**Laser safety**

Chapter

7

 **Control Measures**

**A. Control Measures: Overview**

1. There are four basic categories of controls useful in laser environments. These are **engineering controls, personal protective equipment, administrative and procedural controls, and special controls**. The controls to be reviewed here are based upon the recommendations of the ANSI Z 136.1 standard.
2. Important in all controls is the distinction between the functions of operation, maintenance, and service. First, laser systems are classified on the basis of level of the laser radiation accessible during operation. Maintenance is defined as those tasks specified in the user instructions for assuring the performance of the product and may include items such as routine cleaning or replenishment of expendables. Service functions are usually performed with far less frequency than maintenance functions (e.g., replacing the laser resonator mirrors or repair of faulty components) and often require access to the laser beam by those performing the service functions.

**B. Laser Safety Officer (LSO)**

1. The LSO has the authority to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards. The LSO administers the overall laser safety program where the duties include, but are not limited to, items such as confirming the classification of lasers, doing the NHZ evaluation, assuring that the proper control measures are in place and approving substitute controls, approving standard operating procedures (SOP's), recommending and/or approving eye wear and other protective equipment, specifying appropriate signs and labels, approving overall facility controls, providing the proper laser safety training as needed, conducting medical surveillance, and designating the laser and incidental personnel categories.
2. The LSO should receive detailed training including laser fundamentals, laser bioeffects, exposure limits, classifications, NHZ computations, control measures (including area controls, eye wear, barriers, etc.), and medical surveillance requirements.
3. In many industrial situations, the LSO functions will be a part-time activity, depending on the number of lasers and general laser activity. The individual is often in the corporate industrial hygiene department or may be a laser engineer with safety responsibility. Some corporations implement an internal laser policy and establish safety practices based upon the ANSI Z 136.1 standard as well as their own corporate safety requirements.

**C. Class I, Class II, Class I.A., and Class IIIA Lasers.**

Accident data on laser usage have shown that Class I, Class II, Class I.A., and Class IIIA lasers are normally not considered hazardous from a radiation standpoint unless illogically used.

Direct exposure on the eye by a beam of laser light should *always* be avoided with any laser, *no matter how low the power*.

**D. Beam Path Controls**

There are some uses of Class IIIB and Class IV lasers where the entire beam path may be totally enclosed, other uses where the beam path is confined by design to significantly limit access and yet other uses where the beam path is totally open. In each case, the controls required will vary as follows:

1. **Enclosed (Total) Beam Path**
	1. Perhaps the most common form of a Class I laser system is a high-power laser that has been totally enclosed (embedded) inside a protective enclosure equipped with appropriate interlocks and/or labels on all removable panels or access doors. Beam access is prevented, therefore, during operation and maintenance.
	2. Such a completely enclosed system, if properly labeled and properly safeguarded with protective housing interlocks (and all other applicable engineering controls), will fulfill all requirements for a Class I laser and may be operated in the enclosed manner with no additional controls for the operator.
	3. It should be noted that during periods of service or maintenance, controls appropriate to the class of the embedded laser may be required (perhaps on a temporary basis) when the beam enclosures are removed and beam access is possible. Beam access during maintenance or service procedures will not alter the Class I status of the laser during operation.
2. **Limited Open Beam Path**
	1. It is becoming an accepted work practice, particularly with industrial materials-processing lasers, to build an enclosure that completely surrounds the laser-focusing optics and the immediate area of the workstation. Often a computer-controlled positioning table is located within this enclosure. The design often allows a gap of less than one quarter of an inch between the bottom of the enclosure and the top of the material to be laser processed. Such a design enables the part to be laser cut or welded to move while the laser delivery optics remain stationary.
	2. Such a system might not meet the stringent "human access" requirements of the FLPPS for a Class I laser, but the real laser hazards are well confined. Such a design provides what can be called a limited open beam path. In this situation, the ANSI Z 136.1 standard recommends that the LSO shall conduct a laser hazard analysis and establish the extent of the NHZ.
	3. In many system designs, (such as described above), the NHZ will be extremely limited, and procedural controls (rather than elaborate engineering controls) will be sufficient to ensure safe use. In many cases, the laser units may be reclassified by the LSO as Class I under the specifications of the ANSI Z 136 standard.
	4. Such an installation will require a detailed standard operating procedure (SOP). Training is also needed for the system operator commensurate with the class of the embedded laser.
	5. Protective equipment (eye protection, temporary barriers, clothing and/or gloves, respirators, etc.) would be recommended, for example, only if the hazard analysis indicated a need or if the SOP required periods of beam access such as during setup or infrequent maintenance activities. Temporary protective measures for service can be handled in a manner similar to the service of any embedded Class IV laser.
3. **Totally Unenclosed Beam Path.** There are several specific application areas where high power (Class IIIB and Class IV) lasers are used in an unenclosed beam condition. This would include, for example, open industrial processing systems (often incorporating robotic delivery), laser research laboratory installations, surgical installations, etc. Such laser uses will require that the LSO conduct a hazard analysis and NHZ assessment. Controls are chosen to reflect the magnitude of hazards associated with the accessible beam.

