 to 0.500 μm | 101 |
| Figure 9b. Correction Factor T_2 used to Determine the Extended Source MPE based on Thermal Effects for Exposure Durations Greater than T_2 | 102 |
| Figure 10a. Ocular Point Source MPE ($\alpha \leq 1.5$ mrad) for Visible and Near Infrared Laser Radiation (Wavelengths from 0.400 to 1.400 μm)..... | 103 |
| Figure 10b. Ocular Extended Source MPE ($\alpha = 3.0$ mrad) for Visible and Near Infrared Laser Radiation (Wavelengths from 0.400 to 1.400 μm)..... | 104 |
| Figure 10c. Ocular Extended Source MPE ($\alpha \leq 11$ mrad) for Visible and Near Infrared Laser Radiation (Wavelengths from 0.400 to 1.400 μm)..... | 105 |
| Figure 10d. Ocular Extended Source MPE ($\alpha = 25$ mrad) for Visible and Near Infrared Laser Radiation (Wavelengths from 0.400 to 1.400 μm)..... | 106 |
| Figure 10e. Ocular Extended Source MPE ($\alpha = 50$ mrad) for Visible and Near Infrared Laser Radiation (Wavelengths from 0.400 to 1.400 μm)..... | 107 |
| Figure 11. Ocular Extended Source MPE ($\alpha \geq 110$ mrad) for Visible and Near Infrared Laser Radiation (Wavelengths from 0.400 to 1.400 μm)..... | 108 |
| Figure 12. Ocular Extended Source Radiance MPE ($\alpha \geq 100$ mrad) for Visible and Near Infrared Laser Radiation (Wavelengths from 0.400 to 1.400 μm) for Pulsed or Continuous Exposures less than 1 s | 109 |
| Figure 13. MPE Reduction Factor (C_P) for Repetitive-Pulse Lasers and Multiple Exposures from Scanning Lasers | 110 |

Appendix A

| | |
|---|-----|
| Supplement to Section 1 – Laser Safety Programs | 111 |
| A1. Laser Safety Officer (LSO)..... | 111 |
| A2. Laser Safety Committee..... | 113 |
| A3. Other Personnel Responsibilities | 113 |

Appendix B

| | |
|---|-----|
| Calculations for Hazard Evaluation and Classification..... | 115 |
| B1. General | 115 |
| B2. Symbols..... | 115 |
| B3. Examples of MPE Determination | 118 |
| B4. Laser Classification..... | 133 |
| B5. Central-Beam Irradiance or Radiant Exposure | 143 |
| B6. Formulas and Examples Useful in Evaluation of Various Laser Applications..... | 149 |
| B7. The Brightness (Radiance) Units | 174 |
| B8. Protective Eyewear and Barriers..... | 181 |
| B9. Determination of Extended Source Size | 186 |
| B10. References..... | 188 |

Figures

| | |
|--|-----|
| Figure B1. Intrabeam Viewing – Direct (Primary) Beam | 190 |
| Figure B2. Flat-Top Beam Shape Compared with Gaussian Beam | 190 |
| Figure B3. Intrabeam Viewing – Specularly Reflected..... | 191 |
| Figure B4. Viewing Diffuse Reflections | 192 |
| Figure B5. Beam Expansion with Distance from the Laser | 192 |
| Figure B6. Examples of Use of Laser Range Equations for Determining Nominal Hazard Distances..... | 193 |
| Figure B7. Nominal Hazard Zone for a Diffuse Reflection | 194 |
| Figure B8. Laser Range Equation Nomogram | 195 |
| Figure B9. Diagram of the Laser Arrangement for Example 55 | 196 |
| Figure B10. Determination of Limiting Cone Angle, γ | 197 |

Appendix C

| | |
|---|-----|
| Hazard Evaluation, Classification and Control Measures..... | 198 |
| C1. Alternate Labeling..... | 198 |
| C2. Laser Protection Damage Threshold Evaluation..... | 198 |
| C3. Examples of Typical Lasers or Laser System Classification and MPEs for Selected Lasers | 200 |
| C4. References | 205 |

