CALIFORNIA STATE UNIVERSITY, FRESNO

LASER SAFETY TRAINING GUIDE

Office of

Environmental Health and Safety

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Laser Safety Training Guide

Section 1 - Laser Safety Program

This Guide is intended to give the reader a basic understanding of lasers and laser safety. The Laser Safety Program requires laser users to read and use the information in the Guide.

A. Laser Safety Policy Manual

Your Principal Investigator (PI) has a copy of the Laser Safety Policy Manual available for your reference. You should review the manual prior to starting work with the laser.

B. Laser Safety Training Guide

All laser users are required to read the Laser Safety Training Guide. It is the responsibility of the Principal Investigator to ensure that all users have read the Guide.

Section 2 - The Unique Nature of Laser Radiation

A. Coherent vs. Non-Coherent Radiation Sources

The most unique aspect of the laser is its ability to create a radiation beam that is in-phase or coherent. In a coherent light source, the amplitude of the radiated waves is additive which can result in a beam of great intensity. Non-coherent radiation sources (like a light bulb) propagate light that is out of phase and results in the reduction of the amplitude by cancellation of overlapping wave forms. The intensity of coherent light sources may be greater than the intensity of non-coherent sources by orders of magnitude.

B. Monochromatic Radiation Sources

Many sources produce a broad range of radiation wavelengths. Lasers will normally produce only one or two wavelengths. The single wavelength is called monochromatic radiation and, depending on the type of laser, the radiation produced can fall anywhere in the electromagnetic spectrum between 100 nm (UV) and 1 mm (IR). Monochromatic radiation does not scatter as much as polychromatic radiation when interacting with lenses or mirrors (from chromatic aberration). This lack of scattering can result in very intense spectral or diffuse reflections.

C. Irradiance (Power Density) and Continuous Wave (CW) Lasers

An important factor in determining the hazard of continuous wave lasers is the irradiance (power density) of the laser beam. Irradiance is expressed in W/cm^2 and is a function of the beam power divided by the beam area. Beam area is dependent on the beam size at the aperture, the divergence of the beam and the distance from the aperture. Focusing or defocusing the laser will dramatically affect the irradiance. Obviously, the greater the irradiance, the greater the hazard.

D. Radiant Exposure (Energy Density) and Pulsed Lasers

Not all lasers are operated in a continuous wave mode. Many operate in pulsed modes with various pulse durations and pulse frequencies. These lasers cannot be characterized by their irradiance and we instead consider their radiant exposure (energy density) expressed in J/cm^2. Radiant exposure is a function of power density, pulse duration and pulse frequency. Again, the greater the radiant exposure, the greater the hazard.

Section 3 - Understanding the Laser

A. Basic Operation of the Laser

The basic operating concept of the laser is very simple. Electrons in a lasing medium are moved from a ground state into a higher energy state by absorbing energy from an excitation source. When these electrons descend to their ground state, photons of a specific (monochromatic) wavelength are emitted in a process called “spontaneous emission.” These photons oscillate in a feedback mechanism which increases the laser radiation intensity through stimulating the emission of additional photons of identical wavelength and phase in the excited medium. Finally, the photons are allowed to escape via an output coupler as a laser beam.

B. Types of Lasing Media

Lasing media can be solids, liquids, or gases. The type of medium dictates the wavelength of the laser beam. Some media can be manipulated to allow for tuning of the wavelength. Solid state media (polished crystal rods), gases or vapors (sealed in a glass tube), liquid dyes, and semiconductor (diode) lasers are all common lasing mediums. Halogen gasses mixed with noble gasses can combine in an excited state to create pseudo molecules called “excited dimers” or excimers. Excimer lasers emit laser radiation in the ultraviolet region of the spectrum. It is even possible to use an accelerated beam of free electrons as a lasing media. Free electron lasers (FEL) use a “wiggler” magnet to propagate photons from the electron beam.

C. Types of Excitation Sources

Flashlamps, plasma discharge tubes, high voltage current and radio frequency devices are all sources used to excite the lasing media. Some lasers are used to “pump” other lasers in various applications (for example Ti-Sapphire). It is important to remember that the excitation device itself can present a serious non-beam hazard.