**E. Laser-Controlled Area.**

When the entire beam path from a Class IIIB or Class IV laser is not sufficiently enclosed and/or baffled to ensure that radiation exposures will not exceed the MPE, a "laser-controlled area" is required. During periods of service, a controlled area may be established on a temporary basis. The controlled area will encompass the NHZ. Those controls required for both Class IIIB and Class IV installations are as follows:

1. **Posting with Appropriate Laser Warning Signs**
	1. *Class IIIA (beam irradiance 2.5 mW/cm2), Class IIIB and Class IV lasers*: Require the ANSI **DANGER** sign format: white back-ground, red laser symbol with black outline and black lettering Note that under ANSI Z 136.1 criteria, area posting is required only for Class IIIB and Class IV lasers.
	2. *Class II or Class IIIA areas* (if area warning is deemed unnecessary by the LSO): All signs (and labels) associated with these lasers (when beam irradiance for Class IIIA does not exceed 2.5 mW/cm*2*) use the ANSI **CAUTION** format: yellow background, black symbol and letters.
	3. During times of service and other times when a *temporary laser-controlled area* is established, an ANSI **NOTICE** sign format is required: white background, red laser symbol with blue field and black lettering. This sign is posted only during the time when service is in progress.
2. **Operated by Qualified and Authorized Personnel.** Training of the individuals in aspects of laser safety is required for Class IIIB and Class IV laser installations.
3. **Transmission from Indoor Controlled Area.** The beams shall not, under any circumstances, be transmitted from an indoor laser-controlled area unless for specific purposes (such as testing). In such cases, the operator and the LSO must assure that the beam path is limited to controlled air space.

**F. Class IV Laser Controls--General Requirements**

Those items recommended for Class IIIB but required for Class IV lasers are as follows:

* Supervision directly by an individual knowledgeable in laser safety.
* Entry of any noninvolved personnel requires approval.
* A beam stop of an appropriate material must be used to terminate all potentially hazardous beams.
* Use diffusely reflecting materials near the beam, where appropriate.
* Appropriate laser protective eye wear must be provided all personnel within the laser controlled area.
* The beam path of the laser must be located and secured above or below eye level for any standing or seated position in the facility.
* All windows, doorways, open portals, etc., of an enclosed facility should be covered or restricted to reduce any escaping laser beams below appropriate ocular MPE level.
* Require storage or disabling of lasers when not in use.

**G. Entryway Control Measures (Class IV)**

In addition, there are specific controls required at the entryway to a Class IV laser controlled area. These can be summarized as follows:

* All personnel entering a Class IV area shall be adequately trained and provided proper laser protective eye wear.
* All personnel shall follow all applicable administrative and procedural controls.
* All Class IV area and entryway controls shall allow rapid entrance and exit under all conditions.
* The controlled area shall have a clearly marked "Panic Button" (nonlockable disconnect switch) that allows rapid deactivation of the laser.

