

**Accessible Emission Limit (AEL)** The maximum accessible emission level permitted within a particular class. The AEL is determined as a product of the maximum permissible exposure (MPE) times an area factor called the limiting aperture (LA). The LA is dependent on laser wavelength pupil size.  $AEL = MPE * \text{area of LA}$ .

**Administrative Control Measure** Procedures, training and warning signs designed to inform personnel to safely work near laser radiation.

**Authorized Personnel** Individuals approved by management to operate, maintain, service, or install laser equipment.

**Average Power** The total energy in an exposure or emission divided by the duration of the exposure or emission.

**Aversion Response** Closure of the eyelid, eye movement, pupillary constriction, or movement of the head to avoid an exposure to a noxious or bright light stimulant. The aversion response to an exposure from a bright, visible, laser source is assumed to limit the exposure of a specific retinal area to 0.25 s or less.

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

**Blink Reflex** (see Aversion Response)

**Coherent** A beam of light characterized by a fixed phase relationship (spatial coherence) or single wavelength, i.e., monochromatic (temporal coherence).

**Collecting Optics** Lenses or optical instruments having magnification and thereby producing an increase in energy or power density. Such devices may include telescopes, binoculars, microscopes, or loupes.

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

**Continuous Wave (CW)** A laser operating with a continuous output for a period  $> 0.25$  s is regarded as a CW laser.

**Control Measure** A means to mitigate potential hazards associated with the use of lasers. Control measures can be divided into three groups: engineering, administrative (procedural), or personal protective equipment (PPE).

**Controlled Area (laser)** An area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from laser radiation hazards.

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

**Critical Frequency** The pulse repetition frequency above which the laser output is considered continuous wave (CW). For example, for a short unintentional exposure (0.25 s to 10 s) to nanosecond

(or longer) pulses, the critical frequency is 55 kHz for wavelengths between 0.40 and 1.05  $\mu\text{m}$ , and 20 kHz for wavelengths between 1.05 and 1.40  $\mu\text{m}$ .

**Diffuse Reflection** Change of the spatial distribution of a beam of radiation when it is reflected in many directions by a surface or by a medium. (see “Specular Reflection”)

**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 lasers) is  $1/e$  times the maximum value. Symbol:  $\phi$

**Embedded Laser** An *enclosed laser* that has a higher classification than the laser system in which it is incorporated, where the system's lower classification is appropriate due to the engineering features limiting accessible emission. Many laser cutters are Class 4 lasers in a Class 1 laser enclosure, and require no special laser safety precautions as long as the factory installed safety features remain intact.

**Enclosed Laser** A laser that is contained within a protective housing of itself or of the laser or laser system in which it is incorporated. Opening or removing of the protective housing provides additional access to laser radiation above the applicable MPE than possible with the protective housing in place (an embedded laser is an example of one type of enclosed laser).

**Engineering Control Measure** Key controls, interlocks, beam housings, shutters, etc. designed to prevent exposure to hazardous levels of laser radiation. Engineering controls are considered the most effective laser safety control measures.

**Erythema** Redness of the skin due to exposure from laser radiation.

**Extended Source** A source of optical radiation with an angular subtense at the cornea larger than  $\alpha\text{min}$ . See point source.

**Eye-safe Laser** A Class 1 laser product. Because of the frequent misuse of the term “eye-safe wavelength” to mean “retina-safe,” (e.g., at 1.5-1.6  $\mu\text{m}$ ) and eye-safe laser to refer to a laser emitting at wavelengths outside the retinal-hazard region, the term “eye-safe” can be a misnomer. Hence, the use of eye-safe laser is discouraged.

**Fail-safe Interlock** An interlock where the failure of a single mechanical or electrical component of the interlock will cause the system to go into, or remain in, a safe mode.

**Focal Length** 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.

**Focal Point** The point toward which radiation converges or from which radiation diverges or appears to diverge.

**Infrared Radiation** Electromagnetic radiation with wavelengths which lie within the range 0.7  $\mu\text{m}$  to 1 mm.

