THE UNIVERSITY OF TEXAS AT ARLINGTON

Laser Safety Manual

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I. Laser Safety Program Management

Introduction

The University of Texas at Arlington (UT Arlington) has established a Laser Safety Program (Program) to provide controls and safety guidance relevant to research and educational activities involving lasers. This Program is established to meet the requirements of 25 Texas Administrative Code (TAC) 289.301, other applicable regulations and/or standards, and prudent safety practices. If any conflict occurs between this Program and the TAC, the latter shall prevail.

A. Authority and Responsibility

The Laser Safety Program shall be administered under the authority of the Laser Safety Officer (LSO). The LSO shall have the authority to authorize, suspend, and specify conditions of use for all lasers at facilities of and/or areas administered by UT Arlington.

1. Laser Safety Officer

The Laser Safety Officer (LSO) is a permanent position within the Environmental Health & Safety Office (EH&S). Per requirements of the TAC, the LSO is required to administer specific provisions of the Program. The LSO shall be provided with administrative support and adequate resources as are required to carry out the provisions of the Program.

2. Laser Safety Specialist

The Laser Safety Specialist (LSS) assists the LSO in executing the Program. The LSS shall have such authority as is delegated by the LSO to ensure provisions of the Program are successfully carried out. The LSO or LSS shall have the authority to institute corrective actions including shutdown of laser operations when necessary due to unsafe conditions.

B. Classification and Registration

Classification of lasers shall be in accordance with US Food and Drug Administration (FDA) or American National Standards Institute (ANSI) specification ANSI Z136.1 and the Texas Administrative Code 289.301. Each Class 3B or 4 laser at UT Arlington shall be registered with EH&S and shall have a Laser Device Registration (LDR) on file with the LSO. Class 3R lasers and lower class lasers are permitted, so long as they have sufficient location controls to prevent unauthorized removal. Lasers which are classified as 3R or lower, but which contain 3B or 4 lasers, shall be controlled as the higher classification if the Class 3B or 4 lasers are accessed. Each Principal Investigator (PI) shall be responsible for establishing and supporting laser safety protocols for all their lasers.

1. Classification

a. Classes 1 and 1M

i. Any laser, or laser system containing a laser, that cannot emit accessible laser radiation levels during operation in excess of applicable Class 1 AEL for any emission duration within the maximum duration inherent in the design or intended use of the laser or laser system is a Class 1 laser or laser system during operation. The maximum exposure duration is assumed to be no more than 30,000 s except for infrared systems (>700nm), where 100 s shall be used.

b. Class 2 and 2M Visible Lasers and Laser Systems

    i. Classes 2 and 2M lasers and laser systems are visible (400 to 700nm) CW and repetitive –pulse lasers and laser systems which can emit accessible radiation energy exceeding the appropriate Class 1 AEL for the maximum duration inherent in the design or intended use of the laser or laser system, but not exceeding the Class on AEL for any applicable pulse (emissions) durations <0.25s and not exceeding any accessible average radiant power of 1 mW.

c. Classes 3R and 3B lasers and lasers Systems

    i. Class 3R lasers and lasers systems include lasers and lasers systems which have an accessible output between 2 and 5 times the Class 1 SEL for wavelengths shorter than 0.4µm or longer than 0.7 µm, or less than 5 times the Class 2 AEL for wavelengths between 0.4µm and 0.7µm.

    ii. Class 3b lasers and laser systems operating outside the retinal hazard region (i.e. < 0.4µm and > 1.4µm) which can emit accessible radiation power in excess of the Class 3R AEL during any emission duration within the maximum duration inherent in the design of the laser or laser system, but which cannot emit an average radiant power in excess of 0.5W for T≥0.25s and cannot emit a radiant energy greater than 0.03Ca J per pulse. For this limit, pulses separated by less than t_{max} are to be considered one pulse.

d. Class 4 Lasers and Laser Systems.

    i. Class 4 lasers and laser systems are those that emit radiation that excess the Class 3B AEL.