Tables

| | |
|--|-----|
| Table C1. Typical Laser Classification – Continuous Wave (CW) Point Source Lasers | 201 |
| Table C2. Typical Laser Classification – Single-Pulse Point Source Lasers..... | 202 |

| SECTION | PAGE |
|--|------|
| Table C3a. Point Source MPE for the Eye for Selected CW Lasers | 203 |
| Table C3b. Point Source MPE for the Skin for Selected CW Lasers | 203 |
| Table C4. Point Source MPE for the Eye and MPE for the Skin for Selected Single-Pulse Lasers | 204 |
| Appendix D | |
| Guide for Organization and Implementation of Employee Laser Safety Training Programs..... | 207 |
| D1. Employee Training..... | 207 |
| D2. References..... | 209 |
| Appendix E | |
| Medical Examinations..... | 211 |
| E1. Medical Referral Following Suspected or Known Laser Injury | 211 |
| E2. Medical Surveillance Examinations..... | 211 |
| E3. Medical Examinations..... | 212 |
| E4. Records and Record Retention..... | 213 |
| E5. Access to Records | 214 |
| E6. Epidemiologic Studies..... | 214 |
| E7. References | 214 |
| Appendix F | |
| Non-Beam Hazards | 216 |
| F1. Physical Agents | 216 |
| F2. Chemical Agents..... | 217 |
| F3. Biological Agents | 219 |
| F4. References | 220 |
| Tables | |
| Table F1a. Laser Generated Air Contaminant (LGAC) Thresholds..... | 230 |
| Table F1b. Laser Generated Airborne Contaminants..... | 230 |
| Table F1c. Control Measures for Laser Generated Air Contaminants (LGAC)..... | 234 |
| Appendix G | |
| Biological Effects of the Eye and Skin | 235 |
| G1. Minimal Biological Effects of Laser Radiation on the Eye..... | 235 |
| G2. Biological Effects of Laser Radiation on the Skin..... | 238 |
| Appendix H | |
| Laser Products Classified Under Previous Standards | 241 |
| Table H1. Diameters of the Measurement Apertures and Minimum Distance from Apparent Source Used in IEC 60825-1: 2001 | 243 |
| Table H2a. Comparison of National and International Standards for Classification | 244 |
| Index | 246 |

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

A

α_{\max} 5, 62, 67, 76, 116, 166
 α_{\min} 5-6, 10-12, 45, 62, 66-67, 76, 116-117, 133, 138, 140, 162, 166, 170, 178, 181
 access panel 29
 accessible emission limit 5, 10, 16-21, 26, 67-68, 78, 134-144, 156-157, 184, 202-203
 AEL *see* accessible emission limit
 aided viewing 1, 7, 11, 17-18, 117, 134-135, 137-143, 162, 170, 185, 187-189, 242
 alignment procedures 37-38, 45, 201
 alpha max *see* α_{\max}
 alpha min *see* α_{\min}
 alternate control measures 27, 113
 authorized personnel 4, 6, 28, 34, 37
 aversion response 1, 2, 6, 18, 64, 125, 209, 242, 245

B

barrier 9, 27, 34, 47-48, 55, 186-187, 200-201
 beam conduit 36, 171
 beam diameter 6, 14, 18, 44, 121, 135-138, 141-142, 144-148, 150-153, 156-159, 161-163, 165, 167, 169, 170, 173, 176, 180, 183-189, 193, 242-243
 beam termination 29, 42

C

C_A 6, 20, 72, 74-77, 99, 116, 122, 135-136, 146, 167-169, 188, 225
 Caution 49-50, 63, 82, 242
 C_B 6, 65-66, 74-76, 101, 116, 177, 179, 181, 202
 C_C 6, 72, 74-76, 100, 116, 123, 168
 C_E 6, 18, 62, 72, 74-76, 117, 122, 133-134, 138-140, 161-162, 166, 168-170, 175-178, 180-181, 188-189

