

American National Standard

ANSI Z136.7—2008

*American National Standard
for Testing and Labeling of
Laser Protective Equipment*



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



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**American National Standard
for Testing and Labeling of
Laser Protective Equipment**

Secretariat
Laser Institute of America

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**American
National
Standard**

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Foreword (This introduction is not a normative part of ANSI Z136.7-2008, American National Standard for Testing and Labeling of Laser Protective Equipment.)

In 1968, the American National Standards Institute (ANSI) approved the initiation of the Safe Use of Lasers Standards Project under the sponsorship of the Telephone Group.

Prior to 1985, Z136 standards were developed by ANSI Committee Z136 and submitted for approval and issuance as ANSI Z136 standards. Since 1985, Z136 standards are developed by ANSI Accredited Standards Committee (ASC) Z136. A copy of the procedures for development of these standards can be obtained from ASC Z136 Secretariat, Laser Institute of America, 13501 Ingenuity Drive, Suite 128, Orlando, FL 32826 or viewed at www.z136.org.

ASC Z136 is responsible for the development and maintenance of this Standard. In addition to the consensus body, ASC Z136 is composed of standards subcommittees (SSC) and technical subcommittees (TSC) involved in Z136 standards development. At the time of this printing, the following standards and technical subcommittees were active:

SSC-1	Safe Use of Lasers (parent document)
SSC-2	Safe Use of Lasers and LEDs in Telecommunications Applications
SSC-3	Safe Use of Lasers in Health Care Facilities
SSC-4	Measurements and Instrumentation
SSC-5	Safe Use of Lasers in Educational Institutions
SSC-6	Safe Use of Lasers Outdoors
SSC-7	Eyewear and Protective Barriers
SSC-8	Safe Use of Lasers in Research, Development and Testing
SSC-9	Safe Use of Lasers in Manufacturing Environments
SSC-10	Safe Use of Lasers in Entertainment, Displays and Exhibitions
TSC-1	Biological Effects and Medical Surveillance
TSC-2	Hazard Evaluation and Classification
TSC-4	Control Measures and Training
TSC-5	Non-Beam Hazards
TSC-7	Analysis and Applications
EWG	Editorial Working Group

The five standards currently issued are:

ANSI Z136.1-2007, American National Standard for Safe Use of Lasers (replaces ANSI Z136.1-2000)

ANSI Z136.3-2005, American National Standard for Safe Use of Lasers in Health Care Facilities (replaces ANSI Z136.3-1996)

ANSI Z136.4-2005, American National Standard Recommended Practice for Laser Safety Measurements for Hazard Evaluation (first printing)

ANSI Z136.5-2000, American National Standard for Safe Use of Lasers in Educational Institutions (first printing)

ANSI Z136.6-2005, American National Standard for Safe Use of Lasers Outdoors (replaces ANSI Z136.6-2000)

This American National Standard provides guidance for the testing and labeling of laser protective equipment such as laser eye protection, filters, windows, and barriers for use with lasers and laser systems. Emphasis is given to ensuring adequate testing of laser protective eyewear (e.g., absorptive, interference/reflective, and hybrid filter technologies).

This standard has been published as part of the American National Standard Z136 series. This document is the American National Standard Z136.7. This document may be used independently of ANSI Z136.1 in the determination of required retinal angular protection/coverage. Where applicable, tables from ANSI Z136.1 are included. Instances where additional guidance contained in ANSI Z136.1 is required are noted and referenced in the appropriate sections of this document.

This standard is expected to be periodically revised as new information and experience in the use of lasers are gained. Future revisions may have modified content and use of the most current document is highly recommended. While there is considerable compatibility among other existing laser safety standards, some requirements differ among state, federal, and international standards, particularly with respect to signs, symbols, and control measures.

Suggestions for improvements of the standard are welcome. They should be sent to ASC Z136 Secretariat, Laser Institute of America, 13501 Ingenuity Drive, Suite 128, Orlando, FL 32826.

This standard was processed and approved for submittal to ANSI by the Accredited Standards Committee Z136 for Safe Use of Lasers, whose scope covers protection against hazards associated with the use of lasers and optically radiating diodes. Committee approval of the standard does not necessarily imply that all members voted for its approval.

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Z136 standards and recommended practices are developed through a consensus standards development process approved by the American National Standards Institute. The process brings together volunteers representing varied viewpoints and interests to achieve consensus on laser safety related issues. As Secretariat to ASC Z136, the Laser Institute of America (LIA) administers the process and provides financial and clerical support to the committee.