2. Registration Information

Each Class 3B or 4 laser that is possessed, purchased, donated, or otherwise received by any person or entity at UT Arlington shall have a LDR on file with the LSO. The LDR shall be submitted to the LSO by the receiving party as soon as is practicable, **but in no case longer than 10 days following receipt of the laser**. Additionally, PIs who receive Class 3B or 4 lasers through inter- and intra-departmental transfer or loan are required to file a LDR **within 10 days of the transfer or loan**. The LDR is found in Appendix 3.

A LDR Form is provided as an attachment to this document. Information to be provided on the LDR Form shall include at a minimum:

a. The name, department, and contact information of the Principal Investigator.
b. The location of the laser device, with building, room number, and/or laboratory drawing if necessary.
c. Authorized users including contact information for all personnel working in the laboratory.
d. The manufacturer of the laser.
e. The model and serial number of the laser.
f. The Class of laser 3B or 4.
g. The laser medium type (dye, gas, solid state, semiconductor, etc.).
h. The excitation mechanism (i.e., optical, electrical, chemical, etc.).
i. The operating wavelength(s) or wavelength range of the laser in nanometers.
j. The maximum capable energy level of the laser in Joules.
k. The type of laser (i.e., continuous wave, pulse, repetitively pulsed, mode-locked, etc.).

l. When a pulsed laser is used:
    1) The minimum pulse duration.
    2) The maximum pulse frequency per second.
m. The beam diameter at the exit from the laser.
n. Denote if the laser is fixed or mobile.
o. The date the laser was received on campus.
p. The UT Arlington Inventory number of the laser.
q. Description of personal protective equipment required for use.
r. Other pertinent information, including a brief description of the purpose of the laser (i.e., Doppler measurements, fluorescence, etc.), frequency of use, etc. Include any information that may have a bearing on safety-related issues.

3. Removal of Laser(s) from Registration

The Principal Investigator (PI) shall provide disposition information to UT Arlington LSO prior to leaving UT Arlington. Lasers removed from UT Arlington's control by gift, surplus designation, or transfer to a non-UT Arlington entity shall have information regarding condition and destination provided to the LSO before removal from the controlled area. Lasers that are to be rendered permanently inoperative by disassembly or destruction shall be surrendered to the LSO for destruction.

C. Laboratory Personnel

1. Principal Investigator

The PI is the person whose name appears on the LDR for the laser registered with the LSO. This must be permanent faculty or staff (not a postdoc, graduate student, etc.).

The PI is responsible for the following:

a. Laser Safety in the laboratory.
b. Completing and filing a LDR with the LSO.
c. Ensuring the availability of correct protective eyewear.
d. Providing a Standard Operating Procedure to be approved by the LSO.
e. Providing, implementing, and enforcing the Laser Safety Program specific to the laboratory and/or laser.
f. Ensuring proper training in laser operation and safety.
g. Classifying and labeling all lasers in the laboratory.
h. Notifying the LSO immediately when a laser is purchased or obtained.
i. Notifying the LSO if a laser is to be decommissioned, sold, or transferred.
j. Notifying the LSO immediately if an exposure incident occurs.

2. Authorized User

The authorized user is the person who sets up, aligns, and/or operates the laser.
The laser operator or user is responsible for the following:

a. Following laboratory administrative, alignment, safety, and standard operating procedures while operating the laser.
b. Requesting and receiving prior approval from the LSO before departing from established safety procedures.
c. Completing Laser Safety Training

3. Non – Authorized Personnel

Faculty, students, and other professionals and non –UTA personnel which have not had UTA Laser Safety Training and are not on the PI's list of Authorized users.

D. Laser Laboratory Audit

The LSO or LSS shall audit the laboratory containing the laser(s). The audit shall be performed at least annually, and shall be performed prior to operating a laser for the first time after assembly, maintenance, or modification of the beam path, operating wavelength, or power level. Audit records shall be retained for inspection by the LSO.