Section 4 - Laser Radiation Bioeffects

A. Mechanism of Injury

There are three primary mechanisms of tissue injury associated with laser radiation exposure. These are: thermal effects, photochemical effects, and acoustical transient effects.

Thermal effects can occur at any wavelength and are a function of the irradiance or radiant exposure.

Photochemical effects are related to the time of exposure as well as the irradiance or radiant exposure. In air, photochemical effects occur between the 200 and 350 nm ultraviolet wavelengths.

Acoustical transient effects are related to pulse duration and may occur in pulses up to 1 ms depending on the specific wavelength of the laser. The acoustical transient effect is poorly understood, but it can cause retinal damage that cannot be accounted for by thermal injury alone.

B. Eye Injury Potential

The potential location of injury in the eye is directly related to the wavelength of the laser radiation. For laser radiation entering the eye:

Wavelengths shorter than 300 nm or longer than 1400 nm are absorbed in the cornea.

Wavelengths between 300 and 400 nm are absorbed in the aqueous humor, iris, lens, and vitreous humor.

Wavelengths between 400 nm and 1400 nm are focused onto the retina.

NOTE: Retinal injury can be severe because of the focal magnification of the eye which is approximately 10^5. This means that an irradiance of 1 mW/cm^2 entering the eye will be effectively increased to 100 W/cm^2 when it reaches the retina.

Thermal burns in the eye are caused when the blood flow cannot regulate the heat loading on the tissue. Secondary bleeding into the vitreous humor may occur as a result of burns and obscure vision well beyond the burned area. Although the eye can repair minor damage, major injury to the macula may result in temporary or permanent blindness. Photochemical injury to the eye by ultraviolet exposure may result in photokeratitis (often called welders flash or snow blindness). This painful condition may last for several days and is very debilitating. Long term UV exposure can cause cataract formation.

The duration of exposure also plays a role in eye injury. For example, if the laser is a visible wavelength (400 to 700 nm), the beam power is less than 1.0 mW and the exposure time is not greater than 0.25 second (the human aversion response time), no injury to the retina would be expected to result from an intrabeam exposure. Class 1 and 2 lasers fall in this category and do not normally present an eye hazard. Unfortunately, intrabeam viewing of Class 3R, 3B, or 4 lasers and diffuse reflections from Class 4 lasers may cause an injury before the aversion response can protect the eye.

For pulse lasers, the pulse duration can also effect the potential for eye injury. Pulses less than 1 ms in duration focused on the retina can cause an acoustical transient, resulting in substantial damage and bleeding in addition to the expected thermal injury.

The ANSI Z136.1 – 2007 standard defines the Maximum Permissible Exposure (MPE) that will prevent an injury to the eye under various exposure conditions. If the MPE is exceeded, the probability that an eye injury can result increases dramatically.

The first rule of laser safety is: NEVER LOOK IN THE BEAM! If you can prevent the laser beam and beam reflections from entering the eye, you can prevent a painful and possibly blinding injury.

C. Skin Injury Potential

Skin injuries from lasers primarily fall into two categories: thermal injury (burns) from acute exposure to high power laser beams and photochemically induced injury from chronic exposure to ultraviolet laser radiation.

Thermal injuries can result from direct contact with the beam or spectral reflections. These injuries are easy to prevent through proper beam control and containment.

Photochemical injury may occur over time from ultraviolet exposure to the direct beam, spectral reflections or even diffuse reflections. The effect can be minor or severe sunburn, and prolonged exposure may promote the formation of skin cancer. Proper protective eyewear and clothing may be necessary to control UV exposure.

Section 5 - Laser Beam Hazards and Control Methods

General Considerations

The primary hazard associated with the laser is eye injury caused by intrabeam viewing or the viewing of spectral or diffuse reflections. Hazard control methods are used to prevent the laser beam from entering the eye. These control methods can be divided into three areas:

Administrative controls - signs, labels, procedures, etc.

Engineering controls - barriers, beam blocks, interlocks, etc.

Personal protective equipment - protective eyewear, skin covering, etc.

Experience has shown that reliance on any one of these areas is not as effective as the use of a combination of control methods. For this reason, the Laser Safety Program recommends use of a broad range of controls aimed at reducing the probability of laser injuries. These controls include:

A. Administrative Controls

The use of administrative controls can prove useful in promoting laser safety in the laboratory. The information listed on the LRF should be used to assist in setting up administrative controls.