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High-Rez Diagnostics, Inc.	
Institute of Electrical and Electronics Engineers, Inc. (SCC-39)	
International Imaging Industry Association (I3A)	Joseph Greco
L*A*I International	Thomas Lieb
Laser Institute of America	Richard Greene
Laser Safety Consulting, LLC.	Darrell Seeley
Lawrence Livermore National Laboratory	Ken Barat
LFI International	Roberta McHatton
Los Alamos National Laboratory	Connon Odom
National Aeronautics and Space Administration	Guy Camomilli
National Institute of Standards and Technology (NIST)	Randall Scott (Alt)
Power Technology, Inc.	Shao Yang
Rockwell Laser Industries	
Underwriters Laboratories, Inc.	William Burgess
	William Ertle
	Peter Boden
	David Dubiel (Alt)
University of Texas, Southwestern Medical Center	John Hoopman

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US Department of Health and Human Services, Center for Devices and Radiological Health	Jerome Dennis
US Department of Labor, Occupational Safety and Health Administration	Robert Curtis
US Department of the Air Force, Air Force Research Laboratory	Benjamin Rockwell Robert Thomas (Alt)
US Department of the Air Force, Surgeon General's Office	Krista Wenzel Robert Rodgers (1 st Alt) Scott Braley (2 nd Alt)
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The various subcommittees that participated in developing this standard had the following members:

Eyewear and Protective Barriers, SSC-7

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Darrell Seeley
Dale Smith
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Editorial Working Group, EWG
Nikolay Stoev, Chair

David Ermer
Penelope Galoff
Richard Hughes
Bill Janssen
Thomas Johnson
Ami Kestenbaum
Timothy Reed

Barbara Sams
Darrell Seeley
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Sheldon Zimmerman

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American National Standard for Testing and Labeling of Laser Protective Equipment

1. General

1.1 Scope.

This standard provides recommendations for the testing requirements and labeling of protective equipment (devices) designed for use with lasers and laser systems that operate at wavelengths between 180 nm and 1 mm. All appendices are informative.

1.2 Application.

The objective of this standard is to provide reasonable and adequate guidance on the test methods, protocols and specifications for devices used to provide eye protection from lasers and laser systems. Testing procedures are provided in this document to ensure that eyewear, windows, and barriers maintain their specified level of protection throughout the life of the products.

Such protective devices include laser eye protective devices or instrument filters, laser window filters, and laser area protective barriers, screens or beam blocking curtains. Depending on the protective device, laser type, temporal mode of operation and wavelength(s), different test methods may be required.

Other special application standards, e.g., ANSI/ASSE Z87.1 *Occupational and Educational Personal Eye and Face Protection Devices*, will need to be used in conjunction with this standard to provide complete testing of laser protective materials. The recommended stepwise procedure for using this standard is as follows:

1. Determine the type of protective equipment (device); eyewear, barrier, or window.
2. Determine the filter technology used; absorptive, reflective, or hybrid.
3. Determine the material type of eyewear/windows under study: material, metal, plastic, glass, hybrid, etc.
4. Determine the appropriate laser or laser system: continuous wave, Q-switched, or sub-nanosecond, or some combination of pulse durations.
5. Determine the wavelength or wavelength band of the laser protection.
6. Determine the specified optical density or barrier threshold level as identified by the manufacturer at the wavelength in question.

2. Definitions

The definitions of the terms listed below are based on a pragmatic rather than a basic approach. The terms defined are therefore limited to those actually used in this standard and its appendices, 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.

absorption band. An inclusive range of wavelengths within which a material provides attenuation of incident radiant power (e.g., a device labeled "4 OD @ 500-800 nm", has an absorption band from 500 nm to 800 nm where the device must provide at least 4 OD of protection).

Note: accepted abbreviation for optical density is OD.

accessible emission limit (AEL). The maximum accessible emission level permitted within a particular laser class.

accessible optical radiation. Radiation to which it is possible for the human eye or skin to be exposed during normal usage.

acuity. A measure of the eye's ability to perceive detail. 20/20 acuity corresponds to a resolution of 1 arc minute. Conversion factors for commonly used spatial units are presented in Table 1.

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 of ANSI Z136.1-2007 for criteria).

astigmatism. Defined as a difference in refractive power between meridians of a filter or optical device.

as-worn. The position of the lens relative to the line of sight when the eyewear is properly fitted with the user looking straight ahead (see Figures D2, D3 and D4 in Appendix D).

