American National Standard

American National Standard for Safe Use of Lasers in Research, Development, or Testing

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American National Standard for Safe Use of Lasers in Research, Development, or Testing

Secretariat
Laser Institute of America

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American National Standard

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American National Standard for Safe Use of Lasers in Research, Development, or Testing

1. General

1.1 Scope.

This standard provides guidance and recommendations for the safe use of lasers and laser systems that operate at wavelengths between 180 nm ultraviolet (UV) and 1 mm (1000 µm) infrared (IR), used to conduct research, development, or testing environments predominantly in an indoor setting. Use of this standard requires an assigned laser supervisor or laser safety officer (LSO).

1.2 Application.

The objective of this standard is to provide reasonable and adequate guidance for the safe use of lasers and laser systems in research, development, and testing environments when requirements in the ANSI Z136.1[1, 2] standard may not be practical, for example, where safety controls required for commercial lasers may be either missing, nonexistent, or disabled. Similarly, in testing environments, lasers or laser systems may be operated in conditions or protocols different from normal operation, including access to levels of laser radiation higher than the accessible emission limits (AEL) for the assigned product class.

This is accomplished by first classifying the lasers and laser systems according to their relative hazards and then specifying control measures based upon their relative hazards and conditions of use. For most commercial lasers, this procedure eliminates the need for laser radiation measurements. For lasers and laser systems built by users, radiation measurements may be required to help classify the laser or laser system. For laser classification, the Federal Laser Product Performance Standard (FLPPS), US 21CFR1040.10 and 1040.11[3] should be followed.

1.2.1 ANSI Z136.1 Deviations. The ANSI Z136.1 (latest revision) standard supports this application-specific standard by providing the quantitative methods for hazard analysis and the maximum permissible exposure (MPE) values for optical radiation exposure. Other application-specific standards within the ANSI Z136 series may deviate from the requirements of this standard. It is the responsibility of the LSO to review and use the applicable standards in the series for their actual condition of use.

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[1] ANSI Z136.1, American National Standard for Safe Use of Lasers.

[2] When reference to a standard, regulation, or order is followed by a date, for example, Z136.1-2014, the reference is to that specific document. When the reference to a standard, regulation or order is not followed by a date, for example, Z136.2, FAA order JO 7400.2, it means the latest revision of that document.

[3] CFR Title 21, Chapter I (Food and Drug Administration, Department of Health and Human Services), Subchapter J (Radiological Health), Part 1040.10 (Laser Products), and Part 1040.11 (Specific Purpose Laser Products).

have a greater risk of laser radiation exposure than that of a routine laser used in an industrial setting.

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

1.3.3 Personnel Responsibilities. The LSO should identify the different laser user(s) at their facility based upon their function, activities, and the probability for exposure to optical radiation and NBH. The employer's written laser safety program and standard operating procedures (SOP) need to delineate the responsibilities and expectations required for each type of identified user to comply with the provisions of the program.

1.3.3.1 Employees. Employees who work with lasers or laser systems and their supervisors assume primary responsibility for the safe use of the lasers or laser systems they operate and control. Suggested responsibilities for these individuals are provided in Appendix A.

1.3.3.2 LSO. The LSO should develop, document, and enforce the laser safety program and provide training and expertise to individuals identified in the program.

1.3.3.3 Procurement agents. Procurement agents or other individuals designated by the employer to review and approve laser and laser system purchases should contact the LSO to aid in the implementation of the laser safety program.

1.3.3.4 Installation personnel. Individuals installing room access interlocks, fabricating, altering, or installing a Class 3B or 4 laser or laser system, or a system incorporating an embedded Class 3B or 4 laser, should contact the LSO prior to energizing any such laser or laser system 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
ALSO – assistant laser safety officer
ANSI – American National Standards Institute
ASC – accredited standards committee
ASE – amplified spontaneous emission
BLSO – back-up laser safety officer
CCD – charge coupled device, for example, image sensor
CDRH – Center for Devices and Radiological Health (USA)
CFR – Code of Federal Regulations
CPA – chirped-pulse amplification
CW – continuous wave
DLSO – deputy laser safety officer
DM – deformable mirror
DOE – Department of Energy
EHS – environmental health and safety

Examples: A public area with embedded laser systems, or displays, such as a museum exhibit or a biotechnology lab using Class 1 laser products, for example, gene sequencer cell sorters.

b) **Restricted location:** Access is granted for authorized people and limited for the general public through administrative and engineering control measures. Laser radiation hazards at Class 3B levels or greater may be present and control measures are required. Administrative controls include posted warning signs, attending training, and following established SOPs for a laser system(s). Engineering controls include access control measures such as lockable doors, barriers, defeatable interlocks, and curtains to prevent laser radiation from leaving the restricted location.

Example: A research laboratory or fabrication area containing Class 3B or 4 lasers.

c) **Controlled location:** Access, occupancy, and activities of people within are subject to strict control and supervision. By inference, controlled locations are restricted locations with laser radiation hazards at Class 4 with additional control measures specified by the laser operator, the LSO, and the employer or management.