1. Standard Operating Procedures (SOPs)

The Laser Safety Program recommends the development and documentation of SOPs for alignments, maintenance and normal operations. These SOPs are the logical place to document in-house administrative controls. The SOPs can then be used to train the laser users in the laboratory.

It must be stressed that the administrative controls will not positively impact the laser safety environment unless they are kept up-to-date and are reinforced by the PI through example and action.

2. Posting and Labeling of Laser Systems

All access doors to rooms which contain Class 3R, 3B, or 4 lasers are to be posted with a sign marked with the word “DANGER”, the international laser symbol, a description of the laser class, the wavelength, and the laser power. A room containing more than one laser may include information for each laser on the same sign. In addition, it is recommended that an interlocked lighted sign (that blinks on and off when the laser is operating) be located outside of all Class 4 laser facilities to further warn staff of the presence of laser radiation. All Class 3R, 3B, and 4 lasers are to be marked with the appropriate labels indicating the laser class, laser hazard, and identifying the laser aperture.

B. Engineering Controls

1. Controlling Access to Laser Facilities

All Class 3B and 4 laser facilities are to have appropriate access controls to prevent unauthorized personnel from entering the facility while the laser is in operation. Key or combination locks are useful for this purpose. Doorways to laser facilities are to be kept closed at all times, and locked when the laser user is not in direct attendance.

2. Protective Housings, Interlocks and Shutters

All Class 3R, 3B, and 4 lasers are to have a non-flammable protective housing sufficient to contain the beam and excitation device. It is strongly recommended that the housing be interlocked such that the laser cannot normally be operated with the cover removed. If a housing interlock is required, it must not be disabled except with the approval of the LSO.

Most Class 3B and 4 lasers are equipped with a shutter mechanism which prevents the beam from leaving the housing when activated. If a shutter is required, it must be operational and is not to be disabled except with the approval of the LSO.

3. Key Operation, Power On Indication, and Power Meters

Many laser systems are equipped with key switches that prevent operation when the key is removed. If a key switch is required, it must not be disabled except with the approval of the LSO. In order to prevent unauthorized personnel from operating the laser, the key should be removed from the laser control and stored in a secure location whenever the laser is not being used.

All class 3B and 4 lasers need to have a lighted power on indicator clearly visible to persons in the laser facility. The power on indicator should be interlocked to prevent the laser from being operated if the indicator is not functioning.

It is highly recommended that each laser system have a power level meter to inform the user of the operating power of the laser.

4. Optical Tables, Beam Alignment and Remote Viewing Systems

Most research laser use entails the use of optical tables to manipulate beams. Therefore, the safety issues associated with the specific optical table components and the general table environment must be considered. The primary intent is to prevent the beam from leaving the table top. Optical components must be aligned and secured properly to assure beam control. Be aware of secondary reflections from optical devices and plan to contain them if they are a concern.

Beam height should be planned to avoid eye level (both standing and sitting) in the facility. In situations where the beam needs to be directed to another area, it is important to consider enclosing the beam, using fiber optics, or directing the beam well above eye level as a precaution against accidental exposure.

Beam alignment is the most hazardous aspect of lasers use and results in the majority of eye injuries. For this reason, beam alignment procedures must be carefully thought out, formalized, documented, and users properly trained on the procedures. Beam alignment should be performed at the lowest possible beam power, preferably below the MPE.

If the beam power cannot be reduced, it is recommended that a lower powered laser be used to align the optics. If alignments are being done with power levels above the MPE, the user must use appropriate laser protective eyewear during the procedure. This eyewear normally will be of minimal optical density (OD) because the protection required is from a reflected beam, and not from intrabeam viewing. Alignments must be done so that the user is never looking directly into the beam.

When possible, it is advisable to have two users work together when performing alignments, so as to remind each other of safety considerations. One of the safest methods to use for viewing the beam is the use of a remote camera system. Remote viewing, although expensive, virtually eliminates the eye hazard associated with alignment procedures.