Class IV areas also require some form of area and entryway controls. In the past, doorway interlocking was customary for Class IV installations. The ANSI Z 136 Standard now provides four options that allow the LSO to provide an entryway control suited for the installation. The options include:

1. **Nondefeatable Entryway Controls.** A nondefeatable control, such as a magnetic switch built into the entryway door which cuts the beam off when the door is opened, is one option. In this case, training is required only for those persons who regularly work in the laser area.
2. **Defeatable Entryway Controls**
	1. Defeatable controls may be used at an entryway, for example, during long-term testing in a laser area. In this case the controls may be temporarily made inactive if it is clearly evident that there is no hazard at the point of entry. Training is required for all personnel who may frequently require entry into the area.
	2. Such defeatable controls shall be designed to allow both rapid egress by the laser personnel at all times and admittance to the laser controlled area in an emergency condition. A readily accessible "panic button" or control/disconnect switch shall be available for deactivating the laser under such emergency conditions.
	3. Under conditions where the entire beam path is not completely enclosed, access to the laser-controlled area shall be limited only to persons wearing proper laser protective eye wear when the laser is capable of emitting a beam. In this case, all other optical paths (for example, windows) from the facility shall be covered or restricted in such a way as to reduce the transmitted intensity of the laser radiation to levels at or below the MPE for direct irradiation of the eye.
3. **Procedural Entryway Controls.** A blocking barrier, screen, or curtain that can block or filter the laser beam at the entryway may be used inside the controlled area to prevent the laser light from exiting the area at levels above the applicable MPE level. In this case, a warning light or sound is required outside the entryway that operates when the laser is energized and operating. All personnel who work in the facility shall be appropriately trained.
4. **Entryway Warning Systems.** In order to safely operate a Class IV laser or laser system, a laser warning system shall be installed as described:
	1. A laser activation warning light assembly shall be installed outside the entrance to each laser room facility containing a Class IV laser or laser system.
	2. In lieu of a blinking entryway warning, the entryway light assembly may alternatively be interfaced to the laser in such a manner that a light will indicate when the laser is not operational (high voltage off) and by an additional light when the laser is powered up (high voltage applied) but not operating and by an additional (flashing) light when the laser is operating.

**A laser warning sign shall be posted both inside and outside the laser-controlled area**.

**H. Temporary Laser-Controlled Area**

Should overriding interlocks become necessary during periods of special training, service, or maintenance, and access to Class IIIB or Class IV lasers is required, a temporary laser-controlled area shall be devised following specific procedures approved by the LSO. These procedures shall outline all safety requirements necessary during such operation.

Such temporary laser-controlled areas, which by nature will not have the built-in protective features as defined for a laser-controlled area, shall nevertheless provide all of the safety requirements for all personnel, both within and without the temporary laser-controlled area during periods of operation when the interlocks are defeated.

* 1. **Engineering controls,**

Engineering controls are normally designed and built into the laser equipment to provide for safety. In most instances, these will be included on the equipment (provided by the laser manufacturer) as part of the "performance requirements" mandated by the FLPPS. Specifics on some of the more important engineering controls recommended in the ANSI Z 136.1 standard are detailed as follows:

1. **Protective Housing.** A laser shall have an enclosure around it that limits access to the laser beam or radiation at or below the applicable MPE level. A protective housing is required for all classes of lasers except, of course, at the beam aperture. In some cases, the walls of a properly enclosed room area can be considered as the protective housing for an open beam laser. Such a "walk-in" enclosure can also be a FDA/CDRH Class I provided that controls preclude operation with personnel within the room (viz.: pressure sensitive floor-mat switches, IR sensors, door interlocks, etc.)
2. **Master Switch Control.** All Class IV lasers and laser systems require a master switch control. The switch can be operated by a key or computer code. When disabled (key or code removed), the laser cannot be operated. Only authorized system operators are to be permitted access to the key or code. Inclusion of the master switch control on Class IIIB lasers and laser systems is also recommended but not required.
3. **Optical Viewing System Safety.** Interlocks, filters, or attenuators are to be incorporated in conjunction with beam shutters when optical viewing systems such as telescopes, microscopes, viewing ports, or screens are used to view the beam or beam-reflection area. For example, an electrical interlock could prevent laser system operation when a beam shutter is removed from the optical system viewing path. Such optical filter interlocks are required for all except Class I lasers.
4. **Beam Stop or Attenuator.** Class IV lasers require a permanently attached beam stop or attenuator which can reduce the output emission to a level at or below the appropriate MPE level when the laser system is on "standby." Such a beam stop or attenuator is also recommended for Class IIIA and Class IIIB lasers.
5. **Laser Activation Warning System.** An audible tone or bell and/or visual warning (such as a flashing light) is recommended as an area control for Class IIIB laser operation. Such a warning system is mandatory for Class IV lasers. Such warning devices are to be activated upon system start-up and are to be uniquely identified with the laser operation. Verbal "countdown" commands are an acceptable audible warning and should be a part of the SOP.
6. **Service Access Panels.** The ANSI Z 136.1 standard requires that any portion of the protective housing that permits direct access to an embedded Class IIIB or Class IV laser (intended for removal only by service personnel) must have either an interlock or require a tool in the removal process. If an interlock is used and is defeatable, a warning label indicating this fact is required on the housing near the interlock. The design shall not allow replacement of a removed panel with the interlock in the defeated condition.

The FDA/CDRH Federal Laser Product Performance Standard requires warning labels on removable protective housing panels under all conditions.

1. **Protective Housing Interlock Requirements**
	1. Interlocks, which cause beam termination or reduction of the beam to MPE levels, must be provided on all panels intended to be opened during operation and maintenance of all Class IIIA, Class IIIB, and Class IV lasers. The interlocks are typically electrically connected to a beam shutter. The removal or displacement of the panel closes the shutter and eliminates the possibility of hazardous exposures.
	2. Under the requirements of the ANSI Z 136 Standard, for embedded Class IIIB and Class IV lasers only, the interlocks are to be "fail-safe." This usually means that dual, redundant, electrical series-connected interlocks are associated with each removable panel.
	3. Adjustments or procedures during service on the laser shall not cause the safety interlocks to become inoperative or the laser radiation outside a Class I laser protective housing to exceed the MPE limits, unless a temporary laser-controlled area is established.
2. **Remote Interlock Connector.** All Class IV lasers or laser systems must have a remote interlock connector to allow electrical connections to an emergency master disconnect ("panic button") interlock or to room, door or fixture interlocks. When open circuited, the interlock shall cause the accessible laser radiation to be maintained below the appropriate MPE level. The remote interlock connector is also recommended for Class IIIB lasers
	* + 1. **Administrative and Procedural controls,**
3. **Standard Operating Procedures.** One of the more important of the administrative and procedural controls is the written Standard Operating Procedure (SOP). The ANSI Z 136.1 standard requires an SOP for a Class IV laser and recommends SOP's for Class IIIB lasers.

The key to developing an effective SOP is the involvement of those individuals who operate, maintain and service the equipment under guidance of the LSO. Most laser equipment comes with instructions for safe operation by the manufacturers; however, sometimes the instructions are not well suited to a specific application due to special use conditions.

