

UA Laser Safety Manual

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Table of Contents

Section

Section 1 – Laser Safety Program Administration

Section 2 – Laser Program Guidelines

Section 3 – Laser Categories and Classifications

Section 4 – Warning Signs and Labels, Area Requirements

Section 5 - Laser Effects and Personal Protective Equipment

Section 6 – Non-Beam Hazards

Section 7 – Training

Section 8 – Medical Surveillance and Incident Reporting

Section 9 – Noncompliance

Section 10 – Laser Pointers

Appendix

- I. Optical Densities for Protective Eyewear for Various Laser Types
- II. Control Measures for the Four Laser Classes
- III. Selected ANSI Table Availability

Section 1 – Laser Safety Program Administration

The success of a laser safety program depends upon many people working together to achieve a common goal – the goal ‘to use lasers safely and to comply with regulations and accepted industry standards.’

In order to achieve and maintain this goal, responsibilities are shared among all involved – the institution, the owner, and the users. This manual is based on information from the ANSI Z136.1-2007 *Safe Use of Lasers* standard. Each laser or laser system must meet the safety standards of ANSI Z136.1 or an equivalent level of safety as approved by the UA Laser Safety Officer. This standard is recognized by OSHA and is considered the industry norm for laser users. This standard uses two key words that we will include – ***shall*** and ***should***. According to the standard and this manual, the word ***shall*** is to be understood as mandatory and the word ***should*** is to be understood as advisory. Additional requirements can be imposed by UA in addition to any requirements addressed by the referenced ANSI standard. Anyone operating a Class 3B or Class 4 laser or laser system should have or have access to a copy of this standard. A copy of the most current version of the standard is maintained at EHS.

The Office of Environmental Health and Safety is responsible for the management of the Laser Safety Program at The University of Alabama. The Director of the Office of Environmental Health and Safety shall designate an individual to act as the Laser Safety Officer on behalf of The University of Alabama. The Laser Safety Officer shall report to the RSO who in turn works with Radiation Control Advisory Committee. (RCAC) The RCAC provides oversight and serves in an advisory role to in ionizing radiation issues on campus as well as lasers. State regulations are provided by the Bureau of Health. This Laser Safety Program shall cover all areas and personnel where lasers of any type or classification are used, operated, or stored. The requirements for each area (control measures, signage, training, etc.) vary depending on the laser classification and usage.

Laser pointers are not exempt from all regulations, but they are subject to separate requirements, which are given in a section of this manual.

Laser printers and scanners are not covered in this program.

1.1 – Laser Safety Officer

The LSO is designated by EHS. This individual has the responsibility for overall management of the Laser Safety Program. The LSO is responsible to the radiation safety office. The LSO provides information regarding the program to the RSO and the RCAC. The Radiation Control Advisory Committee (RCAC) provides consultation and oversight. The RCAC may suspend, terminate or restrict the operation of a laser or access of an individual of necessary. Specific duties of the LSO are:

1. The LSO shall establish and maintain adequate policies and procedures for the control of laser hazards. These policies and procedures shall comply with applicable requirements, including federal, state, and local regulations.
2. The LSO shall classify or verify classifications of lasers and laser systems at UA.
3. The LSO shall be responsible for a Laser Hazard Evaluation of the laser work areas prior to any work being initiated, including the establishment of Nominal Hazard Zones (NHZ) where needed. All noted areas of concern on the evaluation must be addressed before laser work can be initiated.
4. The LSO shall be responsible for assuring that the prescribed control measures are implemented and remain in effect. This includes avoiding unnecessary or duplicate controls, as well as recommending or approving substitute or alternate control measures when the primary ones are not feasible or practical.
5. The LSO shall register all Class 3B and Class 4 lasers, and require this standard operating procedure (SOP's) Registration must be completed prior to beginning work.
6. The LSO shall recommend or approve protective equipment (i.e. eyewear, clothing, barriers, screens, etc.) as may be required to assure personnel safety. The LSO shall assure that protective equipment is audited periodically to assure proper working order.
7. The LSO shall review and approve the wording on area signs and equipment labels.
8. The LSO shall review and approve purchases of lasers or laser systems of all classes. The LSO shall review laser installations, facilities and laser equipment prior to use. This also applies to modification of existing facilities and/or equipment.
9. The LSO shall assure that adequate safety education and training are provided to laser personnel. Initial Training is required before any laser work can take place as well as refresher training annually. Additionally, each PI is responsible for laser specific and procedure specific training in his/her area.
10. The LSO shall determine the personnel categories for medical surveillance, if needed.
11. The LSO shall assure that the necessary records required by applicable government regulations are maintained. When a medical surveillance program is required, the LSO shall submit to the appropriate medical officer the names that are included in the medical surveillance program. Other records documenting the maintenance of the safety program, such as training records, audits, SOPs, etc, shall be maintained.
12. The LSO shall periodically audit or survey by inspection the presence and functionality of the laser safety features and control measures required for each Class 3B and Class 4 laser or laser systems on campus. The LSO shall accompany regulatory agency inspectors reviewing laser safety programs or investigating an incident and document any discrepancies or issues noted. The LSO shall assure that corrective action is taken, where required.

13. The LSO should develop a plan to respond to notifications of incidents of actual or suspected exposure to potentially harmful laser radiation. The plan should include the provision of medical assistance for the potentially exposed individual, investigation of the incident and the documentation and reporting of the investigation results.
14. Approval of a Class 3B or Class 4 laser or laser system for operation shall be given only if the LSO, RCAC and RSO are satisfied that laser control measures are adequate. These include SOPs for maintenance and service operations within enclosed systems, for service or alignment of embedded class 1 systems, and operation procedures for Class 3B and Class 4 laser systems. The procedures should include adequate consideration of safety from non-beam hazards.
15. The LSO shall investigate any instances of theft, unauthorized operation, transfers, disposals, or any other deviation from accepted practices report findings to the RSO and RCAC and implement corrective action.
16. The LSO shall provide reports to the RSO regarding registration and all other activities associated with the program.

1.2 – Laser Users

The following are the different types of individuals involved in the laser safety program:

1. Laser Owner – any approved faculty or staff member that owns a laser or laser system of any classification. Owners of Class 3B and Class 4 lasers and laser systems will receive a sublicense for their system and may be further referred to as sublicensee. *A sublicense is only required for Class 3B, Class 4, and some embedded Class 1 lasers.*
Each sublicense issued is good for the duration of the sub licensees' employment at The University of Alabama. Sub licensees who wish to suspend their sublicense may do so in writing with an explanation sent to the LSO. Any lasers not registered to a Laser Owner or Sublicensee will be secured by EHS until such time as someone registers it for use.
2. User - any employee or student documented by the owner/sublicensee as having operational access to a laser or laser system.
3. Student - any individual that is not an employee and is documented by the sublicensee as an onlooker or user of the laser or laser system during a supervised laboratory or class. This individual will not be allowed unsupervised access to any laser or laser beam. Student users may not align any laser or laser beam. Each student shall receive laser safety training prior to any lab or class utilizing the laser.
4. Visitor - any corporate researcher or visiting scholar working with, operating, or planning to work with a laser or laser system. Each visitor shall meet or exceed all of the requirements for a registered operator as outlined in this document.
5. Transient personnel - any individual who may enter a laboratory housing a laser or laser system but who will not have interaction with an operating laser or laser system is considered transient personnel. Maintenance, housekeeping and others are included in this heading.

6. Inspection personnel - any individual that enters a laboratory performing an inspection of the facility or the laser/laser system. The LSO and RSO members of outside regulatory agencies and representatives of EHS are included under this heading.

Operators of lasers in all classes are responsible for:

- Using lasers safely and in accordance with this manual.
- Completing appropriate training **before** operating lasers and annually thereafter.
- Ensuring they are in compliance with any established medical surveillance requirements.
- Promptly reporting to the LSO any malfunctions, problems, etc., which may have an impact on safety, including all near misses.
- Promptly reporting to the LSO any accidents or incidents that involve the laser system or exposure to laser radiation, including all near misses.

1.3 – Radiation Control Advisory Committee (RCAC)

The University of Alabama has a Radiation Control Advisory Committee. The purpose of this group is to provide guidance to the LSO and RSO to ensure that lasers are used safely and in compliance with applicable standards. Membership is appointed by the RSO. The RCAC will:

- Assist with establishing policies and practices in the regulation of control and laser hazards
- Review and approve all Class 3B and 4 Lasers

The RCAC may revoke laser privileges or take other action necessary to protect the University.

1.4 – Service Contractors

Service and repair contractors should perform requested work (maintenance, alignment, installation, etc.). Whether they are UA employees or outside vendors, service and repair personnel must be qualified to perform the requested work. This means that the service and repair providers must be trained by their employers and they must be authorized to work on lasers or laser systems. All work must be done in compliance with ANSI Z136.1 requirements for hazard notification, PPE, temporary signage (for embedded systems), etc. The LSO should be notified before any work is performed. The LSO is responsible for seeing that the contractor, subcontractor, or service/repair personnel follow all specified requirements and that all needed controls are in place. Service/repair personnel shall receive orientation to any additional hazards in the area (chemicals, radiation, etc.). They shall be briefed on the hazard controls in place and on emergency reporting. Laser users must be aware that they are responsible for the safety of these individuals and their compliance with UA rules.