Index

Class 1 1, 3-4, 8-9, 17-19, 21, 25, 28, 30, 36-38, 50-53, 112, 114, 134-144, 156, 184, 201-203, 208-209, 242-243, 245-246
 Class 1M 1, 3, 9, 17-19, 25, 37, 51-53, 112, 134, 139, 141, 208-209, 242, 245
 Class 2 1-3, 9, 18-19, 25, 37, 39, 42, 48-53, 85, 112, 134, 157, 202, 208-210, 242-243, 245-246
 Class 2M 1, 2, 9, 19, 25, 37, 48-49, 51-53, 112, 134, 208-209, 242, 245
 Class 3a 134, 242-243, 246
 Class 3B 2-5, 9, 17, 19-21, 25-33, 36-40, 42-43, 45, 47-53, 57-58, 68, 80-82, 86, 112-113, 115, 134-137, 141, 143-144, 201, 203, 208, 242-243, 246
 Class 3R 2, 9, 19-20, 25-26, 31, 37, 39, 42, 48-53, 85-86, 112, 134, 136, 139-140, 143, 202, 208-209, 242-243, 246
 Class 4 2-4, 9, 20, 25-26, 28-43, 45, 47-53, 57-58, 68, 80-82, 86, 89-90, 112-113, 115, 134-135, 137, 186, 201-203, 208, 246
 collecting optics 7, 29, 47, 245-246
 confined work space *see* limited workspace
 continuous wave *see* CW
 control measures 1-4, 15-16, 20, 22-28, 30, 32, 38-39, 41-42, 52-54, 58-59, 67, 113-114, 171, 209, 218-220, 232, 243
 correction factors 16, 63, 68, 72, 74-75
 C_P 64, 72, 76, 117, 133, 169
 CW 7, 17-19, 45, 57, 63-66, 71, 73, 78, 117-118, 120, 125, 144, 155, 157, 170-171, 200-202, 204, 206, 213, 231, 233

D
 danger 50
 diffuse reflection 2, 3, 7, 21-22, 37, 45, 62, 72, 117, 133-134, 165, 167-170, 172-174, 176, 186-187, 208

divergence 5-7, 9, 63, 67, 118, 133, 138, 146, 151-153, 157, 161, 172, 184-188, 190
 dual limit 65, 128
 dyes 54, 58-59, 61, 199, 217-220, 225

E

education 26, 38, 52, 113-114, 208-209, 235
 engineering controls 9, 24, 27, 36, 41, 48, 54, 59, 182
 exhaust 48, 59-61, 219-220, 231, 235
 exposure duration 9-10, 14, 17-19, 46, 62-66, 72, 77-79, 96, 119-126, 128, 132-133, 137-138, 141-144, 146, 163-164, 170, 175-178, 180-181, 186, 209, 218, 236, *see also* Table 4a
 extended source *see* large source, *see* large source
 eye protection 23-24, 31, 33, 42, 44-46, 73, 171, 182-183, 199

F

federal laser product performance standard 1, 26-27, 36, 51, 61, 67, 69, 83, 242
 field of view 8, 67-68, 117, 181
 FLPPS *see* federal laser product performance standard

G

γ *see* limiting cone angle

H

hazard evaluation 3-4, 10, 15-16, 20-22, 30, 47, 51-53, 63, 78-79, 112-113, 116, 209

I

infrared 6-8, 13, 19-20, 34, 45, 58, 63, 65-66, 68, 119, 122, 128, 138, 145, 154, 159, 212, 232, 236-237, 239, 242
 interlock 8, 28, 30, 36, 58, 217
 intrabeam 3, 9, 138, 157-158, 161, 163, 185, 187, 190, 200, 246
 invisible laser 37, 134, 201