1. **Alignment Procedures.** Many laser eye accidents occur during alignment. The procedures require extreme caution. A written SOP is recommended for all recurring alignment tasks.
2. **Limitations on Spectators.** Persons unnecessary to the laser operation should be kept away. For those who do enter a laser area with unenclosed Class IIIB or Class IV beam paths, appropriate eye protection and instruction is required.
3. **Protective Equipment.** Protective equipment for laser safety generally means eye protection in the form of goggles or spectacles, clothing, and barriers and other devices designed for laser protection.
	1. **Laser Protective Eyewear and Clothing**
		* Eye-protection devices designed to protect against radiation from a specific laser system shall be used when engineering controls are inadequate to eliminate the possibility of potentially hazardous eye exposure (i.e., whenever levels of accessible emission exceed the appropriate MPE levels.) This generally applies only to Class IIIB and Class IV lasers. All laser eye wear shall be clearly labeled with OD values and wavelengths for which protection is afforded.
		* Skin protection can best be achieved through engineering controls. If the potential exists for damaging skin exposure, particularly for ultraviolet lasers (0.200-0.400 m), then skin covers and or sun-screen creams are recommended. For the hands, gloves will provide some protection against laser radiation. Tightly woven fabrics and opaque gloves provide the best protection. A laboratory jacket or coat can provide protection for the arms. For Class IV lasers, flame-resistant materials may be best.
		* In general, other controls should serve as primary protection rather than depending on employees to use protective eye wear. Many accidents have occurred when eye wear was available but not worn. This may be because laser protective eye wear is often dark, uncomfortable to wear, and limits vision.
	2. **Laser Barriers and Protective Curtains**
		* Area control can be effected in some cases using special barriers specifically designed to withstand either direct or diffusely scattered beams. The barrier will be described with a barrier threshold limit (BTL): the beam will penetrate the barrier only after some specified exposure time, typically 60 seconds. The barrier is located at a distance from the laser source so that the BTL is not exceeded in the worst-case exposure scenario.
		* Currently available laser barriers exhibit BTL's ranging from 10 to 350 W/cm2 for different laser wavelengths and power levels. An analysis conducted in a manner similar to the NHZ evaluations described previously can establish the recommended barrier type and installation distances for a given laser. It is essential that the barrier also not support combustion or be itself consumed by flames during or following a laser exposure.

Laser Use Without Protective Housing (All Classes)

In some circumstances, such as during the manufacture of lasers and during research and development, operation of an unenclosed laser or laser system may become necessary. In such cases, the LSO shall determine the hazard and ensure that controls are instituted appropriate to the class of maximum accessible emission to ensure safe operation. Such controls may include but are not limited to:

* access restriction;
* eye protection;
* area controls;
* barriers, shrouds, beam stops, etc.;
* administrative and procedural controls; and
* education and training..

| **Control measures** | **------------------ Class -----------------** |
| --- | --- |
| **I** | **IA** | **II** | **IIIA** | **IIIB** | **IV** |
| Protective housing | X | X | X | X | X | X |
| Without protective housing | -- LSO shall establish alternate controls -- |
| Interlocks on protective housing | a | a | a | X | X | X |
| Service access panel | b | b | b | b | b | X |
| Key switch master | \_ | \_ | \_ | \_ | • | X |
| Viewing portals | \_ | \_ | ◊ | ◊ | ◊ | ◊ |
| Collecting optics | \_ | \_ | ◊ | ◊ | ◊ | ◊ |
| Totally open beam path | \_ | \_ | \_ | \_ | X | X |
| Limited open beam path | \_ | \_ | \_ | \_ | X | X |
| Remote interlock connector | \_ | \_ | \_ | \_ | • | X |
| Beram stop or attenuator | \_ | \_ | \_ | • | • | X |
| Activation warning system | \_ | \_ | \_ | \_ | • | X |
| Emission delay | \_ | \_ | \_ | \_ | \_ | • |
| Class IIIB laser controlled area | \_ | \_ | \_ | \_ | X | \_ |
| Class IV laser controlled area | \_ | \_ | \_ | \_ | \_ | X |
| Laser outdoor controls | \_ | \_ | \_ | \_ | X | X |
| Temporary laser controlled area | b | b | b | b | \_ | \_ |
| Remote firing & monitoring | \_ | \_ | \_ | \_ | \_ | • |
| Labels | \_ | X | X | X | X | X |
| Area posting | \_ | \_ | • | • | X | X |
| Administrative & procedural controls | \_ | X | X | X | X | X |
| Standard operating procedures | \_ | \_ | \_ | \_ | • | X |
| Output emission limitations | \_ | \_ | \_ | --LSO determines-- |
| Education and training | \_ | \_ | \_ | X | X | X |
| Authorized personnel | \_ | \_ | \_ | \_ | X | X |
| Alignment procedures | \_ | \_ | X | X | X | X |
| Eye protection | \_ | \_ | \_ | \_ | • | X |
| Spectator control | \_ | \_ | \_ | \_ | • | X |
| Service personnel | b | b | b | b | X | X |
| Laser demonstration | \_ | \_ | X | X | X | X |
| Laser fiber optics | \_ | \_ | X | X | X | X |
| **Key:**X = Shall.a. = Shall if embedded Class IIIA, Class IIIB, Class IV.b. = Shall if embedded ClassIIIB or Class IV.\_ = No requirement.• = Should.◊ = Shall if MPE is exceeded. |