Section 2 – Laser Program Guidelines

The following are guidelines for the owners and users of lasers on the University of Alabama campus:

1. Any Faculty or Staff member who wishes to purchase or receive a laser must contact the LSO prior to placing an order for the laser. A Laser Equipment Approval (LEA) should be submitted via the EHS website at ehs.ua.edu. This will allow the LSO to review the area of intended use and determine if any facility modifications are required. Quite often, the LSO will be contacted by purchasing when a request is made for a laser system. All such purchase requests are reviewed by several people before approval for purchase is issued. Submission of the LPR concurrent with the purchase request will speed this process.
2. Faculty or Staff who own or are purchasing a laser or laser system must submit a sublicense registration for the Laser Safety Program. A sample of this form can be found in the Appendix - the current version of this form can be found on the EHS website or by contacting the LSO. The registration shall request information concerning training, educational background, laser experience, a basic project outline, and other information.
3. Standard Operating Procedures for use and maintenance of any Class 3b or Class 4 laser or laser system must be submitted when the laser is installed. Any Class 1 laser system which contains an embedded Class 3B or Class 4 laser must also have an SOP for any activities including alignment or maintenance that require access to the beam.
4. Once the laser or laser system is received and installed, it must be reviewed and inventoried by the LSO prior to use.
5. Each laser lab should have a designated notebook or location for laser paperwork. This notebook should be easy to locate and readily accessible at all times. The notebook should contain copies of all applications, sublicenses, registrations, documentation, training, SOPs, etc. The notebook should also include emergency contact information for the sublicensee and anyone else familiar with the laser or laser system, as well as contact information for the LSO and the Office of Environmental Health and Safety. It is the responsibility of each lab to provide and update the laser notebook.
6. Once the LSO has completed inventory and review, any Class 3B or Class 4 applications will be presented to the RCAC, along with any recommendations from the LSO. They will review all documents and may request additional information or SOP modifications.
7. All laser systems must be registered and maintained in an inventory by the LSO. Class 3B and 4 lasers must also be sublicensed upon approval of Class 3B and Class 4 lasers or laser systems, each sublicensee will be assigned a sublicense number. This sublicense number must be obtained prior to any work with lasers.
8. Each laser owner or sublicensee shall assure all laser users have successfully completed the Initial Laser Safety Training. Details about this course can be obtained from the LSO. Upon receipt of a laser registration, the LSO will assign laser safety training. Each user should complete the training. Refresher training every year will also be provided. Documentation of this and any other training should be maintained in the Laser Safety Notebook. As new users are added, it is the responsibility of the PI to request laser safety training assignments before allowing laser use.

9. Each laser owner or sublicensee shall assure all laser users and personnel have been provided specific laser safety training pertaining to the operation and safety features of the instrument for which they are approved. Documentation of this training shall be maintained in the Laser Safety Notebook. Ideas for additional laser safety training topics can be obtained from the LSO.
10. Each laser owner or sublicensee shall maintain a current user registration. This must be updated any time personnel, lasers, or procedures change.
11. Each laser owner or sublicensee shall create a Standard Operating Procedure (SOP) for each Class 3B or 4 laser as well as any embedded Class 1 laser systems that contain a Class 3B or 4 laser for which maintenance or alignment requires beam access. Each laser owner or sublicensee shall assure that all users are trained on this information. A copy of the SOP shall be maintained in the Laser Safety Notebook and filed with the LSO. If you are unsure about the required details for a laser SOP, a template sample is available in the Appendix and is posted on the EHS website. If this template is not a good model for your experiment, contact the LSO.
12. Each laser owner or sublicensee shall assure all laser safety concerns from the LSO are addressed and/or corrected. Documentation of surveys, audits, inspections, and corrections should be maintained in the Laser Safety Notebook.
13. Laser usage privileges and responsibilities may be terminated at any time upon the written request of the sublicensee, which shall be submitted to the LSO. Laser usage privileges and responsibilities may be terminated at any time upon recommendation of the LSO to the RCAC due to safety violations or due to violations of the procedures in this document.
14. Several considerations should be given when disposing of a laser - making the laser inoperative, removing it from both EHS and property control inventory records, and proper disposal of any hazardous materials that may be involved. **Under no circumstances should a Class 3B or Class 4 laser be abandoned.**
 - a. The purpose of disabling the discarded laser is to ensure that it is not subsequently used by an unqualified person who may then be a danger to themselves or others. The laser can be disabled by methods such as cutting the power cord (**unplug it first**) and/or dismantling the controls.
 - b. EHS can store lasers or laser systems if one needs to be removed from active inventory but not disabled or disposed. Contact the LSO if you need a laser stored. Property control paperwork must still be completed.
 - c. When removing a laser for any reason – scavenging, surplus, disposing, etc. - The LSO must be informed.
 - d. Certain lasers, such as those using dyes, may contain hazardous materials that need to be properly disposed. Contact LSO to determine proper procedures for your laser.
 - e. Lasers transferred offsite must comply with a variety of requirements. The LSO should be made aware of these situations well in advance so proper procedures can be in place.

Physical Protection and Security Measures must also be in place for all lasers and laser systems. These can duplicate some part of the control measures for the laser systems.

1. Windows located in an area where a Class 3b or 4 laser or laser system is operated shall be covered with material which will reduce any transmitted laser radiation to levels below that applicable Maximum Permissible Exposure (MPE) levels unless barriers, screens, or curtains are used to prevent the laser light from exiting the area at levels above the applicable MPE level. Each filter or barrier shall be selected to withstand direct and diffusely scattered beams. It is essential that the material used for barriers, screens or filters not support combustion, be consumed by flames or release toxic fumes following laser exposure. All laser protective window coverings should be labeled with a threshold limit value and exposure time for which protection is afforded.
2. The use of a skin cover may be needed in some cases to prevent damaging skin exposure, particularly when using ultraviolet lasers. Skin covers or sunscreens may be recommended; however in most cases tightly woven fabrics, opaque gloves and a lab coat offer good protection.
3. Respirators exhaust ventilation, fire extinguishers and hearing protection may be required under certain circumstances.
4. Class 3b and 4 lasers shall be provided with a permanently attached beam stop or attenuator unless the beam enters a detector. The beam stop or attenuator shall be capable of preventing access to laser radiation in excess of the appropriate MPE level when the laser output is not required (as in during warm up procedures).
5. A warning light (visible through protective eyewear) or a verbal countdown accompanied by visual signals shall be used as an alarm during activation or startup with Class 3b and 4 lasers.
6. The warning system shall be activated a sufficient time prior to emission of laser radiation to allow action to be taken to avoid exposure to laser radiation.
7. Spectators shall not be allowed in a laser controlled area which contains a Class 3b or 4 laser unless:
 - *permission has been granted by the sublicensee
 - *the hazards and avoidance procedures have been explained
 - *appropriate protective measures have been taken

Section 3 – Laser Categories and Classifications

3.1 – Categories

One way to characterize or group lasers is by their active medium, which may be solid, liquid, or gas. There are advantages with each medium with regard to the amount of energy that can be stored, ease of handling and storage, secondary safety hazards, cooling properties, and physical characteristics of the laser output.

3.1.1 – Solid State Lasers

The term ‘solid state’, as it relates to lasers, refers to a group of optically clear materials such as glass or a ‘host’ crystal with an impurity dopant. It does not include semi-conductor materials used in laser diodes. In this group, the host material is chosen for its optical, mechanical, and thermal properties, while the dopant is selected for its ability to form a population inversion and emit laser light. The output wavelength is determined mainly by the dopant material.

3.1.2 – Semiconductor (Diode) Lasers

In terms of sheer numbers, the diode laser is the most common laser today. The two common families of diode lasers are composed of GaAlAs (Gallium/Aluminum/Arsenide) with output wavelengths in the 750-950 nm (commonly used in CD and CD-ROM players) and InGaAsP (Indium/Gallium/Arsenide/Phosphide), which has a wavelength in the 1100-1650 nm range (used in optical telecommunications). Another family of diode lasers (AlGaInP) operates in the visible part of the spectrum (primarily red).

3.1.3 – Liquid (Dye) Lasers

The common liquid lasers utilize a flowing dye as the active medium and are pumped by a flash lamp or another laser, such as an argon laser. Dye lasers are typically rather complex systems, requiring more maintenance. They are operated in either pulsed or continuous wave (CW) mode. One advantage of dye lasers is that they are wavelength tunable over a range of approximately 100 nanometers.

3.1.4 – Gas Lasers

Gas lasers are not unlike fluorescent light bulbs and neon signs. In a Helium-Neon (HeNe) laser, a mixture of helium and neon gas is confined to a hollow glass tube. As in the neon sign, an electric current passing through the tube excites the atoms and causes them to emit light. In a HeNe laser, mirrors at the ends of the tubes form a resonant cavity and primarily determine the laser wavelength.

Other gas laser systems use different gas mixtures to produce over wavelengths. The more common of these are the Carbon Dioxide (CO₂) laser and the Argon (Ar) laser. Another variation is the laser family known as the Excimer lasers (“excited dimer”), such as the Xenon-Chloride (XeCl) laser. Excimers lase in the ultraviolet part of the spectrum.

Gas lasers are relatively inexpensive and can generally be operated CW (excimer lasers are exceptions to both of these). The CO₂ laser can achieve very high (multi-kilowatt) power levels in the CW mode, and is very common in industrial material processing and medical applications.

3.2 – Classifications and Hazard Controls

The American National Standards Institute (ANSI) in ANSI Z126.1 has grouped all lasers in several hazard classes (1-4) according to their hazard potential. Lasers are classified in accordance with the *accessible emission limit* (AEL), which is the maximum accessible level of laser radiation permitted within a particular laser class. The ANSI standard laser hazard classifications are used to signify the level of hazard inherent in a laser system and the extent of safety controls required. These range from Class 1 lasers (which are inherently safe for direct beam viewing under most conditions) to Class 4 lasers (which require the most strict controls). The hazard controls necessary for laser radiation vary with:

1. The laser classification
2. The environment where the laser is used
3. The people operating the laser or in the near vicinity of the laser

The ANSI Z136.1 standard specifies control measures by the class of the laser product. Users determine the required control measures for their particular application by determining the classification, then considering the environment and the people at risk of exposure. In all cases, the safest user is the informed user, so some form of laser safety training or laser safety information is required or recommended for all laser users. Employees or students who operate or supervise operation of a laser are responsible for performing a risk assessment to determine the need for safety equipment or procedures and to determine if any conditions have changed since the last firing of the laser or laser system. This assessment should be documented.