5. Enclosures, Beam Barriers, Beam Stops and Collimators

Whenever possible, enclose as much of the beam as possible without interfering with the application. Enclosures do not have to be sophisticated, but must contain the beam safely and be marked to indicate the presence of the beam inside the enclosure. By totally enclosing the beam, you may eliminate the need for other safety precautions. Be careful not to use flammable enclosure materials with Class 4 laser systems. For example, you might effectively change a Class 4 laser system into a Class 1 system with proper enclosures and interlocks.

Another effective and versatile tool for reducing the hazard from stray laser radiation is the use of beam barriers or beam curtains to surround all or part of the laser system. Labyrinth designs can be used to limit the hazard while maintaining ready access to laser systems. Again, be careful not to use flammable barrier materials with Class 4 laser systems.

For exposed beam paths, beam stops should always be used behind optical devices used to change the direction of the beam. The use of these stops will prevent the beam from leaving the table should the beam become misaligned and miss the optical device. Again, be careful not to use flammable beam stops with Class 4 laser systems.

Beam collimators can also be useful in restricting the path of the beam should misalignment occur. Many optical devices have a metal ring surrounding the device which will act as a beam collimator.

6. Beam Condensation, Enlargement and Focusing

Manipulation of the beam diameter will change the hazard from intrabeam exposure. For example, beam enlargement will reduce the irradiance or radiant exposure level, but will increase the probability of scattering due to the enlarged cross section of the beam as it passes through optics.

A focused beam will present a greatly increased hazard at the focal point, but will diffuse quickly past the focal point, substantially reducing the hazard area as compared to the initial beam.

7. Beam Filtration, Frequency Doubling Crystals and Pumping Lasers

Beam power and other characteristics may be manipulated through the use of filtration devices. Do not rely on filters to eliminate beam hazards unless they are expressly designed for that application. Be aware that prolonged exposure to laser radiation may bleach filter devices, changing their absorption and their ability to reduce hazards.

Nonlinear crystals used to double, triple or even quadruple the frequency of the laser radiation are extremely common in laser usage. The use of these crystals may present multiple laser wavelengths whose hazards must all be considered. The issue of multiple wavelengths also applies to the use of pumping lasers. Whenever possible, it is advisable to enclose unused beams (of differing wavelengths) to limit the scope of the laser hazard.

8. Preventing and Controlling Reflections

Any item placed in the beam path may result in a spectral or diffuse reflection of the laser beam. For this reason, it is important to restrict the items on the optical bench to those intended to manipulate the beam path. Good housekeeping should not be overlooked as a source of laser hazard control. Tools, unused optical devices, and other items should not be left on the optical table.

For invisible beams, the nature of reflection and absorption at the particular wavelength may need to be considered to adequately control reflections on various surfaces.

C. Personal Protective Equipment

1. Laser Protective Eyewear

The use of laser protective eyewear has sometimes been stressed as the only method of laser safety in the laser laboratory. Here, protective eyewear is only one of the laser safety control measures. In general, it is better to control laser hazards through engineering controls, such as enclosures, beam blocks, etc. rather than to rely solely on eyewear.

Protective eyewear is essential during the beam alignment process. Most laser accidents occur during beam alignments and most accidents could have been prevented by wearing the appropriate protective eyewear. The eyewear selected should allow proper viewing of the beam. Laser users have suffered eye injury when they removed their eyewear to view the beam.

All laser protective eyewear must be marked with the intended protective wavelength and optical density (OD) at that wavelength. It is recommended that all laser protective eyewear be color coded to the laser of concern with colored tape. This can prevent mishaps when more than one laser is used in a facility.

Selection of appropriate eyewear is very important. Several different eyewear styles are available depending on the needs of the user. The eyewear selected must have the appropriate OD at the wavelength(s) of concern and must be comfortable enough to wear as required.

2. Skin Protection

UV laser systems or UV excitation systems can present severe hazards to exposed skin surfaces. If scattered UV radiation cannot be adequately enclosed to prevent exposure, it may be necessary to wear appropriate covering to protect the skin. These coverings may include gloves, UV face shield, labcoat, etc.

D. Combined Control Methods

1. Invisible Beam Hazards

The use of invisible beams (UV or IR) presents unique hazards. Be sure that beam paths are clearly identified. For example, tape strips can be used for defining beam paths on optical tables. Have the appropriate viewing aids (such as fluorescent cards or IR intensifiers) available for use during alignment procedures. Avoid the use of burn marks on wood or paper as an alignment reference.