1. Based on highest level accessible during operation.
2. Required wherever and whenever human access to laser radiation above Class I limits is not needed for product to perform its function.
3. Required for protective housings opened during operation or maintenance, if human access thus gained is not always necessary when housing is opened.
4. Interlock requirements vary according to Class of internal radiation.
5. Wording depends on level and wavelength of laser radiation within protective housing.
6. Warning statement label.
7. **CAUTION** logotype.
8. Requires means to measure level of radiation intended to irradiate the body.
9. **CAUTION** if 2.5 mWcm-2 or less, **DANGER** if greater than 2.5 mWcm-2.
10. Delay required between indication and emission.
11. Variance required for Class IIIB or IV demonstration laser products and light shows.
12. **DANGER** logotype.
13. Required after August 20, 1986.

**Warning Signs**







**Glossary of Laser Terms**

Absorb To transform radiant energy into a different form, with a resultant rise in temperature.

Absorption

Transformation of radiant energy to a different form of energy by the interaction of matter, depending on temperature and wavelength.

**Accessible Emission** **Level**

The magnitude of accessible laser (or collateral) radiation of a specific wavelength or emission duration at a particular point as measured by appropriate methods and devices. Also means radiation to which human access is possible in accordance with the definitions of the laser's hazard classification.

**Accessible Emission Limit (AEL)**

The maximum accessible emission level permitted within a particular class. In ANSI Z 136.1, AEL is determined as the product of accessible emission Maximum Permissible Exposure limit (MPE) and the area of the limiting aperture (7 mm for visible and near-infrared lasers).

Aperture An opening through which radiation can pass.

Argon A gas used as a laser medium. It emits blue-green light primarily at 448 and 515 nm.

Attenuation The decrease in energy (or power) as a beam passes through an absorbing or scattering medium.

**Aversion Response**

Movement of the eyelid or the head to avoid an exposure to a noxious stimulant, bright light. It can occur within 0.25 seconds, and it includes the blink reflex time.

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

Beam Diameter

The distance between diametrically opposed points in the cross section of a circular beam where the intensity is reduced by a factor of e-1 (0.368) of the peak level (for safety standards). The value is normally chosen at e-2 (0.135) of the peak level for manufacturing specifications.

Beam Divergence

Angle of beam spread measured in radians or milliradians (1 milliradian = 3.4 minutes of arc or approximately 1 mil). For small angles where the cord is approximately equal to the arc, the beam divergence can be closely approximated by the ratio of the cord length (beam diameter) divided by the distance (range) from the laser aperture.

Blink Reflex See [aversion response](https://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_6.html#aversion_response).

Brightness

The visual sensation of the luminous intensity of a light source. The brightness of a laser beam is most closely associated with the radio-metric concept of radiance.

Carbon Dioxide Molecule used as a laser medium. Emits far energy at 10,600 nm (10.6 µm).

Closed Installation Any location where lasers are used which will be closed to unprotected personnel during laser operation.

CO2 Laser

A widely used laser in which the primary lasing medium is carbon dioxide gas. The output wavelength is 10.6 µm (10600 nm) in the far infrared spectrum. It can be operated in either CW or pulsed.

Coherence

A term describing light as waves which are in phase in both time and space. Monochromaticity and low divergence are two properties of coherent light.

Collimated Light

Light rays that are parallel. Collimated light is emitted by many lasers. Diverging light may be collimated by a lens or other device.

Collimation Ability of the laser beam to not spread significantly (low divergence) with distance.

Continuous Mode The duration of laser exposure is controlled by the user (by foot or hand switch).

Continuous Wave (CW) Constant, steady-state delivery of laser power.

Controlled Area

Any locale where the activity of those within are subject to control and supervision for the purpose of laser radiation hazard protection.