The laser classifications and their control measures are described below:

3.2.1 – Class 1 Lasers and Laser Systems

Class 1 laser cannot, under normal operating conditions, produce damaging radiation levels. These lasers must be registered and labeling must be verified, but they are exempt from the other requirements of the Laser Safety Program.

Class 1M lasers cannot, under normal operating conditions, produce damaging radiation levels unless the beam is viewed with an optical instrument such as an eye-loupe (diverging beam) or a telescope (collimated beam). This may be due to a large beam diameter or divergence of the beam. There is no known hazard from exposure to the output from a Class 1 laser or laser product. Therefore, these are truly considered to be "eye safe" lasers. These lasers must be registered and labeling must be verified, but they are exempt from the other requirements of the Laser Safety Program other than to prevent potentially hazardous optically aided viewing.

Class 1 Embedded lasers or laser systems have higher powered beams completely enclosed and the system is interlocked to ensure that normal operation of the laser would not allow persons to be exposed above the Maximum Permissible Exposure level. Often, a higher-class laser, such as a Class 4 laser, may be contained within the protective housing in such a manner that the user is not exposed to hazardous levels of laser radiation. In this case, the laser product would be Class 1, although there is a high power embedded laser within the protective housing. Such laser products may have service access panels. During maintenance, service, or alignment, standards require that safety controls be in place as if the laser or laser system was the higher power classification.

3.2.2 – Class 2 Lasers and Laser Systems

Class 2 lasers are lasers or laser systems in the visible range that may be viewed directly under carefully controlled exposure conditions. These are "low-power" lasers that only emit visible laser radiation between the wavelengths 400 and 700 nm. Therefore by definition, they are incapable of causing eye injury for unaided viewing within the normal aversion response to bright light (within 0.25 seconds). At these wavelengths, an ocular hazard for unaided viewing can only exist if an individual overcomes their natural aversion to bright light and stares directly into the laser beam. Class 2 lasers and Class 2M lasers do not pose a skin hazard.

Class 2M lasers are low power lasers or laser system in the visible range (400 - 700 nm wavelength) that may be viewed directly under carefully controlled exposure conditions but may present some potential for hazard if viewed with certain optical aids.

There are two product requirements for Class 2 and Class 2M lasers: to have a CAUTION label and to have an indicator light to indicate laser emission. CAUTION labels for Class 2M laser should include the words "Do Not View Directly with Optical Instruments". The three operational safety rules are:

- a. Do not overcome the aversion response and stare into the laser beam.
- b. Do not point the laser at a person's eye.
- c. Do not use an optical instrument such as telescope or magnifying optic to view the beam directly.

3.2.3 – Class 3 Lasers and Laser Systems

Class 3 lasers are medium power lasers or laser systems that require control measures to prevent viewing of the direct beam.

Class 3R denotes lasers or laser systems potentially hazardous under some direct and specular reflection viewing conditions. This laser will not pose either a fire hazard or diffuse-reflection hazard. They may present a hazard if viewed using collecting optics. The Accessible Exposure Limit is 5 times the AEL for Class 1 or 2 as applicable.

Class 3R has replaced the former Class 3A.

Class 3B denotes lasers or laser systems that can produce a hazard if viewed directly. This includes intrabeam viewing or specular reflections. Except for the higher power Class 3b lasers, this class laser will not produce diffuse reflections. The upper limit for a CW Class 3B laser is 500 milliwatts.

Although these "medium-power" lasers usually present a serious potential for eye injury resulting from intrabeam viewing, (especially Class 3B laser beams), they generally do not represent a diffuse reflection hazard, a skin hazard, or a fire hazard. Therefore, control measures for Class 3R and 3B lasers are concentrated on eliminating the possibility of intrabeam viewing by:

- a. Never aiming a laser at a person's eye.
- b. Using proper laser safety eyewear if there is a chance that the beam or a hazardous specular reflection will expose the eyes.
- c. Avoid placement of the unprotected eye along or near the beam axis. Some alignment procedures may place personnel at risk by requiring close proximity to the beam where the chance of hazardous specular reflections is greatest.
- d. Attempting to keep laser beam paths above or below eye level for either sitting or standing positions.
- e. Assuring that individuals do not look directly into a laser beam with optical instruments unless an adequate protective filter is present within the optical train.
- f. Eliminating unnecessary specular (mirror-like) surfaces from the vicinity of the laser beam path, or avoid aiming at such surfaces.
- g. Not aiming at doorways or windows.

Additional control measures for Class 3B lasers and laser systems include:

- h. Assuring that individuals who operate Class 3B lasers are trained in laser safety and authorized to operate a laser.
- i. Permitting only experienced personnel to operate the laser and not leaving an operable laser unattended if there is a chance that an unauthorized user may attempt to operate the laser. A key switch should be used if untrained persons may gain access to the laser. A warning light or buzzer may be used to indicate when the laser is operating.
- j. Enclosing as much of the beam's path as practicable.
- k. Terminating the primary and secondary beams if possible at the end of their useful paths.
- l. Using low power settings, beam shutters and laser output filters to reduce the beam power to less hazardous levels when the full output power is not required.
- m. Assuring that any spectators are not potentially exposed to hazardous conditions.

- n. Attempting to operate the laser only in a well-controlled area. For example, operating the laser system within a closed room with covered or filtered windows and controlled access.
- o. Not permitting tracking of non-target vehicles or aircraft if the laser is used outdoors.
- p. Labeling lasers with appropriate Class 3B danger statements and placarding hazardous areas with danger signs if personnel can be exposed.
- q. Mounting the laser on a firm support to assure that the beam travels along the intended path.

3.2.4 – Class 4

A Class 4 laser is high power laser or laser system that can produce a hazard to the eye and to the skin from intrabeam viewing. Class 4 lasers can be visible or nonvisible and includes all lasers in excess of Class 3 limitations. These "high-power" lasers present the most serious of all laser hazards. Besides presenting serious eye and skin hazards, these lasers may ignite flammable targets, create hazardous airborne contaminants, and may also have a potentially lethal, high current/high voltage power supply. Most of the "associated hazards" previously enumerated are limited to high-power laser operations. The following rules should be carefully followed for all high-power lasers:

- a. Enclose the entire laser beam path if possible. If done correctly, the laser's status could revert to a less hazardous laser classification during usage.
- b. Confine open beam indoor laser operations to a light-tight room.
- c. Interlock entrances to assure that the laser beam cannot emit when the door is open if the nominal hazard zone (NHZ) extends to the entrances.
- d. Insure that all personnel wear adequate eye protection, or ensure that a suitable shield is present between the laser beam(s) and personnel.
- e. Use remote firing and video monitoring or remote viewing through a laser safety shield where feasible.
- f. Use devices when the laser is used outdoors, to assure that the beam cannot intercept occupied areas or intercept aircraft.
- g. Use lower power settings, a beam shutter or laser output filters to reduce the laser beam irradiance to less hazardous levels whenever the full beam power is not required.
- h. Assure that the laser device has a key-switch master control to permit only authorized personnel to operate the laser.
- i. Install appropriate signs (and labels if needed).

- j. Remember that optical pump systems may be hazardous to view and that once optical pumping systems for pulsed lasers are charged they can be spontaneously discharged, causing the laser to fire unexpectedly (as by a cosmic ray triggering a thyatron switch).
- k. Use dark, absorbing, diffuse, fire resistant target and backstops where feasible.
- l. Design safety into laser welding, cutting equipment, and laser devices used in all types of material processing.

3.2.5 - Other Lasers or Laser Systems Information

If you have a laser that is built in your lab OR a laser that you purchase commercially then modify in such a way that the output or safety characteristics have changed, then your laser or laser system may be reclassified. Following any service, repair, or modifications which may affect the output power, operating characteristics, or classification, the LSO shall ascertain whether any changed or additional control measures are needed. Classification issues shall be resolved by the LSO in consultation with the manufacturer and/or the Laser Institute of America. The classification of laser capable of emitting numerous wavelengths shall be based on the most hazardous possible operation. Also, The LSO may determine that certain enclosed laser systems may be lowered in classification level. Additionally, before these lasers or lasers systems can be transferred to another location – including another PI within UA – you MUST contact the LSO for requirements.

There is an increased use of laser devices in miniature work such as biological research (micro-surgery), the scribing of integrated circuit chips, and the trimming of resistors. The use of microscopes or other focusing optics integral to the laser system is common for these applications. If at all possible, such work should be accomplished in a light-tight or baffled interlocked enclosure to eliminate the requirements for eye protection or other control measures associated with Class 4 lasers. Microscopes used for viewing the target object should have a fail-safe method to prevent hazardous laser radiation reflecting back through the optics. This can be accomplished by using either built-in filters or separate optical paths for viewing and for the laser beam.

Laser Alignment and Beam Manipulation: The majority of laser accidents occur while aligning the laser or during similar beam manipulation activities. All possible steps should be taken to prevent such accidents. These activities require carefully developed On-the-Job training covering hazard identification and mitigation techniques. Only laser users who have received training and are authorized by their supervisor, PI, LSO, or designee shall perform laser alignment/beam manipulation activities unsupervised

The following laser alignment techniques should be in every laser alignment procedure:

1. The laser beam is never to be viewed directly, but only indirectly (i.e., by Web cam, CCD, IR/UV Viewer, electronic sensor, video camera, etc.) or as a diffuse reflection for a matted surface) while wearing appropriate protective eyewear to ensure the MPE is not exceeded.
2. Reflective jewelry, ID badges, etc. that may intercept the laser beam must be taken off by those handling the laser.