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

average power. The total energy in an exposure or emission divided by the exposure duration.

bandwidth. The inclusive range of wavelengths which are either generated or transmitted or attenuated by a given device, defined at the points where intensity, transmission or attenuation falls to a predetermined level.

barrier (laser safety). Moveable or fixed equipment (devices) used to block or attenuate laser radiation. Typically placed on or around where a laser is in use. See also *laser protective windows, view ports, and barriers*.

barrier threshold level (BTL). The highest irradiance incident on a laser barrier for which no penetration occurs for an exposure of 100 s at a specified exposure diameter.

base curve. Surface curvature of the lens expressed in diopters (D).

beam. A collection of rays that may be parallel, divergent, or convergent.

beam diameter. The distance between diametrically opposed points in that cross-section of a Gaussian beam where the power per unit area is $1/e$ (0.368) times that of the peak power per unit area.

calorimeter. A device for measuring the total amount of energy absorbed from a source of electromagnetic radiation.

center of eye rotation. For practical purposes, the center of eye rotation is a point approximately 14.8 mm behind the apex of the front surface of the cornea (see Figure 1). The center of rotation will change within a small margin based on the type and eccentricity of the executed eye movement.

coherent. A light beam is said to be coherent when the electric vector at any point in it is related to that at any other point by a definite, continuous function.

collimated beam. Effectively, a “parallel” beam of light with very low divergence or convergence.

conformal filter. A reflective filter in which the fringe planes are parallel to the substrate surface.

continuous wave (CW). In this standard, a laser operating with a continuous output for a period greater than or equal to 0.25 s is regarded as a CW laser.

cornea. The transparent outer layer of the human eye which covers the iris and crystalline lens. The cornea is the main refracting element of the eye.

cross fire. A ray passing through the right side (lens) of a protective device and entering the left eye or vice versa.

cylindrical power. Refractive power of a lens oriented along a specific meridian.

design eye point. The intended position of the pupil behind a protective filter.

diffuse reflection. Change in the spatial distribution of a beam of radiation when it is reflected in many directions by a surface or by a medium.

Note: Flat finish paints or rough surfaces will generally produce a diffuse reflection and not a specular reflection. Surfaces that appear diffuse may produce a specular reflection at far infrared wavelengths. The amount and spatial distribution of energy reflected depends on the illuminating wavelength and the surface imperfections.

diopter. A measure of the refractive power of a lens, defined as $1/f_0$, where f_0 is the focal length of the lens in meters.

divergence. In this standard, the divergence is the increase in the diameter of the laser beam with distance from the exit aperture, based on the full angle at the point where the irradiance (or radiant exposure for pulsed laser) is $1/e$ times the maximum value. Symbol: Φ

electromagnetic radiation. The flow of energy consisting of orthogonal vibrating electric and magnetic fields lying transverse to the direction of propagation. Gamma rays, X ray,

ultraviolet, visible, infrared, and radio waves occupy various portions of the electromagnetic spectrum and differ only in frequency, wavelength, or photon energy.

energy. The capacity for doing work. Energy content is commonly used to characterize the output from pulsed lasers, and is generally expressed in joules (J).

eye centered. An interference filter in which the fringe planes are oriented so that the line of sight is always normal to the fringe plane.

eye relief. Distance from the front surface of the cornea to the rear surface of the nearest filter substrate.

face form angle. Angle in the horizontal plane of a lens with respect to a plane perpendicular to the straight-ahead line of sight.

face shield (laser safety). A protective device commonly intended to shield the wearer's face, or portions thereof, in addition to the eyes, from certain hazards.

field of view. The maximum angle that can be viewed through a protective device in the as-worn position.

filter center. The design location of the relaxed state line of sight through a nonconformal interference filter. Location of the filter center with respect to the spectacle frame is defined relative to the half A – B point of the frame.

filter relief. The distance from the pupil plane to the nearest filter plane.

Note: The pupil is 3.54 mm posterior to the front corneal surface.

focal length (f_0). The distance from the secondary nodal point of a lens to the secondary focal point. For a thin lens imaging a distant source, the focal length is the distance between the lens and the focal point.

fluorescence. Emission of electromagnetic radiation resulting from and occurring only during the absorption of radiation from some other source. Usually visible wavelengths are thought of as 'fluorescence', but fluorescence outside the visible spectrum can affect measurements.

focal point. The point toward which radiation converges or from which radiation diverges or appears to diverge.

fovea. The central depression of the macula (see Figure 1). Area of highest acuity.

frame center. The half A - B point of the frame eye wire defined as half of the maximum height and width, respectively, of the lens frame.

frame eye wire. Wire designed to hold the lens in place.

fringe plane. Planes of alternating high and low index of refraction within a filter media.

goggles (laser safety). Laser protective eyewear intended to fit the face surrounding the eyes in order to shield the eyes from certain hazards. Goggles are often designed to be worn over prescription eyeglasses and to seal against the face to provide peripheral protection for the eyes from laser radiation.

half A – B point. The geometric center of the frame eye wire measured in the vertical (A) and horizontal (B) planes.

half-power point. The value on either the leading or trailing edge of a laser pulse at which the power is one-half of its maximum value.

haze. The fraction of incident light that is not transmitted in a straight line, but is scattered. Typically defined as the percentage of light scattered outside of a 2.5 degree cone.