II. Laser Safety

A. Maximum Permissible Exposure and Nominal Hazard Zone

For all open beam class 3B and 4 lasers the Maximum Permissible Exposure (MPE) will be assumed to be exceeded and appropriate precautions will be taken. The Nominal Hazard Zone (NHZ) will therefore comprise the enclosure (room or area the beam is restricted to by virtue of walls, curtains or other barriers) in which the laser is operating. The LSO may, for specific conditions, determine the NHZ by using information supplied by the laser manufacturer, by measurement, or by using the appropriate laser range equation or other equivalent assessment. The PI shall not allow persons to be exposed to levels of laser radiation exceeding the MPE.

B. Required Laser Safety Features

1. Standard Operating Procedure

Each laser shall have a Standard Operating Procedure (SOP) written for its operation. The SOP must be a laboratory/laser/research-specific protocol that specifies safe use and procedures for the laser system. **The LSO approved SOP must be present at the operating console or control panel of the laser**. The SOP shall include at a minimum, operating instructions, safety eyewear parameters and instructions for proper use, interlock instructions, checklist for operation, and emergency procedures. The SOP shall include clear warnings to avoid possible exposure to laser and collateral radiation in excess of the MPE. The SOP shall be approved by the LSO before the laser is operated.

2. Training

Each person who operates or works with a class 3B or 4 laser shall complete training in laser safety provided by UT Arlington. No person may work in a NHZ prior to completing the online laser safety training. The online laser safety training can be found on the EH&S' online training website http://uta-ded.org/ehs/. Each person is required to retake the online laser safety training every three years.

Each PI is responsible for instructing authorized laser users regarding all task specific methodology in the laboratory. The PI must carry out the required administrative and safety procedures, select those laboratory practices which are applicable to the work, train and supervise their authorized laser users,

acquaint them with proper laser safety practices, and ensure that the laboratory is properly posted as required by 25 Texas Administrative Code (TAC) 289.301.

3. Master Switch

Each class 3B and 4 laser shall be provided with a master switch. This master switch shall be operated by a key, or by a coded access (such as a computer code).

4. Safety Interlocks

All class 3B and 4 lasers shall have interlock on any safety housing that ensures that laser radiation is not accessible above MPE limits, and which is removable without the use of tools. Adjustment during operation, service, testing, or maintenance of a laser containing interlocks shall not cause the interlocks to become inoperative except with permission from the LSO. Pulsed lasers, interlocks shall be designed to prevent firing of the laser; for example, by dumping the stored energy into a dummy load. CW laser interlocks shall turn off the power supply or interrupt the beam (i.e., by means of shutters).

5. Safety Interlocks-Alternatives

The regulations recognize that in situations where an engineering control may be inappropriate, UT Arlington LSO shall specify alternate controls to obtain equivalent laser safety protection. Alternate controls may be submitted in writing to the LSO and, if accepted, will be documented in the SOP.

Where safety latches or interlocks are not feasible or are inappropriate, the following shall apply:

- **a.** All authorized personnel shall be trained in laser safety and appropriate personal protective equipment shall be provided upon entry.
- **b.** A door, blocking barrier, screen, or curtains shall be used to block, screen, or attenuate the laser radiation at the entryway.
- **c.** The exposure levels at the exterior of these devices shall not exceed the applicable MPE, nor shall personnel experience any exposure above the MPE immediately upon entry.
- **d.** At the entryway there shall be a visible or audible signal indicating that the laser is energized and operating at class 3B and 4 levels. A lighted laser warning sign, flashing light are acceptable methods to accomplish this requirement.

C. Protective Eyewear

Each PI shall provide protective eyewear that meets the requirements of 25 TAC 289.301(t)(1). The eyewear shall be located where persons who operate the laser have unrestricted access to the eyewear. The eyewear shall be worn for alignment and operation where the laser beam is not enclosed. No person shall operate a class 3B or 4 laser without protective eyewear specific for that laser and the appropriate training for the specific eyewear.