L

large source 3, 8, 18, 20, 45, 62-63, 66-68, 74, 116, 118-119, 124, 133, 138, 161-162, 165, 167, 175-178, 187, 188
 laser classification 9, 16, 20, 67-68, 79, 142, 201, 209
 laser controlled area 20, 25, 27, 31-35, 38, 41, 50, 80, 83, 88
 laser installation 29, 39, 41, 55, 113, 115, 200, 240
 laser operation 21, 39, 53, 57, 208, 230
 laser personnel 9, 33, 54
 laser pointer 9, 26, 31, 209, 242-243
 laser protective barrier 38, 48, 201
 laser safety officer 2-5, 9, 16, 19-20, 23, 25-41, 46-47, 51-53, 55, 57-58, 60-61, 80-81, 112-115, 183, 208-209, 218-220
 laser generated air contaminants 2, 24, 29, 58-60, 217-220, 223, 226, 231, 233, 235
 LGAC *see* laser generated air contaminants
 limited work space 17, 61
 limiting aperture 10, 17, 44, 62, 65, 68, 74-75, 77-78, 132, 134-137, 141-148, 150, 156-161, 183-184, 203
 limiting cone angle (γ) 10, 18, 62, 75
 limiting exposure duration *see* T_{\max}
 LSO *see* laser safety officer

M

magnifier viewing *see* aided viewing
 maximum permissible exposure *see* MPE
 measurement 2, 7, 10, 13, 17, 19-20, 65, 67-68, 74, 78-79, 117-119, 134-135, 137-143, 147-148, 155, 158-160, 188, 209, 213, 244
 medical surveillance 4, 52-53, 113-114, 212-215
 MPE 6, 8, 10-12, 14, 17-18, 20, 25, 28-31, 33-37, 39-47, 49-51, 62-68, 72, 74-75, 77-78, 80-81, 96-111, 116, 118-134, 136-138, 141-147, 152-153, 155-157, 160-162, 164-171, 173-190, 200, 204-205, 236

multiple pulse 13, 16, 65, *see also*
repetitive pulse

N

Navigable Airspace 35, 80

NHZ 11, 20-22, 30-31, 34-35, 42, 47,
49, 67, 80-81, 165, 170-171, 173, 200

NOHD *see* nominal ocular hazard
distance

nominal hazard zone 11, 116

nominal ocular hazard distance 11, 116,
155

non-beam hazard 11, 23-24, 32, 51-55,
114

O

ocular exposure 6, 43, 63, 116

open beam path 30

optical density 11, 44-48, 117, 183-184,
190

P

photochemical 5-6, 10-11, 14, 18, 24, 62-
65, 67, 72, 74-75, 77, 116-117, 119-120,
128-129, 175, 177-180, 182, 236, *see*
also C_B , T_1 , and \square

plasma radiation 2, 11, 59, 217-218

point source 3, 5-6, 8, 11-12, 17-18, 21,
45, 62, 66-67, 73-74, 95, 102-104, 118-
119, 130, 133, 137-138, 161-162, 165,
168, 177, 186-187, 202-205

protective equipment 23-24, 33-36, 42,
47, 60, 113, 218-220

protective eyewear 14, 32, 37, 42-44, 46-
47, 49, 116-117, 200-201

protective housing 8, 12, 27-28, 30, 35-
36, 38, 57

pulsed 7-8, 12, 14, 17-18, 56, 58, 63, 65,
68, 72, 74-75, 78, 117-118, 134, 136-
137, 155-157, 199, 201, 217-218, 227,
233-234

R

repetitive pulse 13, *see also* multiple
pulse

retinal hazard region 3, 13, 19, 53, 62,
64, 74, 124, 145, 147, 158-159, 161,
166

robotics 61, 207

S

scanning 13, 119, 163, 232

signs and labels 48-50

single pulse 12, 64-65, 71, 73, 78, 118-
119, 122, 124, 128-129, 132, 134, 136-
137, 142-143, 157, 163-164, 167

skin 1-2, 5-6, 8, 10, 23-24, 43-44, 48, 53-
54, 59, 62, 66, 73, 118, 128, 134, 146,
173, 203, 208, 212-215, 218, 234, 237,
239, 240, 245-246

spectator 14

T

T_1 14, 62, 74-76, 102, 119, 177

T_2 14, 65, 74-76, 103, 119, 124, 133,
178, 180-181

telescopic viewing *see* aided viewing or
collecting optics

temporary laser controlled area 31, 35,
41, 50, 80, 88

T_{\max} or T_{MAX} (limiting exposure duration)
10, 14, 17, 19, 63-65, 78, 119, 124-126,
128, 178-179, 181, 202

t_{\min} 14, 20, 64-66, 78, 119, 124, 130-132,
144

training 3-4, 14, 16, 22, 24-27, 35, 37-39,
51-53, 55-56, 113-114, 138, 201, 208,
219-220