**Intrabeam Viewing** The viewing condition whereby the eye is exposed to all or part of a laser beam.

**Iris** The circular pigmented structure which lies behind the cornea of the human eye. The iris is perforated by the pupil.

**Irradiance** Radiant power incident per unit area upon a surface, expressed in watts-per- centimeter-squared (W·cm<sup>-2</sup>). Symbol: E

**Lambertian Surface** An ideal (diffuse) 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, or spatially, or both. An acronym for Light Amplification by Stimulated Emission of Radiation.

**Laser Barrier** A device used to block or attenuate incident direct or diffuse laser radiation. Laser barriers are frequently used during times of service to the laser system when it is desirable to establish a boundary for a controlled laser area.

**Laser Classification** An indication of the beam hazard level of a laser or laser system during normal operation or the determination thereof. The hazard level of a laser or laser system is represented by a number or a numbered capital letter. The laser classifications are Class 1, Class 1M, Class 2, Class 2M, Class 3R, Class 3B and Class 4. In general, the potential beam hazard level increases in the same order.

**Laser-Generated Air Contaminants (LGAC)** Air contaminants generated when Class 4 and some Class 3b laser beams interact with matter. The quantity, composition and chemical complexity of the LGAC depend on the target material, cover gas and beam irradiance. Materials such as plastics, composites, metals and tissues may release carcinogenic, toxic and noxious air contaminants. Ozone is produced around flash lamps and can build up with high repetition rate lasers. Special optical materials used for far infrared windows and lenses may also release hazardous air contaminants.

**Laser Personnel** Persons who routinely work around hazardous laser beams. Such persons must be protected by engineering controls, administrative procedures, or both.

**Laser Pointer** A laser product that is usually hand held that emits a low-divergence visible beam and is intended for designating specific objects or images during discussions, lectures or presentations as well as for the aiming of firearms or other visual targeting practice. These products are normally Class 1, Class 2 or Class 3R.

**Laser Safety Officer (LSO)** One who has authority and responsibility to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards.

**Laser System** An assembly of electrical, mechanical, and optical components which includes a laser.

**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).

**Magnified Viewing** Viewing a small object through an optical system that increases the apparent object size. This type of optical system can make a diverging laser beam more hazardous (e.g., using a magnifying optic to view an optical fiber with a laser beam emitted).

**Maintenance** Performance of those adjustments or procedures (specified in the user information provided by the manufacturer and considered preventative, to maintain optimal performance of the laser system), which are to be carried out by the user to ensure the intended performance of the product. It does not include operation or service as defined in this section.

**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.

**Minimum Viewing Distance** The minimum distance at which the eye can produce a focused image of a diffuse source, usually assumed to be 10 cm.

**Nominal Hazard Zone (NHZ)** The space within which the level of the direct, reflected, or scattered radiation may exceed the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE.

**Nominal Ocular Hazard Distance (NOHD)** The distance along the axis of the unobstructed beam from a laser, fiber end, or connector to the human eye beyond which the irradiance or radiant exposure is not expected to exceed the applicable MPE.

**Non-beam Hazard** A class of hazards that result from factors other than direct human exposure to a laser beam.

**Ocular Fundus** The interior posterior surface of the eye (the retina), as seen upon ophthalmoscopic examination.

**Optically Aided Viewing** Viewing with a telescopic (binocular) or magnifying optic. Under certain circumstances, viewing with an optical aid can increase the hazard from a laser beam (see telescopic viewing or magnified viewing).

**Optical Density** The logarithm to the base ten of the reciprocal of the transmittance at a particular wavelength:  $D\lambda = \log_{10} (1/\tau\lambda)$  where  $\tau\lambda$  is the transmittance at the wavelength of interest. Symbol:  $D(\lambda)$ ,  $D\lambda$  or OD

**Personal Protective Equipment (PPE)** Equipment worn to minimize exposure to laser radiation. The most common PPE is laser protective eyewear. Skin covering may be required for certain applications, e.g. long sleeved shirts for work around UV laser radiation.

**Photochemical Effect** A biological effect produced by a chemical action brought about by the absorption of photons by molecules that directly alter the molecule.