Note: Excessive haze causes blurring.

hertz (Hz). The unit that expresses the frequency of a periodic oscillation in cycles per second.

hybrid filter. A filter that attenuates incoming radiation by combining filter types. The most common hybrid filter combines an absorptive with a reflective filter (i.e., hologram or dielectric stack); however, combinations of reflective filters are becoming more common (i.e., hologram with dielectric).

infrared radiation. For the purposes of this standard, electromagnetic radiation with wavelengths that lie within the range 780 nm to 1 mm.

intrabeam viewing. The viewing condition where the eye is exposed to all or part of a laser beam.

interpupillary distance (IPD). The distance in millimeters between the pupil centers of the user's eyes.

Note: The typical range of IPDs for the 5th to 95th percentile user is 51 to 73 mm.

iris. The circular pigmented structure which lies behind the cornea of the human eye. The aperture in the iris is the pupil.

irradiance (E). Radiant power incident per unit area upon a surface expressed in watts-per-centimeter-squared ($\text{W}\cdot\text{cm}^{-2}$).

joule. A unit of energy. 1 joule = 1 N · m; 1 joule = 1 watt · second.

Lambertian surface. An ideal surface whose emitted or reflected radiance is independent of the viewing angle.

laser. A device that produces radiant energy predominantly by stimulated emission. Laser radiation may be highly coherent temporally, spatially or both. An acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation.

laser damage. A permanent change in optical density afforded by a laser protective device at the damage site.

laser protective windows, view ports and barriers. Absorbing/reflecting devices (e.g., curtains, screens) used to limit the transmission of the laser radiation at or below the MPE.

laser system. An assembly of electrical, mechanical, and optical components which includes a laser.

line of sight (LOS). Line connecting the point of regard/fixation and the center of the entrance pupil of the eye.

luminous transmittance. The spectral transmittance of the lens weighted by the corresponding ordinates of the spectral sensitivity of the CIE (1931) standard

colorimetric observer and by the spectral intensity of a standard illuminant (source must be specified).

macula. The small, uniquely pigmented specialized area of the retina of the eye, which in normal individuals is predominantly employed for acute central vision, i.e., area of best visual acuity.

maximum permissible exposure (MPE). The level of laser radiation to which an unprotected person may be exposed without adverse biological changes in the eye or skin. The criteria for MPE for the eye and skin are detailed in Section 8 of ANSI Z136.1-2007.

modulation transfer function (MTF). A measure of a lens', optical system's, or substrate's ability to transfer spatial information. The test consists of measuring the contrast of the line pairs (grating) of varying spatial frequency through the test substrate.

mrad. 1 milliradian = 1/1000 of a radian.

nasal incidence angle. Any incident ray emanating from the nasal visual field, that is, the hemispheric field located towards the nose, which passes through the cornea and pupil. For the purposes of this document nasal rays will be denoted as a negative (-) incidence angle.

nonconformal filter. A filter geometry in which the fringe planes are not parallel to the substrate surface but rather structured to preferentially reject specific incidence angles.

optical center. The point on the front surface of the lens intersected by the optical axis of the lens.

optical density (D_λ). Logarithm to the base ten of the reciprocal of the transmittance:

$$D_\lambda = \log_{10}(1/\tau_\lambda),$$

where τ_λ is the transmittance at the wavelength of interest.

Note: accepted abbreviation for optical density is OD

pantoscopic tilt. Angle in the vertical plane of a lens with respect to a plane that is perpendicular to the straight-ahead line of sight.

penetration threshold level (PTL). Energy level at which protective device begins to transmit non-attenuated incident test beam.

photobleaching. A transient phenomenon associated with high-irradiance, pulsed laser exposures in which an absorber provides reduced optical density while in the bleached (saturated) state.

photopic luminous transmittance (T_p). Luminous transmittance of a filter weighted by the spectral sensitivity of the day-adapted eye.

plano. A lens that does not incorporate a corrective prescription; this lens is not necessarily flat.

polarization. Light for which the orientation of the electric field is constant, although its magnitude and sign vary in time.

power. The rate at which energy is emitted, transferred, or received. Unit: watts (W) (joules per second).