2. Repair and Maintenance Hazards

During repair or maintenance, access to laser radiation may be greater because of the removal of the laser housing. Only qualified persons should perform laser system maintenance or repair. The appropriate laser protective eyewear must be used whenever exposure to laser radiation is a part of the procedure.

Vendor and service personnel working at the University must follow the established safety practices. It is the responsibility of the PI to inform these persons regarding the appropriate procedures. If the vendor has their own safety procedures, these should also be followed. In the event of conflict between the Laser Safety Program and the vendors procedures, the LSO should be consulted before work begins.

Section 6 - Ancillary Hazards and Control Methods

A. Toxic Dye Hazards

The dyes (associated with dye lasers) can present substantial hazards due to their toxicity. Some of these dyes may be carcinogenic or mutagenic. The solvents used for mixing may be flammable, toxic, or present other health hazards. Material Safety Data Sheets (MSDS) are available from your department or by contacting the LSO.

Because the dyes normally come in a dry powder form, they are readily dispersible and should be handled and mixed with great care. A labcoat, disposable gloves, safety glasses or goggles, and a properly functioning chemical fume hood must be used when handling or mixing the dyes. Good housekeeping should be maintained before, during, and after the mixing. Provide double containment for dye solutions when they are being stored and used. Clean up any spills immediately using the appropriate protective equipment. Contact the LSO if you need additional information.

B. Toxic Products Hazards

The interaction of the laser beam with target materials may produce toxic dusts, vapors or gasses. This is particularly true during cutting or welding processes. Toxic products resulting from laser operations must be properly controlled by use of adequate ventilation and filtration. The LSO should be consulted whenever toxic products may result from the laser use.

C. Cryogen Hazards

Some lasers and laser systems may require the use of cryogenic liquids (such as: liquid nitrogen, oxygen, hydrogen, etc.). These liquids present skin and eye hazards from their extremely low temperatures and should not be handled without insulated gloves, goggles and a face shield. The dewars used for transport and storage of cryogens may present implosion hazards if they are made of glass. Glass dewars should be carefully wrapped with strong tape to contain glass fragments if they implode.

If the liquid is allowed to warm to room temperature, it will expand to hundreds of times its volume in the liquid state. Once it expands to become a gas, the properties of the gas may be hazardous, displacing the air in the room or serving as a fire hazard. The specific hazards of the cryogen can be found in the MSDS. The LSO should be consulted whenever cryogenic liquids are to be used.

D. Compressed Gas Hazards

The use of compressed gasses is common in the laser laboratory. Labs use both pure gasses and gas mixtures as the lasing media. The high pressure of the gas translates into substantial potential energy stored in the cylinder. If this pressure is released in an uncontrolled manner (such as a broken nozzle) the cylinder can become an unguided missile. Compressed gas cylinders must be properly restrained to prevent damage to the nozzle or regulator.

The gasses themselves may present a variety of hazards if they leak from the cylinder. Depending on the gas, it may be toxic, corrosive, flammable, etc. Again, refer to the MSDS for detailed information on the gas in question. If the hazards are sufficient, it may be necessary to provide a gas cabinet under negative pressure to control the hazard in the case of a leak.

E. High Voltage Power Hazards

The high voltage power supplies associated with laser systems have been responsible for serious injuries and electrocutions. For this reason, it is important to know the hazards associated with your laser's power supply. Capacitor systems are of particular concern because they can remain dangerous even after the main power is disconnected. Capacitor systems should be safely discharged several times with the main power off in order to reduce the hazard before beginning work. Be aware that capacitors may store some charge even with the power off.

Only qualified persons should perform high voltage power supply maintenance or repair. As a precaution, a second person (knowledgeable in high voltage safety and CPR) should always be in attendance when high voltage work is being performed.

F. Collateral Radiation Hazards

Laser excitation systems and power supplies may produce hazardous collateral radiation of several varieties. These hazards are normally controlled by the equipment housings, and are only a problem when the protective housings are removed.