Example: A research & development (R&D) area with positive access control and video surveillance, such as a clean room.

d) **Exclusion location:** Occupancy by people is possible, but is denied by the LSO during the operation of the laser system.

Example: A free electron laser target or experimental room or beam path, or an area with an open kilowatt beam path.

e) **Inaccessible location:** Occupancy is not possible due to its dimensions.

Example: An enclosed beam path on an optical table or open path of a laser scanning confocal microscope.

3.5 Possible Personnel Exposure.

The LSO shall consider the people who may be in the vicinity of the laser, its direct or scattered emitted beams, NBH, and whether or not to adopt additional control measures.

4. Control Measures

4.1 General Considerations.

Control measures shall be devised to reduce the possibility of exposure to the eye and skin from hazardous levels of laser radiation and other hazards associated with lasers and laser systems during operation, service, and maintenance

Engineering controls, including items incorporated into the laser or laser system or designed into the installation by the user, shall be given primary consideration in instituting a control measure program for limiting access to laser radiation. Enclosure of the laser equipment and

4.4.2.1 Training at User Facilities. Due to the nature of user facilities, users may spend only a short length of time at the facility. Users may not be familiar with local safety codes; therefore, they should complete safety orientation including requirements to operate lasers, sweep procedures, and limitations on their activities in addition to general safety, such as evacuation routes. Visiting users under constant supervision of an authorized laser user may be exempt from required laser safety training if that is the facility policy. However, all laser users having access to open beam laser radiation, regardless of the visit duration, shall have met all the requirements of an authorized user.

4.4.2.2 In-house Supervisor. Because of the nature of user facilities, an in-house supervisor should be assigned to experimental set ups, such as beamlines, experimental halls, and laser labs. It is the responsibility of this individual to ensure all the temporary users who will have potential exposure to laser radiation take all required instructional courses, follow SOPs, and understand the requirements of the user facilities safety culture. This person may have the title of Laser Safety Supervisor, Beamline Scientist, or Lead Scientist.

4.4.3 Laser Optical Fiber Use (All Classes). Laser systems, where the radiation is transmitted through an optical fiber, shall be considered enclosed with the optical cable forming part of the enclosure. If disconnection of a connector results in accessible radiation reduced to below the applicable MPE. **.** by fiber loss or engineering controls, then connection or disconnection may take place in an uncontrolled area and no other control measures are required. When the system provides access to laser radiation above the applicable MPE via a connector, the conditions in 4.4.3.1 or 4.4.3.2 shall apply.

NOTE—The use of NHZ and nominal ocular hazard distance (NOHD) calculations can be taken into consideration in determining if an LCA should be established during connection or disconnection of fibers.

4.4.3.1 Connection or Disconnection. Connection or disconnection during operation shall take place in an LCA. Optical fibers or optical fiber cables attached to Class 3B and 4 lasers or laser systems should not be disconnected prior to termination of transmission of the beam into the fiber. In cases when laser radiation above the applicable MPE can be made accessible by disconnection of a connector, the connector shall bear a label or tag bearing the words "Hazardous Laser Radiation when Disconnected", or a similar message. Procedures, such as automatic power reduction, should be instituted to prevent inadvertent personnel exposure from an unterminated or severed fiber. When the connection or disconnection is only possible with the use of a specific tool, this is equivalent to an interlocked system.

4.4.3.2 Fiber Optic Safety Guidelines.

a) Do not smoke in work areas.

b) Do not look straight into the end of a fiber.

c) Always work with fiber optics as if they were active or live.

d) The NHZ from a fiber with a microlens is similar to that of a collimated beam.

e) Make sure fibers are terminated into a power meter or with suitable end caps.

7.2.4 Extended Work Hours. The LSO needs to recognize that in many research environments, excessive work hours can be the norm. These extended hours can be from project or self-imposed work pressures. Fatigue is a common cause, or at least a contributing factor, in all types of accidents, including those involving lasers. Many of the reported laser accidents have occurred after normal work hours due in part to fatigue. The issue of fatigue associated with extended work hours should be brought up to laser users to make them aware of the risk they present to themselves, equipment, and others when project pressures, real or self-imposed, expand the work and lead to fatigue.

7.2.5 Building Codes. Consideration should be given to local building codes that many times reflect local natural disasters, as well as local fire codes, ventilation controls, chemical storage, and seismic controls that affect room set-up.

NOTE—Wattage line is optional.

NOTE—Wattage line is optional.

Figure 1a. Sample Warning Sign for Class 3B and 4 Lasers

NOTE—Wattage line is optional.

Figure 1b. Sample Warning Sign Class 1M, 2M, 2 and 3R Lasers

Appendix B
Frequently Asked Questions

B1. Introduction

There are several questions concerning this standard that either repeatedly come up in LSO training classes or should be asked. This appendix has been created to provide the reader with a greater understanding of the standard and address frequently asked questions about laser safety programs and laser technology.