3. Whoever manipulates or moves optics shall be responsible for checking for stray reflections. When found, these reflections shall be contained to the optical table even if they are below an eye hazard level. Alignment should be conducted optic-to-optic and constantly checked for stray reflections.
 4. Alignment procedures must be performed at the minimum-required laser output.
 5. Remote viewing approaches should always be considered.
 6. Use of low-power, co-axial visible alignment beams shall be considered.
 7. Use of alignment eyewear for visible beams is allowed with the approval of the LSO.
 8. Terminate the beam path at the end of its useful path.
 9. Locate the beam path at a point other than eye level when standing or when sitting at a desk.
 10. Orient the laser so that the beam is not directed toward entry doors or aisles.
 11. Minimize specular reflections.
 12. Securely mount the laser system on a stable platform to maintain the beam in a fixed position during operation and limit beam traverse during adjustments.
 13. Confine primary beams and dangerous reflections to the optical table. This can be accomplished through beam blocks, perimeter guards, complete table enclosures, etc. Any exceptions to this (beam crossing walkways, beams from one room to another, vertical beams), must be carefully planned and associated hazards must be mitigated (i.e., through the use of labeled beam blocks or enclosed tubes, etc).
 14. Clearly identify beam paths and ensure that they do not cross populated areas or traffic paths.
 15. When the beam path is not totally enclosed, locate the laser system so that the beam will be outside the normal eye-level range, which is between 1.2 to 2 meters from the floor. A beam path that exits from a controlled area must be enclosed where the beam irradiance exceeds the MPE.
- Protective housings should be provided for all classes of lasers (Engineering Control).

3.2.6 – Special Issues

1. Lasers used outdoors shall meet the applicable ANSI recommendations and requirements for operation, use and control. For specific information, contact the LSO.
2. Lasers used in demonstrations or events involving the general public shall meet the applicable ANSI recommendations and requirements for operation, use and control. For higher powered lasers involved in public events, FDA permitting may be required. For specific information, contact the LSO.
3. Access to University of Alabama laboratories, workshops, and other areas housing hazardous chemicals, physical agents, or machinery is limited to trained and authorized faculty, staff and students of the UA. It is the obligation and responsibility of personnel who arrange for visits to hazardous or potentially hazardous areas to contact the individual or department in charge of the space prior to entry. The person responsible for visitors must ensure that those entering any of these areas are adequately protected from hazards and are informed about the safety and emergency procedures relevant to their activities. Other persons, in particular young children, are not permitted in hazardous work areas such as laboratories, with the exception of University

sanctioned tours and visits or visits authorized by a Department. In these instances, careful supervision must be exercised by the tour leader or other knowledgeable personnel.

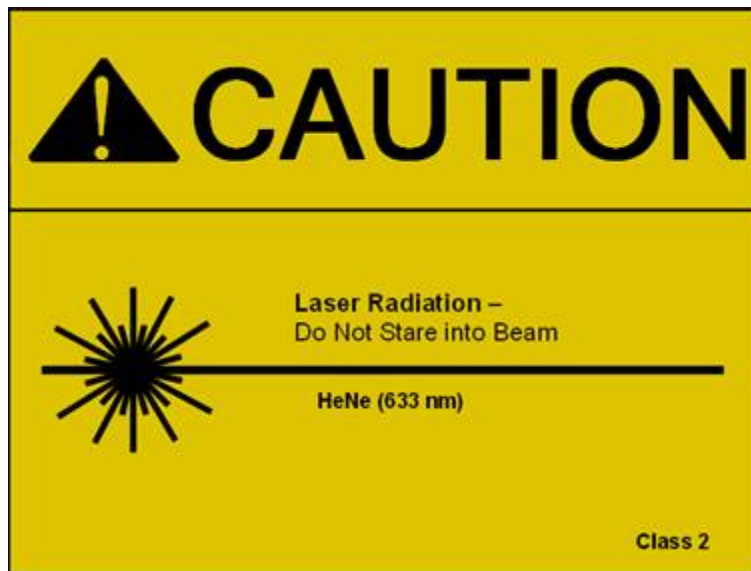
Exceptions to the foregoing, such as cooperative use of UA facilities and equipment by university and corporate researchers or use of university facilities and equipment by visiting scholars, must be approved by appropriate college and university officials, and must be documented by written agreements MOA (Memorandum of Agreement), Sponsored Research Agreement, etc., signed by an authorized UA official. Contact the Office of the Vice President for Research to begin the process of obtaining approval for such use of university equipment and/or facilities.

4. Lasers used in health care facilities as medical or therapeutic treatment shall meet the applicable ANSI recommendations and requirements for operation and control. As such they are not directly covered by this manual but rather by the applicable health care standards. For more information, contact the LSO.

Section 4 – Warning Signs and Labels, Area Requirements

Labels and warning signs should be displayed conspicuously in areas where they would best serve to warn individuals of potential safety hazards. Normally, signs are posted at entryways to laser controlled areas and labels are affixed to the laser in a conspicuous location. All Class 2, 3 and 4 laser equipment must be labeled indicating hazard classification, output power/energy, and lasing material or wavelength with words and symbols. Some samples are given in this manual:

Class 2 laser equipment: CAUTION, Laser Radiation (or laser symbol), Do Not Stare Into Beam



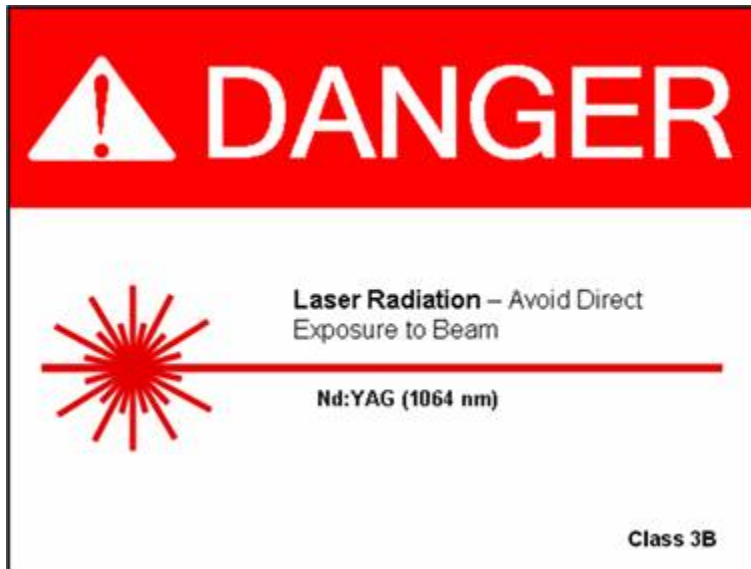
Class 3R laser equipment, below MPE: Danger, Laser Radiation (or laser symbol), Do Not Stare into Beam or View Directly with Optical Instruments



Class 3R laser equipment, above MPE: DANGER, Laser Radiation (or laser symbol), Avoid Direct Eye Exposure



Class 3B laser equipment: DANGER, Laser Radiation (or laser symbol), Avoid Direct Exposure to Beam



Class 4 laser equipment: DANGER, Laser Radiation (or laser symbol), Avoid Eye or Skin Exposure to Direct or Scattered Radiation



AREA/EQUIPMENT INTERLOCK AND CONTROL REQUIREMENTS

- Class 3B and 4 lasers must be interlocked in some way so that hazard warning signage is energized before or at the same time as the laser or laser system.
- Protective housings that enclose Class 3b or 4 lasers should have an interlock system that is activated when the protective housing is opened, and for which a manual reset is necessary.
- Enclosure of the laser equipment or beam path is preferred method of control.
- Service access panels intended to be removed by service personnel only and which permit direct access to laser radiation associated with Class 4 lasers should either be interlocked or should require a tool for removal and have an appropriate warning sign.
- The responsible individual in a laser area controlled by a warning light is permitted to momentarily override (bypass) door interlocks to allow access of authorized persons if all of the following conditions are met:
 - There is no laser radiation hazard at the point of entry.
 - The necessary protective devices are worn by the personnel entering the area.
 - An interlock bypass circuit is designed into the interlock control system.
- If interlocks are not feasible, the department manager may consider the use of alarms, voice warnings, danger lights, door locks, key cards, or extensive security. LSO must be consulted and approve alternatives to interlocks.
- Work areas in which lasers are used must be designed so that personnel can enter and leave under emergency conditions.
- All Class 4 lasers must have a master switch that should be operated with a key or coded access (i.e., computer authorization password) that prevents use once the key has been removed or the code has been entered incorrectly. The key cannot be left in the control panel when the laser is not in use.
- An alarm, warning light, or verbal countdown command must be used with a Class 4 laser to signal activation. For Class 4 lasers there must be an emission delay to allow action to be taken to avoid exposure.
- When possible, Class 4 lasers should be fired and monitored from a remote position.
- Lasers must have a permanently attached beam stop or attenuator and emission delays.
- Laser controlled areas shall be established that have **limited access, covered windows and doors**, and only diffuse reflective material. The facility must be a **fully enclosed room** with floor-to-ceiling walls. **Access to the area during laser operation requires the permission of the responsible operator.**
- Class 4 infrared laser beams with a wavelength greater than or equal to 710 nanometers, according to ANSI Z136.1 must be terminated with fire resistant material.
- Securely fasten all mirrors, prisms, beam stops, etc. in the beam path.