U

ultraviolet 7, 13, 15, 46, 48, 63, 68, 119,
128, 199, 212, 214-215, 221-222, 225,
236-237, 240

V

visible laser 21, 22, 34, 37, 45, 66, 75,
116, 120, 123, 134, 137, 145, 157, 158,
165, 166, 167, 169, 176, 201, 242

W

warning 22, 25, 26, 28, 31, 32, 33, 34,
36, 38, 41, 49, 50, 51, 56, 82, 201, 210,
217



Laser Institute of America

Laser Applications and Safety

Founded in 1968, the Laser Institute of America (LIA) is the professional membership society dedicated to fostering lasers, laser applications, and laser safety worldwide. Serving the industrial, medical, research and government communities, LIA offers technical information and networking opportunities to laser users around the globe.

The LIA is the secretariat and publisher of the American National Standards Institute (ANSI) Z136 series of the laser safety standards. These documents provide a thorough set of guidelines for implementing a safe laser program. The ANSI Z136 series is recognized by OSHA, and is the authoritative series of laser safety documents in the United States. LIA also offers a wide array of products and services including safety and application publications, training videos, signs and labels, laser safety officer training, and conferences.

Laser Institute of America members receive the Journal of Laser Applications[®] and the LIA Today newsletter throughout the year. Furthermore, every member receives a membership card, an annual Membership Directory, and substantial discounts on all LIA courses, publications, and conferences.

For more information or to receive a free catalog, contact the LIA.

CONTACT INFORMATION

Publications

pubs@laserinstitute.org

Membership

lia@laserinstitute.org

Conferences

conferences@laserinstitute.org

Education/Training

courses@laserinstitute.org

Journal of Laser Applications

jla@laserinstitute.org

General

lia@laserinstitute.org

Laser Institute of America

13501 Ingenuity Drive, Suite 128

Orlando, FL 32826

Phone: (407) 380-1553 · Fax: (407) 380-5588

lia@laserinstitute.org · www.laserinstitute.org

American National Standard

The standard in this booklet is one of more than 10,000 standards approved to date by the American National Standard Institute.

The Standards Institute provides the machinery for creating voluntary standards. It serves to eliminate duplication of standards activities and to weld conflicting standards into single, nationally accepted standards under the designation "American National Standards."

Each standard represents general agreement among maker, seller, and user groups as to the best current practices with regard to some specific problem. Thus the completed standards cut across the whole fabric of production, distribution, and consumption of goods and services. American National Standards, by reason of Institute procedures, reflect a national consensus of manufacturers, consumers, and scientific, technical, and professional organizations, and government agencies. The completed standards are used widely by industry as well as commerce and often by municipal, state, and federal governments.

The Standards Institute, under whose auspices this work is being done, is the United States clearinghouse and coordinating body for voluntary standards activity on the national level. It is a federation of trade associations, technical societies, professional groups, and consumer organizations. Some 1000 companies are affiliated with the Institute as company members.

The American National Standards Institute is the United States member of the International Organization for Standardization (ISO) and International Electro-technical Commission (IEC). Through these channels U.S. standards interests make their position felt on the international level. American National Standards are on file in the libraries of the national standard bodies of more than 60 countries.

Secretariat & Publisher



**Laser Institute
of America**



**13501 Ingenuity Drive, Suite 128
Orlando, FL 32826
407.380.1553
Fax: 407.380.5588
www.laserinstitute.org**