**Photosensitizers** Substances which increase the sensitivity of a material to exposure by optical radiation.

**Pigment Epithelium (of The Retina)** The layer of cells which contain brown or black pigment granules next to and behind the rods and cones.

**Point Source** A source with an angular subtense at the cornea equal to or less than alpha-min ( $\alpha_{min}$ ), i.e.,  $\leq 1.5$  mrad.

**Point Source Viewing** The viewing condition whereby the angular subtense of the source,  $\alpha$ , is equal to or less than the limiting angular subtense,  $\alpha_{min}$ .

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

**Protective Housing** An enclosure that surrounds the laser or laser system and prevents access to laser radiation above the applicable MPE. The aperture through which the useful beam is emitted is not part of the protective housing. The protective housing limits access to other associated radiant energy emissions and to electrical hazards associated with components and terminals, and may enclose associated optics and a workstation.

**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. 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 less than 0.25 s.

**Pupil** The variable aperture in the iris through which light travels to the interior of the eye.

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

**Radiance** Radiant flux or power output per unit 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: joules (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:  $\Phi$

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

**Reflectance** The ratio of total reflected radiant power to total incident power. Also called "reflectivity."

**Repetitive Pulse Laser** A laser with multiple pulses of radiant energy occurring in a sequence.

**Retina** The sensory tissue that receives the incident image formed by the cornea and lens of the human eye.

**Retinal Hazard Region** Optical radiation with wavelengths between 0.4 and 1.4  $\mu\text{m}$ , where the principal hazard is usually to the retina.

**Safety Latch** A mechanical device designed to require a conscious decision to override the latch to gain entry into a controlled area.

**Scanning Laser** A laser having a time-varying direction, origin, or pattern of propagation with respect to a stationary frame of reference.

**Secured Enclosure** An enclosure to which casual access is impeded by an appropriate means, e.g., a door secured by a magnetically or electrically operated lock or latch, or by fasteners that need a tool to remove.

**Service** The performance of procedures, typically defined as repair, to bring the laser or laser system or laser product back to full and normal operational status. It does not include operation or maintenance as defined in this section.

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

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

**Spectator** An individual who wishes to observe or watch a laser or laser system in operation, and who may lack the appropriate laser safety training.

**Specular Reflection** A mirror-like reflection. (see “Diffuse Reflection”)

**Standard Operating Procedure (SOP)** Formal written description of the safety and administrative procedures to be followed in performing a specific task.

**Threshold Limit (TL)** The term is applied to laser protective eyewear filters, protective windows, and barriers. The TL is an expression of the “resistance factor” for beam penetration of a laser protective device. This is generally related by the Threshold Limit (TL) of the protective device, expressed in  $\text{W}\cdot\text{cm}^{-2}$  or  $\text{J}\cdot\text{cm}^{-2}$ . It is the maximum average irradiance or radiant exposure at a given beam diameter for which a laser protective device provides adequate beam resistance. Thus, laser exposures delivered on the protective device at or below the TL will limit beam penetration to levels at or below the applicable MPE.

**T<sub>min</sub>** For a pulsed laser, the maximum duration for which the MPE is the same as the MPE for a 1 ns exposure. For thermal biological effects, this corresponds to the “thermal confinement duration” during which heat flow does not significantly change the absorbed energy content of the thermal relaxation volume of the irradiated tissue.

**Ultraviolet Radiation** Electromagnetic radiation with wavelengths between 0.18 and 0.40 µm (shorter than those of visible radiation).

**Uncontrolled Area** An area where the occupancy and activity of those within is not subject to control and supervision for the purpose of protection from radiation hazards.

**Viewing Window** A visually transparent part of an enclosure that contains a laser process. It may be possible to observe the laser processes through the viewing windows.

**Visible Radiation (light)** The term is used to describe electromagnetic radiation which can be detected by the human eye. This term is used to describe wavelengths which lie in the range 0.4 to 0.7 µm. Derivative standards may legitimately use 0.38 – 0.78 µm for the visible radiation range.