- Ensure that the laser is also securely fastened.
- Circuit breakers must be clearly identified for each laser.

BEAM ENCLOSURE REQUIREMENTS

- The entire beam path of Class 4 lasers, including the target area, should be surrounded by an enclosure equipped with interlocks that prevent operation of the laser system unless the enclosure is properly secured. When total enclosure of the laser beam path is not possible, both the non-enclosed laser beam and any strong reflections must be terminated at the end of their useful path using such devices as backstops, shields or beam traps.
- Lasers with viewing portals should have means (i.e., interlock, filter, attenuators), to maintain laser radiation below the MPE. Class 4 lasers must be provided with a permanently attached beam stop attenuator.
- The laser should be set up so the beam path is not at normal eye level (i.e., so it is below 4.5 feet and above 6.5 feet).
- All collecting optics intended for viewing use should incorporate means to maintain laser radiation transmitted through the collecting options to levels below the MPE.

REFLECTIVE SURFACE REQUIREMENTS

- Controlled laser areas must be surveyed with appropriate measuring devices to locate and identify direct and reflected beams that exceed the MPE. Shielding may be necessary to limit unwanted radiation.
- Materials that diffusely reflect laser radiation must be used in place of specularly reflective surfaces wherever possible.
- To minimize personnel exposure, specularly reflecting surfaces that are needed for beam-path control should be enclosed or shielded. Also, wearing jewelry (watches, rings, etc.) is often an overlooked source of exposure to a beam reflected by a mirror-like surface on the jewelry. Wearing jewelry should be discouraged.

INVISIBLE BEAM Ultraviolet (UV) and infrared (IR) Lasers REQUIREMENTS

- UV and IR lasers that emit invisible beams require shielding that must be installed to lower UV radiation to levels below the MPE for the wavelength being used.
- UV and IR lasers that emit invisible beams require the control of hazardous concentrations of by-products formed by the reaction of intense UV radiation with materials in the area.
- IR beam enclosures and backstops must be made from IR-absorbent material and must be fire-resistant.

Section 5- Laser Effects and Personal Protective Equipment

5.1 – Skin

Skin injury is normally not possible with low- and medium-powered lasers, but only with Class 3B and Class 4 lasers. Class 4 lasers have the potential to burn the skin from direct or scattered beams. Skin protection should be a part of any laser safety program that involves Class 3B and Class 4 lasers and the personal protective equipment required should be written into the SOP for that laser or laser system.

One type of laser of particular concern would be those emitting in the ultraviolet wavelengths (200-400 nm), such as excimer lasers. This type of radiation causes sunburn, and chronic overexposures can leave to increased risk of skin cancer, especially in the UV-B region (280-320 nm). It is important to cover up any exposed skin when working with an ultraviolet laser, for both the direct beam and the scattered radiation. Long pants, closed toed shoes, and long sleeves or lab coats should be worn. Additionally, barrier creams, such as sunscreen, should be applied to any potentially exposed skin when working with sources of UV radiation like lasers.

Acute Effects (skin) (occur soon after exposure)	Chronic Effects (skin) (occur some longer time after exposure)
Skin burns from some Class 3B and Class 4 lasers	Increased risk of skin cancer from exposure to ultraviolet laser radiation
Sunburn from exposure to ultraviolet laser radiation	

5.2 – Eyes

Although skin burns may be painful during the short term, they are less serious than an eye exposure because 1) unlike the eye, skin has the ability to heal and 2) the skin is not nearly as specialized an organ as the eye. The eye is the organ most sensitive to direct laser radiation, especially the visible and near infrared wavelengths. Most laser exposures to the eye are both severe and permanent. This increased hazard is a direct result of the eye's focusing process. The wavelength of the incoming energy will determine where the energy will be deposited in the eye. Different structures of the eye may be injured depending upon which structure absorbs the greatest radiant energy per volume tissue.

Eye Structure	Type of Damage
Cornea	Corneal Burn
Lens	Cataracts
Retina	Decreased vision/vision loss
Optic Nerve	Blindness

Retinal effects can be expected to occur when the laser wavelength is within the visible and near infrared spectral regions (about 400-1400 nm), which includes Argon, HeNe, Ruby, Gallium Arsenide diode, and Nd:YAG lasers. The retina is not very vulnerable if the laser radiation is in the ultraviolet or far-infrared portions of the spectrum. Far infrared (FI) is absorbed in the anterior portion of the eye, exposures to the cornea may cause ultraviolet photokeratitis (a sort of severe sunburn to the eye), a very painful condition which feels akin to ground glass in the eye and lasts several days.

Protective eyewear in the form of spectacles or goggles with appropriately filtering optics can protect the eyes from the reflected or scattered laser light with a hazardous beam power, as well as from direct exposure to a laser beam. Eyewear must be selected for the specific type of laser, to block or attenuate in the appropriate wavelength range. For example, eyewear absorbing 532 nm typically has an orange appearance, transmitting wavelengths larger than 550 nm. Such eyewear would be useless as protection against a laser emitting at 800 nm. Eyewear is rated for optical density (OD) which is the base-10 logarithm of the attenuation factor by which the optical filter reduces beam power. For example, eyewear with OD 3 will reduce the beam power in the specified wavelength range by a factor of 1000. In addition to an optical density sufficient to reduce beam power to below the maximum permissible exposure, laser eyewear used where direct beam exposure is possible should be able to withstand a direct hit from the laser beam without breaking.

- Eye protection shall be worn by all persons in areas where Class 3b or 4 lasers are operated unless engineering or administrative controls are sufficient to eliminate potential exposure in excess of the applicable MPE. These controls must be documented in the SOP for the laser system and approved by the LSO.
- When purchasing laser safety eyewear, require that the manufacturer send the following information with each new pair of eyewear:
 - *corresponding optical density and wavelength for protective eyewear
 - *any pertinent data pertaining to the protective eyewear and laser safety
 - *recommendations on storage of laser safety eyewear
 - *instructions for proper cleaning methods of eyewear
- Laser protective eyewear shall be periodically cleaned and inspected for:
 - *pitting, glazing, cracking, and discoloration

*integrity of the frame

*light leaks and coating damage

Laser protective eyewear should be reviewed before each use to protect the user.

- Physical or chemical hazards to the eye can be reduced by the use of face shields or goggles. Consult ANSI Z87.1 (latest version) for information on eyewear selected for protection against other agents.

5.3 - Personal Protective Equipment (PPE) for Class 3 and 4 lasers

Protective eyewear in the form of spectacles or goggles with appropriately filtering optics can protect the eyes from the reflected or scattered laser light with a hazardous beam power, as well as from direct exposure to a laser beam. Eyewear must be selected for the specific type of laser, to block or attenuate in the appropriate wavelength range. For example, eyewear absorbing 532 nm typically has an orange appearance, transmitting wavelengths larger than 550 nm. Such eyewear would be useless as protection against a laser emitting at 800 nm. Eyewear is rated for **optical density** (OD), which is the base-10 logarithm of the attenuation factor by which the optical filter reduces beam power. For example, eyewear with OD 3 will reduce the beam power in the specified wavelength range by a factor of 1,000. In addition to an optical density sufficient to reduce beam power to below the maximum permissible exposure, laser eyewear used where direct beam exposure is possible should be able to withstand a direct hit from the laser beam without breaking.

1. Eye protection shall be worn by all persons in areas where Class 3b or 4 lasers are operated unless engineering or administrative controls are sufficient to eliminate potential exposure in excess of the applicable MPE.
2. The LSO must review and approve protective eyewear to assure that it is appropriate for the use for which it is intended. In accordance with ANSI Z136.1, laser protective eyewear may include goggles, face shields, spectacles, or prescription eyewear using special filter materials or reflective coatings (or a combination of both) to reduce the potential ocular exposure below the applicable MPE level.
3. Laser protective eyewear shall be specifically selected to withstand either direct or diffusely-scattered beams. In this case, the protective filter shall exhibit a damage threshold for a specified exposure time (typically 10 seconds). The eyewear shall be used in a manner so that the damage threshold is not exceeded in the “worst case” exposure scenario. Important in the selection of laser protective eyewear is the factor of flammability (see ANSI Z87 Impact Requirements). Studies have indicated that existing laser eye protective filters (plastic, glass, interference, or hybrid filters) often exhibit non-linear effects such as saturable absorption when exposed to ultra-short (femtosecond) pulse durations. Laser users should request test data from laser eyewear manufacturers.
4. Look at the laser type (Clear, CO₂) wavelength and OD (9.0µM – 11.6µM) when selecting the appropriate type of laser safety glasses/goggles.

The choice of protective eyewear depends on the wavelength(s) and intensity of the accessible radiation.

Remember the following:

- No matter how good the glasses, they do not provide any protection unless they are worn.
- All safety glasses may shatter and all plastic lenses may melt when maximum Irradiance or radiant exposure for the particular lens is exceeded.

- Eyewear must be inspected periodically by the user for pitting and cracking of the lenses, and for mechanical integrity and light leaks in the frame.
- Laser safety glasses may not provide eye protection with other than the laser for which they are specified unless the frequency produced is the same and power output is not greater.
- Eyewear designed for protection at one wavelength may not provide protection at another wavelength.
- Laser protective eyewear must be approved by the ANSI Standard ANSI Z136.1, and clearly labeled with optical densities and wavelengths for which protection is afforded.
- In some cases, other protective equipment, such as clothing to protect the skin from burns, may be required. Such requirements must be addressed in the Laser Safety SOP.
- Protective equipment is not a substitute for good work practices.