The laser excitation device may produce very intense radiation that can be hazardous. Collateral ultraviolet radiation may injure both the eye and the skin if there is a long exposure duration. Blue light presents a special hazard because of its ease of absorption in the retina. This "Blue Light Hazard" is thought to create photochemical injury in the retina in excess of the expected thermal injury from very intense sources. Exposure to any very intense visible light source can seriously degrade color vision and night vision capabilities. Exposure to these intense light sources should be carefully controlled or eliminated by leaving the housings in place.

Laser power supplies capable of creating energies greater than 15 kVp may be a source of x-rays if they contain high voltage vacuum tubes. Electric discharge lasers may also be a source of x-rays. Generally, these x-rays are low energy and are shielded by the equipment housings.

G. Fire and Explosion Hazards

As mentioned before, Class 4 lasers can present fire hazards. Lasers being operated in a CW mode with a beam power that exceeds 0.5 watt can cause combustion in flammable materials left in the beam path. Beam stops, barriers, and curtains used with Class 4 lasers must be made of non-combustible materials for fire prevention. All Class 4 laser labs should have an ABC Type extinguisher readily available as a fire precaution. Laser users should also receive fire prevention training.

Explosion hazards in the laser lab include the storage and use of flammable solvents and gasses (both compressed and cryogenic), and the potential from implosion from dewars and excitation flashlamps. Proper storage and control of these should reduce the potential hazard.

H. Noise Hazards

Some laser systems create significant levels of noise in the laser laboratory. If the noise level seems unpleasant or painful, contact EH&S to have a noise survey done.

Appendix A

LASER SAFETY GUIDELINES

1) Never look directly into any laser beam.

2) Enclose the laser beam path whenever possible.

3) Use laser safety eyewear for all laser beam alignments.

4) Restrict unauthorized access to the laser facility.

5) Inform the LSO of any new, modified or relocated lasers.

6) Have users read the Laser Safety Training Guide.

7) Mark all laser facility entrances with a laser hazard sign.

8) Eye exams may be required for Class 3B and 4 laser users.

9) Inform the LSO of any transfer or sale of lasers.

10) Laser facilities are inspected periodically by the LSO.

11) Do not operate lasers at eye level.

12) Shield all laser light pumping sources.

13) Remove all reflective or combustible materials from the beam path.

14) Use diffuse (non-reflective) beam stops, barriers and curtains.

15) Use the lowest beam power possible for alignments.

16) Remove all keys from interlocks when the laser is not in operation.

17) Alert persons in the area when the beam is operating.

18) Be aware of and protect users from all non-beam hazards.

19) Report all accidents or suspected eye injuries to EH&S.

20) Never override any laser system safety interlock.

Appendix B

LASER TYPES AND WAVELENGTHS

LASER MEDIA	WAVELENGTH (nm)
ULTRAVIOLET	100 nm - 400 nm
Fluorine (diatomic gas excimer)	157
Argon Fluoride (excimer)	193
Krypton Chloride (excimer)	222
Krypton Fluoride (excimer)	248
Xenon Chloride (excimer)	308
Helium Cadmium	325/354
Nitrogen	337.1
Krypton	351/356
Xenon Fluoride (excimer)	351
Argon	351/364
VISIBLE	400 nm - 700 nm
Helium Cadmium (blue)	442
Argon (blue)	458
Helium Selenium (tunable)	460 - 1260
Krypton (blue)	476
Argon (blue)	477
Argon (blue)	488
Rhodamine 6G (tunable dye)	500 - 650
Copper Vapor (green)	511

Argon (green)	515
Krypton (green)	531
Manganese Vapor (green)	534/1290
Helium Neon (green)	544
Erbium: YLF (green)	551
Krypton (yellow)	568
Copper Vapor (yellow)	578
Helium Neon (yellow)	594
Helium Neon (orange)	612
Gold Vapor (red)	628/312
Helium Neon (red)	633
Krypton (red)	647
Gallium Aluminum Arsenide (red diode)	670
Titanium Sapphire (tunable)	670 - 1130
Krypton (red)	676
Ruby (red)	694
NEAR INFRARED	700 nm - 1400 nm
Alexandrite (tunable)	700 - 815
Lead Vapor	723
Krypton	753
Chromium: LiSAF (tunable)	780 - 1010
Gallium Aluminum Arsenide (diode)	840
Calcium Vapor	852/866

