American National Standard

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American National Standard Recommended Practice for Laser Safety Measurements for Classification and Hazard Evaluation

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American National Standard Recommended Practice for Laser Safety Measurements for Classification and Hazard Evaluation

Secretariat
Laser Institute of America

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American National Standard

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American National Standard Recommended Practice for Laser Safety Measurements for Classification and Hazard Evaluation

1. General

1.1 Scope.

This document provides practical guidance for measurement procedures used for classification and hazard evaluation of lasers. This document is intended to provide guidance for manufacturers, laser safety officers (LSOs), and trained laser users.

1.2 Application.

This document addresses only the measurement of those parameters associated with the laser output beam required for classification and hazard evaluation. Evaluation consists of comparing measured exposures with the maximum permissible exposure (MPE) values found in the American National Standards Institute (ANSI) Z136.1 *American National Standard for Safe Use of Lasers* (latest revision). The MPE is based on the ability of the direct, reflected, or scattered laser beam to cause biological damage to the eye or skin. Classification consists of comparing accessible radiation levels with accessible emission limits (AEL), such as those in the latest editions of the ANSI Z136.1, the Code of Federal Regulations (CFR) 21 CFR 1040.10 and 21 CFR 1040.11, or the International Electrotechnical Commission (IEC) 60825-1 laser safety standard. The two CFR sections are commonly known as the Federal Laser Product Performance Standard (FLPPS) and are referred to as such by the Occupational Safety and Health Administration (OSHA) and others in reference to laser hazards and safety measures.

Regulations such as in the FLPPS or IEC 60825-1 require laser manufacturers to self-certify their laser products. Other circumstances under which measurements for laser classification or hazard evaluation may be appropriate are when:

a) the manufacturer's information is not available,
b) the laser or laser system has not been classified,
c) suspected malfunctions or alterations to a system may have changed its classification or the potential hazard,
d) there is uncertainty in the laser parameters that determine the optical density (OD) requirements for laser eyewear protection (LEP),
e) the borders of a nominal hazard zone (NHZ) cannot be determined from the laser controlled area (LCA) configuration, or
f) it is useful to determine a smaller NHZ than what the LCA configuration provides.

For laser manufacturers and developers of lasers modified for specific application in the research environment, measurements are important, but other laser users may find these measurement techniques useful or even needed as well.

If there is a potential for exposure to laser radiation within the NHZ, then ANSI Z136.1 (latest revision) should be consulted for appropriate control requirements, and the measurements should be attempted only by personnel experienced in laser technology and radiometry. Routine survey measurements for hazard assessment of lasers or laser systems are neither required nor advisable when the laser classifications are known, except as noted above.

The suggested procedure for using this recommended practice is to use ANSI Z136.1 (latest revision) to obtain necessary information such as the MPE, AEL, aperture sizes, and measurement distances, and to determine the controls for mitigating laser safety and non-beam hazards. Additionally, the guidance should be used when performing measurements needed for laser classification or hazard evaluation.

Consult ANSI Z136.1 (latest revision) for information pertaining to non-beam hazards associated with lasers and laser systems. Lasers or laser systems certified for a specific class by a manufacturer in accordance with the FLPPS or IEC 60825-1 standard may be considered as fulfilling all classification procedures of this recommended practice. In cases where the laser or laser system classification is not provided or where the class may change because of system alteration or the addition or deletion of engineering control measures, the LSO should ensure that reclassification of the laser or laser system is in accordance with ANSI Z136.1 (latest revision), FLPPS, or IEC 60825-1.