5.4 – Maximum Permissible Exposure, Nominal Hazard Zones, Laser Control Areas

5.4.1 – MPE

The Maximum Permissible Exposure (MPE) is defined as the level of laser radiation which a person may be exposed to without hazardous effect or adverse biological changes in the eye or skin. It should be noted that the MPE is not an exact limit between safe and dangerous exposures, but a guideline used to control exposures.

Because of their different tolerances and damage thresholds, the ANSI Z136.1 Standard lists separate MPE values for eyes and skin. The eye MPE is generally much more restrictive. When a new laser is registered with the Laser Safety Program, the MPE for eyes and for skin will be calculated. These values should be included in the laser safety notebook and posted in the lab.

MPE's are dependent primarily upon laser wavelength and exposure duration. Other factors, such as temporal mode (ie, whether the laser is continuous wave or pulsed), the pulse repetition frequency, and others should be known to calculate the MPE. MPE tables for both eye and skin are found in Tables 5a, 5b, and 7 in the ANSI Z136.1 Standard.

5.4.2 - NHZ

The Nominal Hazard Zone (NHZ) is the physical area in which the MPE can be exceeded by direct, scattered, or diffuse laser radiation. It can be calculated by knowing various parameters of the laser and its use, including wavelength, MPE, beam power, divergence, emergent beam diameter, lens focal length, scattering angle, and others. Entering the NHZ would require that certain controls be in place such as requirements for protective eyewear.

It should be noted that the NHZ does not apply if the laser beam is totally enclosed from beginning to end. The NHZ should be known for any beam which is not totally enclosed. When a new laser is registered with the Laser Safety Program, the NHZ will be calculated. This area will be reviewed in the laser usage area and any additional controls will be implemented in that zone.

5.4.3 – Laser Control Area

As previously mentioned, laser hazard analysis shall be conducted by the LSO. If the analysis determines that the classification associated with the maximum level of accessible radiation is Class 3b or 4, a laser control area shall be established.

1. In addition to all other requirements, a Class 3b or 4 laser control area shall:

- *be under the supervision of the sublicensee

- *have only diffusely reflecting materials in or near the beam path wherever feasible

- *access is limited to authorized personnel

- *all personnel within the area wear appropriate eye protection

- *have the laser secured such that the exposed beam path is above or below the eye level of a person in any sitting or standing position (exception for medical use)

- *cover all windows, doorways, portals, etc, or provide barriers in such a manner to reduce transmitted laser radiation to levels below the applicable ocular MPE.

- *store or disable the laser when not in use

- *the source of activation shall be secured or disabled when the laser is not in use

2. In addition to all other requirements, including those for Class 3b, Class 4 laser control areas shall:

- *have sufficient security to prevent entry of personnel into the laser-controlled area

- *have a clearly marked emergency shut off which will deactivate the laser

- *whenever possible, Class 4 lasers shall be monitored and fired from remote positions

Section 6 – Non-Beam Hazards

Non-beam hazards are seldom encountered outside the research and engineering laboratory environments. Most of them are associated with high-powered Class 4 lasers, but some span all laser classes. In addition, these hazards are normally found in some commercial laser material processing equipment.

6.1 - Noise

The primary source of noise around laser activities is from capacitor bank discharges. EHS can establish a hearing conservation program and assist in the selection of appropriate hearing conservation equipment (earplugs and muffs) if required.

6.2– X-ray Radiation

Whenever potentials in excess of 15 kV exist in a vacuum, the production and propagation of X-radiation outside the containment must be considered possible. Most laser systems use voltages less than 8 kV, and typically, the higher voltages are on low current devices such as Q-switches. However, some research models are now operating at voltages in the neighborhood above 20 kV. If the existence of an X-radiation hazard associated with your operation is possible, contact the LSO.

6.3 - Plasma Radiation

When the beam of a Class 4 laser is used in materials processing, it is possible to produce broadband radiation at non-laser wavelengths. This bright white light is called plasma radiation, and has been observed most frequently for the beams of Nd:YAG and carbon dioxide lasers used in applications such as welding, cutting, and drilling metallic materials. Wavelengths of greatest concern include actinic ultraviolet (UV-C and UV-B), and blue light. Plasma radiation may be controlled by the use of absorbing window materials, such as certain plastics. If used, it may be necessary to select materials that include yellow or amber dyes that will also absorb blue light.

6.4 - Fire Protection

The beam power of Class 4 lasers is sufficient to produce a fire when absorbed by flammable or combustible materials. Some firefighting equipment should be provided; however, the purpose of such equipment should be understood. It is to be used to extinguish or control small fires only.

6.5 - Flash Lamps

Flash lamps pose a dual hazard, both of which can be controlled. They may emit hazardous levels of ultraviolet radiation if quartz tubing is used. The ultraviolet radiation can be attenuated readily by certain plastics and heat resistant glasses. Flash tubes also explode on occasion, and should be provided with covers adequate to contain the explosion.

6.6 - Electrical Hazards

Electrical shock is very serious potential hazard associated with lasers. Several precautions and procedures should be used to minimize the hazard.

General Guidelines:

1. Use the buddy system, especially after normal working hours or in isolated areas.
2. Do not engage in any hazardous activities when fatigued or under medication which would impair judgment.
3. Do not engage in any hazardous activity when mental attitude, whether through emotional or chemical stimulus, would incline a person toward risk taking.

Specific guidelines to prevent electrical shock:

A. Precautions for all lasers

1. Learn CPR rescue procedures for helping victims of apparent high voltage shock: Kill the circuit, remove the victim with a non-conductor if still in contact with an energized circuit, initiate CPR respiration immediately, call for emergency aid, and continue respiration until relieved by emergency medical staff.
2. Avoid wearing rings, metallic watchbands and other metallic objects.
3. When possible, use only one hand in working on a circuit or control device.
4. Never handle electrical equipment when hands, feet or body are wet, perspiring, or when standing on a wet floor.
5. With high voltages, regard all floors as conductive and grounded unless covered with a well maintained, dry rubber matting of a type suitable for electrical work.

B. Precautions with high-power lasers

1. Provide fault-current-limiting devices such as fuses or resistors, capable of clearing or dissipating total energy. In some cases, these are incorporated in the laboratory bench wiring.
2. Provide protection against projectiles that may be produced during faults by the use of suitable enclosures and barriers.
3. Provide enclosures designed to prevent accidental contact with terminals, cables or exposed electrical contacts.
4. Provide a grounded metal enclosure that is locked and/or interlocked.
5. Prevent or contain fires by keeping combustible materials away from capacitors.

6. Automatically dump or crowbar capacitors before opening any access door.
7. Provide a sufficiently short discharge time constant in the grounding system.
8. Check that each capacitor is discharged, shorted and grounded before allowing access to capacitor area.
9. Provide reliable grounding, shorting and interlocking.
10. Install crowbars, grounding switches, cables and other safety devices to withstand the mechanical forces that could exist when faults occur or crowbar currents flow.
11. Provide suitable warning devices such as signs and lights.
12. Place shorting straps at each capacitor during maintenance while capacitors are in storage.
13. Provide manual grounding equipment that has the connecting cable visible for its entire length.
14. Supply safety devices such as safety glasses, rubber gloves and insulating mats.
15. Provide metering, control and auxiliary circuits that are protected from possible high potentials even during fault conditions.
16. Inspect routinely for deformed or leaky capacitor containers.
17. Provide a grounding stick that has a discharge resistor at its contact point, an insulated ground cable (transparent insulation preferred), and a grounding cable permanently attached to the ground. Such a grounding stick should not be used to ground an entire large bank of capacitors. Large capacity shorting bars, with resistors, should be part of the stationary equipment. Final assurance of discharge should be accomplished with a solid-conducting grounding rod.

C. Capacitors

Capacitors are electrical devices used to discharge large amounts of energy into TEA lasers or optical pumping systems in a relatively brief period of time. Power capacitors are both an electrical and an explosion hazard and should be enclosed in cabinets of suitable construction with integral interlocking access panels. High-energy capacitors should be in cabinets with walls of one-eighth inch steel.

Explosion failure is normally preceded by a leakage of stored energy between the plates through the dielectric and evidenced by a degradation of system pulses. When not in use, the high voltage terminal should be kept at ground potential by appropriate grounding measures.

Capacitors life expectancy is reduced by high operating temperatures charging greater to that of the capacitors rated voltage, and excessive voltage reversal during discharge (> 20%, i.e. negative overshoot). Under certain conditions of use due to R/LC considerations, the "discharged" capacitor may retain or restore a significant portion of its original charge.

6.7 - Cryogenics

Cryogenic liquids (especially liquid nitrogen, LN₂) are used occasionally to cool lasers, and frequently to cool sensors used as receivers of reflected or transmitted laser signals. The boiling point of LN₂ is almost 13° Kelvin colder than the condensation temperature of oxygen. Therefore, under certain conditions of use (namely, when the LN₂ is temporarily stored in a wide open vessel), an increase of liquid oxygen in the cryostat, due to condensation out of the atmosphere, can be anticipated. Enough oxygen may be condensed into the LN₂ to require that it be treated in accordance with liquid oxygen safety guidelines. Insulated handling gloves of quick-removal type should be worn. Clothing should not have pockets or cuffs that may catch spilled cryogenics. If a spill occurs on the skin, irrigate the skin with large quantities of unheated water, and then apply cold compresses. If blistering occurs or the eyes are involved, get the patient to a physician immediately.

For pouring operations, eyes must be protected by face shields or safety goggles with side-shields. Safety goggles without side-shields are not considered adequate. When dumping "inert" gases such as liquid nitrogen, precautions should be taken to ensure there is adequate ventilation, otherwise the inert gas may exclude oxygen from the lungs of personnel in the area. This may lead to unconsciousness or even death.