Protective eyewear shall meet the following requirements:

i. Provide a comfortable and appropriate fit all around the area of the eye.
ii. Be in proper condition to ensure the optical filter(s) and holder provide the minimum Optical Density (OD) or greater at the specific wavelength of the laser, and retain all protective properties during its use.

iii. Be of adequate OD for the laser energy involved.
iv. Have the OD of associated wavelengths prominently and permanently labeled by the manufacturer on the filters or eyewear.
v. Be examined at intervals not to exceed 12 months, to ensure the reliability of the protective filters and integrity of the holders. Unreliable eyewear shall be discarded and replaced.
vi. The OD of the protective eyewear shall be appropriate for the specific frequency and pulse length of the laser beam, and shall provide reduction of the incident energy to less than the MPE of the laser. It is important to include the pulse length and frequency of pulse repetition of pulsed lasers in selecting appropriate protective eyewear.
vii. Persons working in a laboratory with multiple lasers shall be made aware of the various frequencies and other operating parameters by the laser operator/users.
viii. Persons working with tunable lasers or any laser that is frequency doubled or frequency tripled shall be aware of the effect of frequency manipulation and shall choose protective eyewear that will provide protection for the effective operating frequency of the laser.

D. Laser Control Room Requirements

1. Warning Systems

Each class 3B or 4 lasers shall provide visual or audible indication during the emission of accessible laser radiation. The indication shall occur prior to emission of radiation with sufficient time to allow appropriate action to avoid exposure. Any visual indication shall be visible through protective eyewear for the wavelength of the laser.

2. Controlled Area and Posting

Each class 3B and 4 laser shall only be operated in a Controlled Area. A controlled area shall be established by the PI to limit access of personnel to laser radiation. Each controlled area shall be posted conspicuously with signs as specified in 25 TAC 289.301(v). Access to the controlled area shall be controlled by a door, blocking barrier, screen, or curtain, which attenuates the laser radiation to below the MPE, and individuals who enter the controlled area, shall not experience radiation above the MPE immediately upon entry.

3. Controlled Area and Posting for 3R Lasers

There are no registration or Controlled Area requirements for 3R lasers at this time. However, an area which contains a Class 3R laser or laser system should be posted with the appropriate sign.

E. Miscellaneous Safety Issues

1. Fiber Optic Transmission

Optical cables used for transmission of laser radiation shall be considered part of the laser protective housing. Disconnection of a fiber optic connector that results in access to radiation in excess of the MPE shall take place in a controlled area. All connectors shall bear appropriate labels. Optical cables shall be encased in an opaque sleeve to prevent leakage of laser radiation in case of breakage.

2. Skin protection

Persons in the controlled area shall wear appropriate Personal Protective Equipment (PPE) such as clothing, gloves, and/or shields to prevent exposure of the skin to levels exceeding the skin MPE.

3. Infrared Lasers

An infrared laser beam shall be terminated in a fire-resistant material so that the laser beam is not inappropriately reflected. Inspection of the terminating material shall occur during the annual audit.

4. Magnification of Laser Beam

If, at any time, a laser beam is optically magnified or concentrated, special precautions shall be taken by the PI to prevent specular or diffuse reflection or other exposure greater than the MPE for the laser. The special precautions shall be documented in the SOP for the laser and approved by the LSO prior to implementation.

5. Records

Records of Surveys, Training, NHZ and MPE calculations, and other laboratory-specific information shall be maintained by the LSO. Records shall be maintained as specified in 25 *TAC 289.301(ee)*.

6. Non-Radiation Hazards

Each laser may be evaluated for non-radiation hazards which may be present as part of the laser's construction or operation. This evaluation may include electrocution, chemical, cutting edge, compressed gases, noise, confining space, fire, explosion, ventilation, and/or physical safety hazards.

7. Incident Reporting

Each PI shall immediately seek appropriate medical attention for an injured individual and notify the LSO by telephone within 24 hours of any exposure injury involving a laser possessed by UT Arlington. The LSO shall be notified within 48 hours of any non-injury incident that involves potential exposure to laser radiation exceeding the MPE. A written summary of an injury or non-injury incident shall be forwarded to the LSO no later than one week following the incident. Records of the incident shall be maintained by the LSO.

III. Laser Hazards

A. Biological Effects

The biological effects are dependent on the laser beam properties and vary with duration, wavelength, photon energy, target tissue, and tissue condition. Therefore, all effects have to be weighed on a case by case basis. However, safety and prevention are the best protection against personal injury.