B2. Laser Safety Programs – Frequently Asked Questions

1. Is a laser inventory required?

There is no specific section in the ANSI Z136 standards that requires the LSO to maintain a laser inventory. An inventory of Class 3B and 4 lasers is advantageous for the LSO and laser user community. Some laser-safety calculation software also can maintain an inventory.

2. Where can I find MPE values?

There are two recommended sources, ANSI Z136.1 (latest revision) and International Commission on Non-Ionizing Radiation Protection (ICNIRP). ANSI Z136.1 (latest revision) is the primary source. It provides tables of MPE values and information on how to use them, for example, determining OD requirements, NHZ boundaries, and classification. The ICNIRP MPE values can be downloaded from the ICNIRP website[19]. ICNIRP also publishes the MPEs in the *Health Physics Journal*[20]. There may be some differences between the ANSI Z136 and the ICNIRP MPE values. Appendix B of ANSI Z136.1-2014 also provides many examples of calculations.

3. What is the case for and against Class 5?

The output of lasers has been steadily increasing in terms of emission power or energy and beam quality. These two factors contribute to the ability of achieving high intensity levels when brought to focus. Interaction with the target material can breach certain thresholds generating secondary hazards such as true plasma and ionizing radiation, or new LGACs different from those liberated during material melting or vaporization at lower intensity levels. It has been asked if there should be a laser classification above Class 4 for certain lasers and laser systems. The current hazard classification scheme groups biological breakpoints with respective control measures. It has been historically problematic for the Z136 Standards Committee to sufficiently identify and agree upon the next breakpoint where Class 5 would start and what it would cover. Primary control measures for the laser beam hazards are proportional to the hazard and risk they represent. Secondary effects achieved or possible with very high-power lasers fall under NBH and their control measures. It is incumbent upon the LSO to ensure these are identified and addressed accordingly with control measures that are robust and reliable enough to safeguard personnel. Normally such non-beam control measures

[19] www.icnirp.org/en/publications/index.html

[20] www.icnirp.org/cms/upload/publications/ICNIRPLaser180gdl_2013.pdf

The information contained in this appendix is not part of this American National Standard (ANS) and has not been processed in accordance with ANSI's requirements for an ANS. As such, this appendix may contain material that has not been subjected to public review or a consensus process. In addition, it does not contain requirements necessary for conformance to this standard. It is intended for information only.

Appendix F
High Intensity Lasers (HIL) and High Energy Lasers (HEL)

F1. Introduction

The development, use, and accessibility of HIL or lasers with outputs in the kilowatt range and irradiances above 10^{17} W/cm^2 have exploded upon the R&D arena. Examples include research in terawatt and petawatt lasers, amplification of few-cycle pulses, laser fusion technologies, extreme ultraviolet (EUV) and x-ray sources based on lasers, plasmas in ultrahigh fields, and advances in attosecond science, laser weapons, and relativistic nonlinear phenomena.

These devices present another unique challenge and often involve the LSO in collaboration with other safety professionals, for example, health physicists. The goal of this appendix is to present several topics and controls that the LSO may need to address. The topics below are not all inclusive and may not apply in all situations but are certainly ones that the LSO should be aware of as HIL become more common. As a reminder, terawatt and petawatt systems are no longer exclusive to national research facilities but can be ordered from commercial firms for delivery.

The majority of the safety concerns and control measures that follow are similar to those that would apply to any Class 4 laser system capable of producing extremely high irradiance or radiant energy that can produce new secondary hazards and concerns for safety. This warrants a detailed evaluation of the hazards, their scale, potential for exposure to personnel, and the respective safety control measures applied to these systems, so that any remaining residual risk is as low as reasonably acceptable and practicable.

F2. HIL Safety Considerations

HIL use facilities may need to consider the following items:

a) Interlocks.
b) Skin protection.
c) Two-person rule.
d) Personnel exclusion.
e) Beam blocks or dumps.
f) Optical damage sensors.
g) Laser turn-on checklists.
h) Laser shutter indicator lights.
i) Concern over back reflections.
j) Detailed alignment procedures.

APPENDIX

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Form H2.C
Risk Assessment Form

This form must be completed with respect to each registered laser used on institutional premises.

______________________	______________________	______________________
Lab Location	**Department**	**Principal Investigator**

A: Laser Associated Hazards and Existing Controls	
1. Has the laser been registered with the institution's Laser Safety Officer?	☐Yes ☐No
2. Give brief details of the laser to be used, and its location. If this form is used to record a review of a previous assessment, you may refer to that assessment and just note changes.	Manufacturer: Model: Serial No.: Inventory ID: Wavelength(s): Output: Other: (Open beam, embedded, enclosed, fiber optic)
3. Give a summary of the work activity.	*Example summary: Used for experiments using the technique of particle image velocimetry and as a coherent light source for spectroscopic experiments*
State whether open beam work is proposed.	*Example entry: Open beam work in the main, although the beam path is shielded where possible*

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The LIA is the secretariat to ASC Z136 and publisher of the American National Standards Institute approved Z136 series of 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. LIA members receive substantial discounts on all LIA courses, publications, and conferences. We invite you to become a member and be part of the LIA experience.

For more information, contact the LIA.

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