Diffuse Reflection

Takes place when different parts of a beam incident on a surface are reflected over a wide range of angles in accordance with Lambert's Law. The intensity will fall off as the inverse of the square of the distance away from the surface and also obey a Cosine Law of reflection.

Divergence

The increase in the diameter of the laser beam with distance from the exit aperture. The value gives the full angle at the point where the laser radiant exposure or irradiance is e-1 or e-2 of the maximum value, depending upon which criteria is used.

Embedded Laser

A laser with an assigned class number higher than the inherent capability of the laser system in which it is incorporated, where the system's lower classification is appropriate to the engineering features limiting accessible emission.

Emission

Act of giving off radiant energy by an atom or molecule.

Enclosed Laser Device

Any laser or laser system located within an enclosure which does not permit hazardous optical radiation emission from the enclosure. The laser inside is termed an "embedded laser."

Energy (Q)

The capacity for doing work. Energy is commonly used to express the output from pulsed lasers and it is generally measured in Joules (J). The product of power (watts) and duration (seconds). One watt second = one Joule.

Excimer "Excited Dimer"

A gas mixture used as the active medium in a family of lasers emitting ultraviolet light.

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.

Gas Discharge Laser

A laser containing a gaseous lasing medium in a glass tube in which a constant flow of gas replenishes the molecules depleted by the electricity or chemicals used for excitation.

Gas Laser A type of laser in which the laser action takes place in a gas medium.

Helium-Neon (HeNe) Laser

A laser in which the active medium is a mixture of helium and neon. Its wavelength is usually in the visible range. Used widely for alignment, recording, printing, and measuring.

Infrared Radiation (IR)

Invisible electromagnetic radiation with wavelengths which lie within the range of 0.70 to 1000 µm. These wavelengths are often broken up into regions: IR-A (0.7-1.4 µm), IR-B (1.4-3.0 µm) and IR-C (3.0-1000 µm).

Intrabeam Viewing

The viewing condition whereby the eye is exposed to all or part of a direct laser beam or a specular reflection.

Irradiance (E)

Radiant flux (radiant power) per unit area incident upon a given surface. Units: Watts per square centimeter. (Sometimes referred to as power density, although not exactly correct).

Laser

An acronym for light amplification by stimulated emission of radiation. A laser is a cavity with mirrors at the ends, filled with material such as crystal, glass, liquid, gas or dye. It produces an intense beam of light with the unique properties of coherency, collimation, and monochromaticity.

Laser Accessories

The hardware and options available for lasers, such as secondary gases, Brewster windows, Q-switches and electronic shutters.

Laser Controlled AreaSee [Controlled Area](https://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_6.html#controlled_area).

Laser Device Either a laser or a laser system.

Laser Medium (Active Medium) Material used to emit the laser light and for which the laser is named.

Laser Rod

A solid-state, rod-shaped lasing medium in which ion excitation is caused by a source of intense light, such as a flash lamp. Various materials are used for the rod, the earliest of which was synthetic ruby crystal.

**Laser Safety Officer (LSO)**

One who has authority to monitor and enforce measures to control 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. Under the Federal Standard, a laser in combination with its power supply (energy source).

Lens A curved piece of optically transparent material which, depending on its shape, is used to either converge or diverge light.

Light

The range of electromagnetic radiation frequencies detected by the eye, or the wavelength range from about 400 to 760 nm. The term is sometimes used loosely to include radiation beyond visible limits.

**Limiting Aperture**

The maximum circular area over which radiance and radiant exposure can be averaged when determining safety hazards.

Maintenance

Performance of those adjustments or procedures specified in user information provided by the manufacturer with the laser or laser system, which are to be performed by the user to ensure the intended performance of the product. It does not include operation or service as defined in this glossary.

Maximum Permissible Exposure (MPE)

The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin.

Nd:Glass Laser

A solid-state laser of neodymium:glass offering high power in short pulses. A Nd-doped glass rod used as a laser medium to produce 1064 nm light.

Nd:YAG Laser Neodymium:Yttrium Aluminum Garnet. A synthetic crystal used as a laser medium to produce 1064 nm light.

Neodymium (Nd) The rare earth element that is the active element in Nd:YAG laser and Nd:Glass lasers.