1. Eye

Injuries to the eye are primarily due to two main types of biological effects which may or may not occur separately. Biological effects to the eye are dependent on exposure conditions, wavelength, and irradiation levels. The main tissue types of the eye which suffer these biological effects are the cornea, lens and retina.

(a) Photochemical - High energy laser light photons may interact with molecules in the eye tissue causing chemical bonds to be broken. The injury depends on the tissue of the eye affected.

(b) Thermal- Heat dissipation is a major factor in causing to the eye. Heat flow could travel horizontally along the same tissue or vertically through different depths of underlying tissues.

(c) Summary-Types of eye damage from laser radiation are:

Cornea - Corneal Burn
Lens - Cataracts
Retina - Decreased Vision/ Vision Loss
Optic - Nerve Blindness

2. Skin

Skin tissue is at risk from laser exposure. The skin can tolerate higher levels of radiation that the eye in wavelength range 400-1400nm. However, the higher the power of the laser, the greater the risk to the skin.

(a) Thermal- is an actual burn to the skin due to an increase in temperature. The severity of the burn is dependent upon the penetration of the skin tissue.

(b) Erythema - is due to the intense ultraviolet beam exposure, the skin will be affected. Typically, this affect is equivalent to a photochemically induced sunburn.

(c) Summary- Types of skin damage from laser radiation are:
Erythema, skin burns, skin cancer, and skin aging.

B. Non-Beam Hazards

In addition to the direct hazards to the eye and skin from the laser beam itself, it is also important to address other hazards associated with the use of lasers. These non-beam hazards, in some cases, can be life threatening, e.g. electrocution, fire, and asphyxiation. The only fatalities from lasers have been caused by non-beam hazards.

1. Chemical Hazards

Compressed gases should be handled with care and compressed gas cylinders need to be secured. Laser dyes or solvents may be toxic and/or carcinogenic and should be handled appropriately.

2. Electrical Hazards

Power supplies – high voltage precautions should be designed to prevent electrocution Voltages greater than 15 kV – may generate x-rays.

3. Fire Hazards

Electrical components, gases, fumes and dyes – can constitute a fire hazard; use of flammables should be avoided, and flame-resistant enclosures should be used.

APPENDIX 1

ACRONYMS

FDA Food and Drug Administration, United States.

LDR Laser Device Registration

LSO Laser Safety Officer, the individual responsible for the University's Laser Safety Program.

LSS Laser Safety Specialist, works under the supervision of the LSO in support of the Laser Safety Program.

MPE Maximum Permissible Exposure, the maximum amount of laser energy allowed entering the eye of an observer.

NHZ Nominal Hazard Zone, the space within which the level of the direct, reflected, or scattered radiation may exceed the applicable MPE.

OD Optical Density is a measure of the attenuations (reduction in transmission) of an optical filter.

PI Principal Investigator

PPE Personal Protective Equipment, eyewear, UV face shield, laboratory coat etc. used to protect an individual, in this case from laser radiation.

SOP Standard Operating Procedure, the document that describes how to appropriately and safely operate a laser.

APPENDIX 2

GLOSSARY

Absorption - the transformation of radiant energy to a different form by interaction with matter.

Access Control - Entry must be restricted to only authorized laser personnel during the operation of laser equipment.

Accessible Emission Level (AEL) - the maximum accessible emission level permitted within a particular class of laser.

Average Power - the total energy imparted during exposure divided by the exposure time.

Aversion Response - the movement of the eyelid or the head to avoid an exposure to a noxious stimulant or bright light. It can occur within 0.25 seconds, including blink reflex time.

Aperture - any opening in the protective housing or other enclosure of a laser product through which laser radiation is emitted, thereby allowing human access to such laser radiation.

Attenuation - the decrease in the radiant flux as it passes through an absorbing or scattering medium.

Beam - a collection of rays which may be parallel, divergent or convergent.

Beam Diameter - the distance between diametrically opposed points in the cross-section of a beam where the power per unit is l/e times that of the peak power per unit area.