Keep all combustibles away from liquid oxygen. No smoking or open flame is permitted in areas where liquid oxygen is stored or used. Cryogenic mixtures that contain oxygen or that have been open to the atmosphere for more than a few minutes should be treated with the same precautionary measures as liquid oxygen.

6.8 - Airborne Contaminants

Laser Generated Air Contaminants (LGAC) may be produced when certain Class 3B, Class 4, and in some rare cases where beams interact with matter. While it is difficult to predict what

LGAC may be released in any given situation; it is known that contaminants, including new compounds, can be produced with many types of lasers. When the target irradiance reaches a given threshold, approximately 107 W/cm², target materials may liberate toxic and noxious airborne contaminants. Optical materials used with carbon dioxide (materials processing lasers) that have been damaged by the beam may also be a source of LGAC. It is the responsibility of the LSO to ensure the appropriate industrial hygiene characteristics of exposure to LGAC are affected in accordance with federal, state and local requirements.

6.9 - Other Chemical Agents

These include compressed gases and dye/solvents systems. Compressed gases used with excimer lasers include halogens such as chlorine or fluorine. These gases are irritants and corrosives, and are reactive. Control measures include gas cabinets with flow indicators and halogen sensors, and supply tubing that is stainless steel. Dyes and solvents are used to generate laser radiation with dye lasers. Dyes are solid, organic compounds that may be mutagenic or toxic. Organic solvents may be volatile, toxic, and flammable. The control of these chemicals includes the use of exhaust ventilation, emergency eyewashes and safety showers, and containment of pumps and reservoirs. Personal protective equipment, such as safety glasses and gloves, may also be necessary.

Section 7 – Training

Anyone who works with lasers of any classification shall complete the University of Alabama Laser Safety Training course. This training or a refresher is required annually.

Anyone who works with lasers shall receive initial training and procedures specific information from the owner/PI/Sublicensee. This includes training on the Laser Safety Notebook. At a minimum, this training should include emergency procedures, laser safety principles, operating procedures, and any other information related to hazards unique to the lab and the laser, how it will be used, or the area of usage. Personnel who administer training shall maintain records of training. These records must include name, identifier, and a written/printed example of the material covered. A copy of these records should be submitted to EHS upon separation from UA. Anyone using a laser or laser system should review the manufacturer's manual for operating procedures, cautions, and safety requirements. Any owner/PI/Sublicensee and their users shall attend any laser safety information sessions outlining changes that have been made to the program, as well as any pertinent safety issues. The owner/PI/Sublicensee shall provide additional training to all users whenever conditions or regulations change.

Failure to attend or to provide required training may void the privilege to work with lasers. The RCAC may direct EHS to secure the laser or laser system from unauthorized use until such training is completed. Contact the LSO for more information regarding training.

Section 8 – Medical Surveillance and Incident Reporting

8.1 – Medical Surveillance

Some individuals who operate or work in close proximity to Class 3B or Class 4 lasers or laser systems may receive a pre-assignment and a post-assignment eye examination performed by a consulting ophthalmologist. This is not required by the ANSI Standard, but it can be required by the laser owner/PI/sublicensee. Contact the LSO for more information.

Baseline medical exams, when required, shall include:

- *ocular history
- *visual acuity for far and near vision
- *macular function
- *color vision discrimination

Further exams should be done as deemed necessary.

8.2 – Laser Injury

Employees with a suspected injury due to occupational exposure to lasers shall be treated according to the University Injury Policy. Contact the LSO immediately after any potential accident or incident. Employees must complete an OJI and should be sent to an ophthalmologist for treatment. Notify University Medical Center. Students shall complete a non-employee accident/incident report and be sent to an ophthalmologist for treatment. Notify Russell Student Health. All forms can be accessed via the EHS website at ehs.ua.edu.

Records related to medical surveillance or treatment shall be maintained indefinitely by the attending physician. The LSO shall be provided with copies of all physician reports for baseline examinations and subsequent exams.

8.3 – Accidents and Incidents

Retinal injuries with loss of sight from visible and near-infrared laser systems have been the most catastrophic of all effects from direct laser radiation. Although high-power lasers have caused burns in hands and clothes, these are inconsequential in comparison to a serious retinal injury. Skin burns normally heal, and the skin is dissimilar to the eye in that the eye performs an extremely specialized function. Retinal injuries are essentially permanent with little chance of repair. Specific causes for accidents include such things as:

- Unanticipated eye exposure during alignment
- Misaligned optics and upwardly directed beams
- Available eye protection not used, usage not enforced

- Equipment malfunction
- Improper methods of handling high voltage
- Intentional exposure of unprotected personnel
- Operators unfamiliar with laser equipment
- Lack of protection for non-beam hazards
- Improper restoration of equipment following service
- Failure to follow SOPs
- Bypassing interlocks
- Turning on power supply accidentally
- Accidental laser firing by unintentional capacitor discharge
- Alteration of beam path by moving laser or optical components
- Adding optical components without regard to effect on beam path or the reflected beam
- Damage to laser enclosure
- Removal of safety devices in order to align beam or adjust laser
- Insertion of reflective materials into beam path

Section 9 – Noncompliance

1. Noncompliance issues may be classified in one or more of the following categories: initial violation, repeat violation, severe violation and immediately hazardous to health violation.
2. Initial violations are those violations that occur for the first time during a twelve month period.
3. Repeat violations are those violations which occur for the second time in a twelve month period.
4. Severe violations are those violations that occur three or more times during a twelve month period or for which a clear pattern of repeat violations is demonstrated over time.
5. Immediately hazardous violations are those violations that are deemed by the LSO as presenting an immediate hazard to persons who may be present in the area or facility.
6. Initial and repeat violations shall be documented by the LSO or other EHS personnel. The responsible Sublicensee shall be informed in writing of the nature of the noncompliance, ways to implement correction and the consequences of failure to comply.
7. In the event of an immediately hazardous violation the LSO or RSO may immediately cease operation of the laser, secure the area, suspend the privileges of the responsible sublicensee and take other action as deemed necessary to protect the health of individuals or the safety of University facilities. The responsible sublicensee shall be informed in writing of the nature of the violation, ways to implement corrective action and that as a result of this noncompliance the RCAC will evaluate the incident to determine appropriate punitive action.
8. The Laser Safety Program is a part of the University of Alabama Hazardous Material Management Program. As such the Director of EHS may refer violations to the Vice President for the affected area.

Section 10 – Laser Pointers

The University of Alabama does not endorse the use of any laser pointer exceeding 5 mW. There are even more powerful laser pointers, which may be purchased that may present a potential eye hazard if viewed directly. At present time, the potential for eye injury directly related to laser pointers has not been completely determined. For this reason, pointers shall not be used at any time during athletic events on campus. Instructors or lecturers on campus may only use pointers as long as they meet the above specifications. Laser pointers above 5mW may be registered at the Office of Environmental Health and Safety by contacting the Laser Safety Officer.

Any individual utilizing a laser pointer must be aware of both the possibility of hazards related to the direct beam and ocular effects attributed to the laser pointer, such as afterimage, flash blindness, vision dysfunction, or glare. This may be particularly hazardous if the exposed individual is operating a moving vehicle or machinery.

The FDA has addressed laser pointers under the definition of a surveying, leveling, and alignment laser product, which is included in 21 CFR Part 1040.11 of the U.S. Federal Laser Product Performance Standard. This standard indicates that the laser product must comply with all of the requirements for a Class 1, 2, or 3a laser product and not permit access to laser radiation. On December 13, 1997 the FDA issued a warning to parents and school officials regarding the possible hazard associated with laser pointers. ANSI Z136.1 (2000) encourages education and training as the best approach of a safety program regarding laser pointers. Below are a number of suggested safety rules for dealing with laser pointers:

- NEVER point a laser pointer (of any power) at anybody. Pointers should be used to point out or emphasize inanimate objects such as slide images, building components, or laboratory apparatuses, etc.
- Avoid "mirror like" (specular) targets and NEVER stare into a pointer! Also, NEVER view a laser beam using an optical instrument (such as binoculars, microscope, etc.) unless appropriate safety personnel have technically approved the procedure.
- Always use LOWEST power rating possible and highest divergence where possible. No laser pointer rated at a Class 3B should ever be used without special provisions-such as medical surveillance and approval of a LSO.
- These laser pointers are not toys and should not be used by juveniles. As an aid for this suggestion, it is recommended that the batteries be taken out of the pointer when not in use.
- The users of these devices should register them with the LSO at the Office of Environmental Health and Safety in order to impress on users the need for safety awareness. The appropriate safety personnel should require that all laser pointers be correctly and conspicuously labeled with the correct warning signs.

- Safety personnel and pointer users should be aware that wavelengths around 400 to 500 nm (i.e. blue light region) could cause biological effects of a photo-biological nature (e.g. like "sunburn").
- One should NEVER use a laser pointer above 5 mW.