prism power. The deviation in centimeters of a light ray measured at the distance of 1 meter. One prism diopter = 1 cm displacement at a distance of 1 meter.

protective eyewear (laser). Equipment such as laser protective eyecups, face shields, goggles, eye shields, spectacles, and visors intended to provide eye protection from beam hazards.

pulse duration. The duration of a laser pulse, usually measured as the time interval between the half-power points on the leading and trailing edges of the pulse. Typical units:

microseconds (μs)	=	10^{-6}s
nanosecond (ns)	=	10^{-9}s
picosecond (ps)	=	10^{-12}s
femtosecond (fs)	=	10^{-15}s

Symbol: t

pulse repetition frequency (PRF). The number of pulses occurring per second expressed in hertz. Symbol: F

pulsed laser. A laser which delivers its energy in the form of a single pulse or a train of pulses. In this standard, the duration of a pulse is $< 0.25\text{ s}$.

pupil. The variable aperture in the iris through which light travels to the interior of the eye. Maximum dilation for purposes of this document is assumed to be 8 mm, the diameter of the crystalline lens.

pupil plane. The plane which lies 3.54 mm posterior to the front surface of the cornea.

Q-switch. A device for producing very short ($\sim 10\text{-}250\text{ ns}$), intense laser pulses by enhancing the storage and dumping of energy in and out of the lasing medium, respectively.

Q-switched laser. A laser that emits short ($\sim 10\text{-}250\text{ ns}$), high peak power pulses by means of a Q-switch.

radian (rad). A unit of angular measure equal to the angle subtended at the center of a circle by an arc whose length is equal to the radius of the circle. $1\text{ radian} \sim 57.3\text{ degrees}$; $2\pi\text{ radians} = 360\text{ degrees}$.

radiance . Radiant flux or power output per unit area per solid angle per unit area expressed in watts-per-centimeter squared per-steradian ($\text{W}\cdot\text{cm}^{-2}\cdot\text{sr}^{-1}$). Symbol: L

radiant energy. Energy emitted, transferred, or received in the form of radiation. Unit: joule (J). Symbol: Q

radiant exposure. Surface density of the radiant energy received, expressed in units of joules-per-centimeter squared ($\text{J}\cdot\text{cm}^{-2}$). Symbol: H

radiant flux. Power emitted, transferred, or received in the form of radiation. Unit: watts (W). Also called *radiant power*. Symbol: Φ

radiant intensity (I) (of a source in a given direction). Quotient of the radiant flux leaving the source and propagated in an element of solid angle containing the given direction, by the element of solid angle. Unit: watts per steradian ($\text{W}\cdot\text{sr}^{-1}$).

radiant power. Power emitted, transferred, or received in the form of radiation expressed in watts (W). Synonym: *radiant flux*.

radiometry. For the purposes of this standard, the measurement of infrared, visible, and ultraviolet radiation.

reflectance. The ratio of total reflected radiant power to total incident power. Also called reflectivity.

reflection. Deviation of radiation following incidence on a surface.

refractive power. A measure of the ability of a lens to focus light rays, expressed in diopters.

repetitively pulsed laser. A laser with multiple pulses of radiant energy occurring in a sequence.

retina. The sensory membrane that receives the incident image formed by the cornea and lens of the human eye. The retina lines the inside of the eye.

retinal hazard region. Optical radiation between $0.4\ \mu\text{m}$ and $1.4\ \mu\text{m}$.

safety zone. The three dimensional space (volume) behind a filter in which the eye is protected against incoming radiation at the design wavelength.

saturable absorption. Property of a material used for eye protection that has a decreased optical density when illuminated with a high peak irradiance or high radiant exposure.

scotopic luminous transmittance (T_s). Luminous transmittance of a filter weighted by the spectral sensitivity of the night-adapted eye.

shall. The word *shall* is to be understood as mandatory.

shard. A small piece, fragment, or splinter of filter material.

should. The word *should* is to be understood as advisory.

solid angle. The three-dimensional angular spread at the vertex of a cone measured by the area intercepted by the cone on a unit sphere whose center is the vertex of the cone. Solid angle is expressed in steradians (sr).

source. A laser or a laser-illuminated reflecting surface.

spatial frequency. Cycles of a bar pattern of variable contrast specified as the number of cycles per unit space, typically degrees of visual angle, e.g., 30 cycles per degree equals 1 arc min of resolution equals 20/20 acuity. Conversion units for commonly used spatial units are listed in Table 1.

spectacle (laser safety). A protective device intended to shield the user's eyes from hazardous radiation. A side shield should be added to protect the eye from peripheral exposures. A side shield shall protect the entire orbit.