Beam Divergence (O) - the full angle of the beam spread.

Beam Expander - any combination of optical elements which can increase the diameter of the laser beam.

Beam Splitter - an optical device which uses controlled reflection to produce two beams from a single incident beam.

C0-2 Laser - wave-length 10.6 micrometers (for infrared, invisible).

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

Continuous Wave (CW) - the output of a laser which is operated in a continuous rather than pulse mode for a period greater than 0.25 seconds.

Controlled Area - an area where the occupancy and activity of those within are subject to control and supervision for the purpose of protection from radiation hazards.

Diffraction - the deviation of a part of a radiation beam, determine by the wave nature of the radiation, and occurring when the radiation beam passes the edge of an opaque obstacle.

Diffuse Reflection - the change of the spatial distribution of a beam of radiation when it is reflected in many directions by a surface or by a medium.

Emergent Beam Diameter (a) - the diameter of the laser beam at the exit aperture of the laser product, measured in centimeters (cm).

Energy (Q) - the capacity for doing work. Energy content is commonly used to characterize the output from pulsed laser products and is generally expressed in joules (Jo).

Energy Density - the emittance (M) or irradiance (E) of electromagnetic radiation, energy per unit area, e.g., joules meter^2 or joules/centimeter^2.

Exposure – optical radiation of incident on the surface of the eyes or skin, or the product of an irradiance

(E) and its duration.

Gas Laser - a type of laser where the laser action takes place in a gaseous medium.

Helium-Neon (HeNe) Laser – is a gas laser with a wave length of 632.8 nanometers.

Hertz (Hz) - the unit which expresses the frequency of a periodic oscillation in cycles per second.

Human Access - access at a particular point to laser or collateral radiation by any part of the human body or by an object. A laser product or installation shall be considered to permit human access if radiation in excess of an accessible emission limit is incident at a point that can be reached by a straight object.

Incident - an unusual event or occurrence.

Infrared Radiation - the electromagnetic radiation with wavelengths that lie in the 0.7 micrometer to l millimeter range.

Intensity - the amount of energy or energy per unit time passing through a unit area perpendicular to the line of propagation at the point in question.

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

Irradiance (E) - the quotient of the radiant power incident on an element of a surface by the area of what element, expressed in watts per square centimeter (W/cm^2).

Joule (J) - a unit of energy, one J = l Watt/second.

Laser - Light Amplification by Stimulated Emission of Radiation. A device that generates directional, coherent optical radiation through a process of stimulated emissions.

Laser Controlled Area - any area which contains one or more lasers and in which the activity of personnel is subject to control and supervision for the purpose of protection from laser radiation hazards.

Laser Protective Device - any device, the intended function of which is the control of laser radiation with the intent of reducing or eliminating the exposure of personnel to such radiation.

Laser Radiation - all electromagnetic radiation which is produced as a result of controlled stimulation emission.

Laser Safety Officer (LSO) - any individual, qualified by training and experience in occupational and public health aspects of lasers, who is designated to evaluate the radiation hazard of and to establish, administer, and be responsible for, laser radiation protection.

Laser System - a laser in combination with an appropriate laser energy source with or without additional incorporated components.

Lasing Medium - a material emitting coherent radiation by virtue of stimulated electronic or molecular transitions to lower energy levels.

Limiting Aperture - the maximum circular area over which radiance or radiant exposure can be averaged.

Maintenance - the 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 insure the intended performance of the product.

Maximum Emission Duration - the maximum duration of repeated, or continuous operation of which the laser product is capable, whichever is greater.

Maximum Output - that maximum magnitude of energy or power, at any time after manufacture, of total

accessible laser radiation emitted by a laser product over the full range of operational capability.

Maximum Permissible Exposure (MPE) – is the highest level of laser exposure at the eyes or skin that is generally considered safe.

Neodymium Yttrium Aluminum Garnet (Nd.YAG) Laser - wavelength (A) 1 06 nanometers.

Nominal Hazard Zone (NHZ) - the space within which the level of the direct, reflected, or scattered radiation during normal operation exceeds the applicable MPE.