Appendix

- I. Optical Densities for Protective Eyewear for Various Laser Types
- II. Registration of Personnel
- III. Laser Equipment Approval/Registration
- IV. Laser Safety Audit
- V. Application for Laser Sublicense

I. Optical Densities for Protective Eyewear for Various Laser Types

Laser Type/ Power	Wavelength (μm)	OD 0.25 seconds	OD 10 seconds	OD for 600 seconds	OD for 30,000 seconds
XeCl 50 watts	0.308 ^a	---	6.2	8.0	9.7
XeFl 50 watts	0.351 ^a	---	4.8	6.6	8.3
Argon 1.0 watt	0.514	3.0	3.4	5.2	6.4
Krypton 1.0 watt	0.530	3.0	3.4	5.2	6.4
Krypton 1.0 watt	0.568	3.0	3.4	4.9	6.1
HeNe 0.005 watt	0.633	0.7	1.1	1.7	2.9
Krypton 1.0 watt	0.647	3.0	3.4	3.9	5.0
GaAs 50 mW	0.840 ^c	---	1.8	2.3	3.7

Nd:YAG 100 watt	1.064 ^a	---	4.7	5.2	5.2
Nd:YAG (Q-switch) ^b	1.064 ^a	---	4.5	5.0	5.4
Nd:YAG^c 50 watts	1.33 ^a	---	4.4	4.9	4.9
CO₂ 1000 watts	10.6 ^a	---	6.2	8.0	9.7
^a Repetitively pulsed at 11 Hertz, 12 ns pulses, 20mJ/pulse. ^b OD for UV and FIR beams computed using 1 mm limiting aperture which presents a “worst case scenario. All visible/NIR computations assume 7 mm limiting aperture. ^c Nd:YAG operating at a less common 1.33 μm wavelength. NOTE: All OD values determined using MPE criteria of ANSI Z-136.1					

I. Control Measures for the Four Laser Classes

Control Measures	Classification						
	1	1M	2	2M	3R	3B	4
Engineering Controls	X	X	X	X	X	X	X
Protective Housing	X	X	X	X	X	X	X
Without protective housing	Laser Safety Officer establishes alternative controls						
Interlocks on protective housing	◇	◇	◇	◇	◇	X	X
Service Access Panel	◇	◇	◇	◇	◇	X	X
Key Control	--	--	--	--	--	•	X
Viewing Portals	Assure viewing limited < MPE						
Collecting Optics							
Totally Open Beam Path	--	--	--	--	--	X NHZ	X NHZ
Limited Open Beam Path	--	--	--	--	--	X NHZ	X NHZ
Enclosed Beam Path	None required if protective housing and interlocks in place						
Remote Interlock Connector	--	--	--	--	--	•	X
Beam Stop or Attenuator	--	--	--	--	--	•	X
Activation Warning Systems	--	--	--	--	--	•	X
Indoor Laser Controlled Area	--	--	--	--	--	--	X
Class 3B Indoor Laser Controlled Area	--	--	--	--	--	X	--
Class 4 Laser Controlled Area	--	--	--	--	--	--	--
Outdoor Control Measures	--	--	--	--	--	--	--

Laser in Navigable Airspace	X	• NHZ	X NHZ	• NHZ	Ξ NHZ	Ξ MPE	Ξ MPE
Temporary Laser Controlled Area	◇ MPE	◇ MPE	◇ MPE	◇ MPE	◇ MPE	--	--
Controlled Operation	--	--	--	--	--	--	•
Equipment Labels	X	X	X	X	X	X	X
Laser Area Warning Signs	--	--	--	X	•	X	X
Administrative and Procedural Controls							
Standard Operating Procedure	--	--	--	--	--	•	X
Output Emission Limitations	--	--	--	--	--	LSO Determines	
Education and Training	--	•	•	•	•	X	X
Authorized Personnel	--	*	--	*	--	X	X
Alignment Procedures	◇	◇	◇	◇	◇	X	X
Protective Equipment	--	*	--	*	--	•	X
Spectator	--	*	--	*	--	•	X
Service Personnel	◇	◇	◇	◇	◇	X	X
Demonstration with Public	--	*	X	*	X	X	X
Laser Fiber Optic Systems	MPE	MPE	MPE	MPE	MPE	X	X
Laser Robotic Installation	--	--	--	--	--	X NHZ	X NHZ
Protective Eyewear	--	--	--	--	--	• MPE	X MPE
Window Protection	--	--	--	--	--	X	X NHZ
Protective Barriers and Curtains	--	--	--	--	--	•	•
Skin Protection	--	--	--	--	--	X	X MPE
Warning Signs and Labels	--	--	•	•	•	X NHZ	X NHZ
Skin Protection	--	--	--	--	--	X MPE	X MPE
LEGEND	X = shall • = should -- = no requirement NHZ = NHZ analysis required						
	◇ = shall if enclosed Class 3b or 4 MPE = shall if MPE is exceeded						

III. Laser Purchase Requisition – Sample – most recent version is posted at www.ehs.ua.edu

Laser Purchase Requisition

Date of Request: _____

Date of Review: _____

Date of Approval: _____

How is system being acquired? Purchase Donation Assembly Other

Contact information:	Name	Email	Phone
Principle Investigator			
Lab Contact			
Other			

Location of Use: _____

Class	1	1M	2	2M	3R	3B	4
Type							
Manufacturer							
Model							
Max Power							
Wavelength							
Emission Type	Continuous Wave			Pulsed			
If Pulse, Pulse Duration							
Fiber Optics	Yes			No			
Beam Exposed	Yes			No			
Fixed	Yes			No			
Alignment Performed By	PI/Lab	UA	Manufacturer		Vendor	Other	
More Lasers in Lab	Yes			No			

Experimental Purpose:

Any other relevant information:

III. Laser Safety Self Audit

Laser Safety Self Audit

** Complete a Self Audit inspection form and submit to EHS. Maintain a copy for your lab records. These can be used to prepare for EHS Inspections

PI/Lab Supervisor _____

Inspected By _____

Building/Room _____

Date of Inspection _____

General Questions for all Lasers and all Lasers Systems

Are lasers classified appropriately?	Y	N	NA	CAI		
What is the classification for this laser/laser system? 1 1M 2 2M 3R 3A 3B 4						
Are all lasers labeled correctly?	Y	N	NA	CAI		
Are written Standard Operating Procedures in place?	Y	N	NA	CAI		
Are written alignment procedures available?	Y	N	NA	CAI		
Are written maintenance procedures available?	Y	N	NA	CAI		
Have all laser users completed Basic Laser Safety training?	Y	N	NA	CAI		
Have all laser operators received training specific to laser operation in the lab?	Y	N	NA	CAI	NA	CAI
Are appropriate warning signs posted at lab entrances?	Y	N	NA	CAI		
Is protective housing present and in good condition?	Y	N	NA	CAI		
Are there beam enclosures?	Y	N	NA	CAI		
Do surfaces minimize specular reflections?	Y	N	NA	CAI		
Is there any exposed wiring or circuits?	Y	N	NA	CAI		
Are electrical circuits overloaded?	Y	N	NA	CAI		
Is a clearly visible 'power on' indicated incorporated in the laser device?	Y	N	NA	CAI		
Are windows and ports which could allow a laser beam to stray into uncontrolled areas covered or protected with non-reflective material during laser operation?	Y	N	NA	CAI	NA	CAI
Are beams stops present at the end of all beam paths?	Y	N	NA	CAI		

Are the beam stops noncombustible?	Y	N	NA	CAI			
Are barriers and screens noncombustible?	Y	N	NA	CAI			
Are there any burn holes in the barriers and screens?	Y	N	NA	CAI			
Is appropriate PPE available?	Y	N	NA	CAI			
Is appropriate PPE used?	Y	N	NA	CAI			
Do laser users wear jewelry or watches while lasers are operating? Y		N	NA	CAI			
Have all commercially produced lasers and all lasers made or modified on campus been registered with the Laser Safety Officer at EHS? Y		N	NA	CAI			
All lab personnel know how to access the Laser Safety Policy on the EHS website? Y		N	NA	CAI			

For Class 3B and 4 Lasers

Do protective housings have interlocks to kill the beam if opened?	Y	N	NA	CAI			
Are only authorized personnel permitted in the laser area?	Y	N	NA	CAI			
Is spectator access limited?	Y	N	NA	CAI			
Have the hazard calculations been determined and posted?	Y	N	NA	CAI			
___Nominal Hazard Zone ___Nominal Optical Hazard Zone ___Maximum Permissible Exposure ___Skin ___Eye							
Does the laser have remote firing/operating capabilities?	Y	N	NA	CAI			
Does the laser have remote viewing capabilities?	Y	N	NA	CAI			
Is protective eyewear appropriate for laser operations?	Y	N	NA	CAI			
Is each pair of eyewear labeled (from the manufacturer) with the optical density and wavelength for which protection is provided?	Y	N	NA	CAI			
Is protective eyewear clean and free of damage?	Y	N	NA	CAI			
Is eyewear inspected for cracks, scratches, and breaks before each use? Y		N	NA	CAI			
Does eyewear have side shield protection?	Y	N	NA	CAI			
Are skin covers or other protective clothing (lab coats) are worn during operation of laser equipment? (particularly those operating in the UV region)	Y	N	NA	CAI			
Is flame retardant clothing worn while using high powered class 4 lasers? Y		N	NA	CAI			
Are all stray beams traced and dumped?	Y	N	NA	CAI			
Are beam paths enclosed where possible?	Y	N	NA	CAI			
Are all lasers positioned above or below eye level of the users?	Y	N	NA	CAI			
Is the laser area free of unnecessary reflective items? Y N NA CAI							
Is an operational key switch available to prevent unauthorized use of equipment? Y		N	NA	CAI			
Do laser operators work in pairs/groups in case of accident/incident/injury? Y		N	NA	CAI			
Is point source ventilation or canopy exhaust available?	Y	N	NA	CAI			

Comments:

IV. Application for Laser Sublicense

Name _____

Building _____

Lab(s) _____

Telephone _____

Email _____

Describe education and training related to lasers:

Describe Experience related to lasers:

Describe the proposed use of the laser:

Describe the Laser SOD:

Laser Specs

Manufacture:

Model:

Serial Number:

Class:

Type: (Continuous/Pulsed):

Description:

Wavelengths:

Maximum Power:

Pulse Duration:

Beam Dimensions:

Describe Set up (Open, enclosed, etc.)

Who Will Service Laser? _____

Describe protective eyewear to be utilized:

Describe training to be provided to be users:

Applicant Signature _____ Date _____