2. Acronyms, Variable Symbols, and Definitions

2.1 Acronyms and Abbreviations Used in this Standard.

AEL – accessible emission limit
ANSI – American National Standards Institute
CIE – International Commission on Illumination
CW – continuous wave
CCD – charge coupled device
D^* – normalized detectivity
DPSS – diode-pumped solid-state
ECPR – electrically calibrated pyroelectric radiometer
EMP – electromagnetic pulse
FIR – far infrared
FLPPS – Federal Laser Product Performance Standard
FOV – field of view
IEC – International Electrotechnical Commission
IR – infrared
ISO – International Organization for Standardization
LED – light emitting diode
LEP – laser eyewear protection
LSO – laser safety officer
MPE – maximum permissible exposure
NEJ – noise equivalent joule

4. Laser Measurements

4.1 General Considerations.

Measurements are performed to obtain values for quantities used in calculations of classification or hazard. These quantities can be categorized by the characteristics of the laser beam. The MPE used for classification, through the AEL, and hazard evaluation depends on a few spectral, temporal, and spatial characteristics of the laser beam. These are wavelength, pulse duration and PRF, and apparent visual angle. The radiometric and spatial characteristics of the laser beam determine the accessible exposure for classification and hazard calculations. The radiometric characteristics are power or irradiance for CW lasers, and energy or radiant exposure for pulsed lasers. There are many relevant spatial characteristics including:

a) divergence,
b) beam quality,
c) angular subtense,
d) waist location and size, and
e) beam profile (size and shape).

Measurement techniques for the spectral, temporal, radiometric, and spatial characteristics are detailed in the following sections.

4.2 Wavelength.

The wavelength of the laser is often known or specified by the manufacturer. For example, the wavelength of an Nd:YAG laser is known to be 1064 nm. The wavelength is critical, especially for lasers operating near either end of the retinal hazard region, for lasers that can emit more than one wavelength, and for tunable lasers. The spectral bandwidth can also be very important, for example with ultrashort (<100 fs) lasers. The wavelength can be measured using a wavemeter, optical spectrum analyzer, monochromator, spectrometer, or special wavelength filters. Two considerations are relevant. First, the device used for the measurement must operate at the wavelength of the laser. This includes ensuring any optics in the path of the beam transmit at that wavelength. Second, only a fraction of the beam needs to be measured so that damage to the device from high power lasers can be avoided.

Some lasers may emit radiation at wavelengths other than the primary or intended one, for example, those with frequency doubling. If this is a concern, the wavelength of these emissions should be measured using the considerations of the previous paragraph.

4.3 Temporal Characteristics.

Lasers may emit a single pulse or repetitive pulses. The temporal characteristics of the pulse(s) are duration and repetition frequency. Generally, the temporal characteristics are available from the manufacturer. When it is necessary to measure the time-varying output of a laser, a detector with a time constant of, at most, a tenth of the pulse rise time should be used.

Appendix A
Photobiological Quantities

For all photobiological effects, it is necessary to measure the appropriate radiometric quantity. The surface exposure dose rate is termed the irradiance, with units of watts per square centimeter ($W \cdot cm^{-2}$), and the surface exposure dose is termed the radiant exposure, with units of joules per square centimeter ($J \cdot cm^{-2}$). There are also parallel dose rate and dose concepts within scattering tissue. These quantities are termed fluence rate, with units of watts per square centimeter ($W \cdot cm^{-2}$), and dose within tissue that is termed the fluence, with units of joules per square centimeter ($J \cdot cm^{-2}$). The existence of two terms for the same radiometric unit seems curious and this has confused many scientists with the result that the terms are frequently misused. The concepts are different, and the distinctions are important. The quantities irradiance and radiant exposure are what instruments measure at the exposed surface and follow Lambert's Cosine Law. Fluence rate and fluence include backscattered light and are useful for photochemical calculations within tissue, as in photodynamic therapy. Table A1 provides the principal current internationally standardized radiometric terms and units according to the International Commission on Illumination (CIE).

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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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ANSI provides the machinery for creating voluntary consensus standards. It serves to eliminate duplication of standards activities and to weld conflicting standards into single, nationally accepted standards under the designation “American National Standard.”

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 ANSI 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.

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