Nominal Ocular Hazard Distance (NOHD) - the distance along the axis of the unobstructed beam from the laser to the human eye beyond which the irradiance or radiant exposure during normal operation is not expected to exceed the appropriate MPE.

Operable Laser - a laser that can produce laser radiation.

Operation - the performance of the laser or laser system over the full range of its intended functions (normal operation). It does not include “maintenance” or “service” as defined in this section.

Optical Density (OD) - the logarithm to the base ten of the reciprocal of the transmittance.

Output Power and Output Energy - the laser output power used primarily to rate CW lasers since the energy delivered per unit time remains constant (output measured in watts). In contrast, pulsed lasers deliver energy in pulses and their effects can be best categorized by energy output per pulse.

Power (P) - the time rate at which energy is emitted, transferred, or received; usually expressed in watts.

Protective Housing - those portions of a laser product which are designed to prevent human access to laser and collateral radiation.

Pulse Duration - the time increment measured between the half-peals-power points of the leading and trailing edges of the pulse.

Pulse Repetition Frequency (PRF) - the number of laser pulses per unit time (usually expressed in seconds).

Pulsed Laser - a laser which delivers its energy in the form of a single pulse or a train of pulses, where the duration of a pulse is less than or equal to 0.25 seconds.

Q-switch - a device for producing very short (approximately 30 nanoseconds), intense laser pulses by enhancing the storage and dumping of electronic energy in and out of the basing medium, respectively.

Q-switched Laser - a laser, which emits short (approximately 30 nanoseconds), high-power pulses by utilizing a Q-switch.

Radiance (L) - radiant power per unit area of radiation surface per unit solid angle of emission, expressed in watts per square centimeter per steradian ($w/cm^2/Sr$).

Radiant Energy (Q) - energy emitted, transferred or received in the form of radiation, expressed in joules (J).

Radiant Exposure (H) - the quotient of radiant energy incident on an element of a surface by the area of that element, expressed in joules per square centimeter (J/cm^2).

Radiant Intensity (I) - (of a source in a given direction) - means the quotient of the radiant flux leaving the source, propagated in an element of solid angle containing the given direction, by the element of solid angle. Expressed in watts per steradian (w/Sr).

Radiant Power - power emitted, transferred or received in the form of radiation, expressed in watts (W).

Reflectance, Reflectivity (ρ) - the ratio of total reflected radiant power to total incident power.

Reflection - the deviation of radiation following incidence on a surface.

Remote Control Connector - a two-terminal connector which permits the connection of external controls placed apart from other components of the laser product to prevent human access to all laser and collateral radiation in excess of limits specified.

Safe Eye Exposure Distance - the distance from an operating laser such that the energy that might infringe upon the eye is less than the MPE.

Safety Interlock - a device associated with the protective housing or enclosure of a laser product to prevent human access to excessive radiation under conditions specified.

Service - the performance of those procedures or adjustments described in the manufacturer's service instructions which may affect any aspect of the performance of the laser or laser system. It does not include "maintenance" or "operation" as defined in this section.

Source - the term used to describe either a laser or laser-illuminated reflecting surface.

Specular Reflection - a mirror-like reflection.

Transmission - the passage of radiation through a medium.

Transmittance (T) - the ratio of total transmitted radiant power to total incident radiant power.

Ultraviolet Radiation - the electromagnetic radiation with wavelengths shorter than those for visible radiation (0.2 - 0.4 micrometers). This region is often broken down into three spectral bands by wavelength: VV-A (315 - 400 nanometers), UV-B (280 -315 nanometers), and UV-C (200 - 280 nanometers).

Unrestricted Area - any area to which access is not controlled for the purposes of protection of individuals from exposure to radiation.

Vaporization - the conversion of a solid or liquid into vapor.

Visible Radiation (Light) - all electromagnetic radiation that can be detected by the human eye. It is commonly used to describe wavelengths which lie in the range between 400 nm and 700nm.

Watt (W) - a unit of power, or radiant flux.

Wavelength - only the propagation wavelength in air of electromagnetic radiation.