Gallium Arsenide (diode)	905
Neodymium: YAG	1064/1320
Barium Vapor	1130/1500
Helium Neon	1152/3390
FAR INFRARED	1400 nm - 1 mm
Erbium: Glass	1540
Holmium: YLF	2060
Thulium: YAG	2010
Holmium: YAG	2100
Erbium: YAG	2490
Erbium: YSGG	2790
Hydrogen Fluoride	4000 - 6000
Carbon Monoxide	5000 - 5500
Carbon Dioxide	9.6/10.6 (um)
Water Vapor	18 (um)
Hydrogen Cyanide	337 (um)

Appendix C

Glossary of Laser Terms

Accessible exposure limit (AEL) - The maximum allowed power within a given laser classification.

American National Standards Institute (ANSI) - The technical body which releases the Z136.1 – 2007 Standard for the Safe Use of Lasers.

Coherent radiation - Radiation whose wave forms are in-phase. Laser radiation is coherent and therefore very intense.

Continuous wave (CW) - A term describing a laser which produces a continuous laser beam while it is operating (verses a pulsed laser beam).

Diffuse Reflection - When an incident radiation beam is scattered in many directions, reducing its intensity. See spectral reflection.

Environmental Health & Safety/Risk Management Office (EH&S/RN) - The Office is responsible for setting campuswide laser safety policy.

Intrabeam exposure - Exposure directly involving the laser beam. Looking into the laser beam would constitute intrabeam exposure. Never look directly into any laser beam.

Infrared (IR) radiation - Invisible radiation with a wavelength between 700 nm and 1 mm.

Irradiance - The power delivered over the area of the laser beam when striking a surface. Also called power density, irradiance applies to CW lasers and is expressed in W/cm^2.

Laser - Light amplification by stimulated emission of radiation. A monochromatic, coherent beam of radiation resulting from spontaneous emission.

Laser user - Any person who uses a laser for any purpose on campus.

Laser Safety Policy Manual - A document defining the Laser Safety Program. Copies are available from the EH&S/RM Office.

Laser Registration Form (LRF) - The mechanism used to track lasers on campus. The LRF includes information for Class 3B and 4 lasers.

Laser Safety Officer (LSO) - The LSO is responsible for the day to day implementation of the Laser Safety Program.

Maximum permissible exposure (MPE) - The maximum level of radiation which human tissue may be exposed to without harmful effect. MPE values may be found in the ANSI Z136.1 – 2007 Standard.

Material Safety Data Sheet (MSDS) - A document, required by law, that is supplied by the manufacturer of a chemical. The MSDS details the hazards and protective practices required for protection from those hazards, as well as other information.

Nominal hazard zone (NHZ) - The area surrounding an operating laser where access to direct, scattered or reflected radiation exceeds the MPE.

Optical density (OD) - Also called transmission density, the optical density is the logarithm to the base ten of the reciprocal of the transmittance.

Principal investigator (PI) - The person directly responsible for the laser and its use. The PI has direct responsibility for all aspects of safety associated with his/her research and/or teaching.

Radiant exposure - The energy delivered over the area of the laser beam when striking a surface. Also called energy density, radiant exposure applies to pulsed lasers and is expressed in J/cm^2.

Spectral reflection - When an incident radiation beam is reflected in primarily one direction, preserving its intensity. See diffuse reflection.

Standard operating procedure (SOP) - A procedure which explains a standard procedure or practice. For lasers, SOPs usually deal with alignment procedures.

Ultraviolet (UV) radiation - Invisible radiation with a wavelength between 400 nm and 100 nm. Note: Wavelengths below 200 nm are absorbed in the atmosphere and are known as the vacuum ultraviolet.

Appendix D

Laser Safety Training Certification

Name of Principal Investigator: ____
(print) Last First

Name of Laser User: ____
(print) Last First

Dept.: ____________________ Office: ________________ Phone No.: ________________

Laser Laboratory Location: ____

I have read and understand the Laser Safety Training Guide and have received any necessary instruction from the Principal Investigator (or his/her designee) in the use of the laser system, associated optics, and laser safety systems. I am aware that I am responsible for following the established safety standards and laboratory SOPs and that I am responsible for my own safety in the laboratory.

Signed ____ Date: ______________________

Return the completed form to the Laser Safety Officer at M/S PO 140