**Nominal Hazard Zone (NHZ)**

The nominal hazard zone describes the space within which the level of the direct, reflected or scattered radiation during normal operation exceeds the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE level.

Optical Cavity (Resonator) Space between the laser mirrors where lasing action occurs.

**Optical Density** A logarithmic expression for the attenuation produced by an attenuating medium, such as an eye protection filter.

Optical Fiber

A filament of quartz or other optical material capable of transmitting light along its length by multiple internal reflection and emitting it at the end.

**Optical Pumping** The excitation of the lasing medium by the application of light rather than electrical discharge.

Optical Radiation Ultraviolet, visible, and infrared radiation (0.35-1.4 µm) that falls in the region of transmittance of the human eye.

**Output Power**

The energy per second measured in watts emitted from the laser in the form of coherent light.

**Power**

The rate of energy delivery expressed in watts (Joules per second). Thus: 1 Watt = 1 Joule x 1 §

Protective Housing

A protective housing is a device designed to prevent access to radiant power or energy.

**Pulse**

A discontinuous burst of laser, light or energy, as opposed to a continuous beam. A true pulse achieves higher peak powers than that attainable in a CW output.

**Pulse Duration**

The "on" time of a pulsed laser, it may be measured in terms of milliseconds, microseconds, or nanoseconds as defined by half-peak-power points on the leading and trailing edges of the pulse.

Pulsed Laser

Laser which delivers energy in the form of a single or train of pulses.

Pump

To excite the lasing medium. See [Optical Pumping](https://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_6.html#optical_pumping) or [Pumping](https://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_6.html#pumping).

Pumped Medium

Energized laser medium.

Pumping

Addition of energy (thermal, electrical, or optical) into the atomic population of the laser medium, necessary to produce a state of population inversion.

**Radiant Energy (Q)**

Energy in the form of electromagnetic waves usually expressed in units of Joules (watt-seconds).

**Radiant Exposure (H)**

The total energy per unit area incident upon a given surface. It is used to express exposure to pulsed laser radiation in units of J/cm2.

Reflection

The return of radiant energy (incident light) by a surface, with no change in wavelength.

Refraction

The change of direction of propagation of any wave, such as an electromagnetic wave, when it passes from one medium to another in which the wave velocity is different. The bending of incident rays as they pass from one medium to another (e.g., air to glass).

Resonator

The mirrors (or reflectors) making up the laser cavity including the laser rod or tube. The mirrors reflect light back and forth to build up amplification.

Ruby

The first laser type; a crystal of sapphire (aluminum oxide) containing trace amounts of chromium oxide.

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., door secured by lock, magnetically or electrically operated latch, or by screws).

Semiconductor Laser

A type of laser which produces its output from semiconductor materials such as GaAs.

Service

Performance of adjustments, repair or procedures on a non-routine basis, required to return the equipment to its intended state.

Solid Angle

The ratio of the area on the surface of a sphere to the square of the radius of that sphere. It is expressed in steradians (sr).

Source

The term source means either laser or laser-illuminated reflecting surface, i.e., source of light.

Tunable Laser

A laser system that can be "tuned" to emit laser light over a continuous range of wavelengths or frequencies.

Tunable Dye Laser

A laser whose active medium is a liquid dye, pumped by another laser or flash lamps, to produce various colors of light. The color of light may be tuned by adjusting optical tuning elements and/or changing the dye used.

Ultraviolet (UV) Radiation

Electromagnetic radiation with wavelengths between soft X-rays and visible violet light, often broken down into UV-A (315-400 nm), UV-B (280-315 nm), and UV-C (100-280 nm).

Visible Radiation (light)

Electromagnetic radiation which can be detected by the human eye. It is commonly used to describe wavelengths in the range between 400 nm and 700-780 nm.

Wavelength

The length of the light wave, usually measured from crest to crest, which determines its color. Common units of measurement are the micrometer (micron), the nanometer, and (earlier) the Angstrom unit.

YAG

Yttrium Aluminum Garnet, a widely used solid-state crystal composed of yttrium and aluminum oxides and a small amount of the rare earth neodymium.