UA Laser Safety Manual
March 2012

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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 primarily based on information from the ANSI Z136.1-2007 *Safe Use of Lasers* standard. 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. This individual has the authority and responsibility to monitor and enforce the control and laser hazards and to effect the knowledgeable evaluation and control of laser hazards. 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 an individual designated by the employer with the authority and responsibility to affect the knowledgeable evaluation and control of laser hazards and to monitor and enforce the control of such hazards. The LSO shall have authority to suspend, restrict or terminate the operation of a laser or laser system if he/she deems that the laser hazard controls are inadequate. The LSO can remove or restrict any individual or user from laser usage or from the Laser Safety Program if they are not in compliance with these regulations and the ANSI standards. 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). All noted areas of concern on the evaluation must be address 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 in connection with the Laser Safety Committee (below) shall approve Class 3B and Class 4 Standard Operating Procedures (SOPs) and other procedures that may be part of the requirements for administrative and procedural controls. Approval must be issued prior to beginning any work with lasers at UA. The LSO and the committee shall also approve any SOPs required for embedded class 1 lasers or laser systems that contain a Class 3B or Class 4 laser if any activities (including maintenance, service, alignment, etc) require access to the beam.
6. The LSO shall recommend or approve protective equipment (ie 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. UA requires initial training before any laser work can take place and 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.
11. The LSO shall assure that the necessary records required by applicable government regulations are maintained. The LSO shall also submit to the appropriate medical officer the names that are included in the medical surveillance program and shall assure that appropriate records are maintained and that applicable medical exams have been scheduled and performed. 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 for 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 is 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, authorized operation, transfers, disposals, or any other deviation from accepted practices and implement corrective action.

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. Owners of Class 3B and Class 4 lasers and laser systems will receive a sublicense for their system and may be referred to as sublicensee. A sublicense is only required for Class 3B, Class 4, and some embedded Class 1 lasers.
   Each sublicense is issued for a period of up to one year, with an March 31 expiration date. Sublicensees will receive renewal information from the LSO. Sublicensees who do not wish to renew shall inform the LSO by written response to the renewal notification. Sublicensees who do not respond and/or allow their sublicenses to expire must reapply to resume working with lasers.
   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 graduate student documented by the owner/sublicensee as having access to a laser or laser system.
3. Student - any individual that is not an employee or graduate student 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.
6. Inspection personnel - any individual that enters a laboratory performing an inspection of the facility or the laser/laser system. The LSO, 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 or laser equipment on UA campus.
- Ensuring they are in compliance with 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 – Laser Safety Subcommittee

The University of Alabama has a Laser Safety Subcommittee operating under the auspices of the Radiation Control and Advisory Committee (RCAC). The purpose of this group is to provide guidance to the LSO and laser users to ensure that lasers are used safely and in compliance with applicable regulations and standards. Membership may include but is not limited to the LSO and others who are knowledgeable in laser safety, laser users, management representatives, and others as needed. The committee, either thru the subcommittee or the full RCAC, will work to:

- Assist the LSO with establishing and maintaining adequate policies and practices for the evaluation and control of laser hazards, including the recommending of appropriate laser safety training programs and materials.
- Maintain an awareness of all applicable new or revised laser safety standards.
- Assist with the review and approval of all Class 3B and Class 4 lasers in connection with the LSO.

The committee may revoke laser privileges or take other punitive action if an individual disregards safety procedures, fails to adhere to the provisions of the Laser Safety Program or habitually creates laser hazards.

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 Purchase Requisition (LPR – sample at the end of the Appendix, current version posted on the EHS website) must be completed and submitted to the LSO before an order or receipt can be approved. 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 registration for the Laser Safety Program. For Class 3b and 4 lasers, this will also serve as the sublicense application. 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. An initial Laser Safety Self Audit must be completed by the sublicensee and submitted with the SOP. A sample of this document is available in the Appendix and the current version is posted on the EHS website or by contacting the LSO.
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 for laser paperwork. The application and registration should be maintained in the notebook, along with all other noted 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, Class 4, or embedded Class 1 applications will be presented to the LSC subcommittee, along with any recommendations from the LSO. They will review all documents and may request additional information or SOP modifications. Once this review is completed, the packet will be sent to the RCAC for an approval vote. This can be a scheduled meeting or an electronic vote. Either the RCAC may approve, modify or deny an application. **All applications must be approved prior to any laser usage.**

7. Upon approval of Class 3B and Class 4 lasers or laser systems, each sublicensee will be assigned a sublicense number with an March 31 expiration date. This sublicense number must be obtained prior to any work with lasers. Once in effect, the control number will remain in effective until March 31 of the following year.
8. Each laser owner or sublicensee shall assure all laser users have successfully completed the University of Alabama Laser Safety Training Course. Details about this course can be obtained from the LSO. Upon receipt of a laser registration, the LSO will assign laser safety training via the SkillSoft Academy. Each user should complete the training and print copies of their certificates. Refresher training every year will also be provided via the Academy. 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 Laser Registration. This must be updated by March 31 or 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 which require 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 sublicense, 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 LSC 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. In addition, any laser warning signs that are no longer needed from doors or other locations should be removed.
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 for 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) operate 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 (CO_2) 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 CO_2 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.

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 such as LIDAR, 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 thyratron 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 is subject to the requirements set forth by the Center for Devices and Radiological Health (CDRH). 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 or members of the ANSI committee. 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.

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.

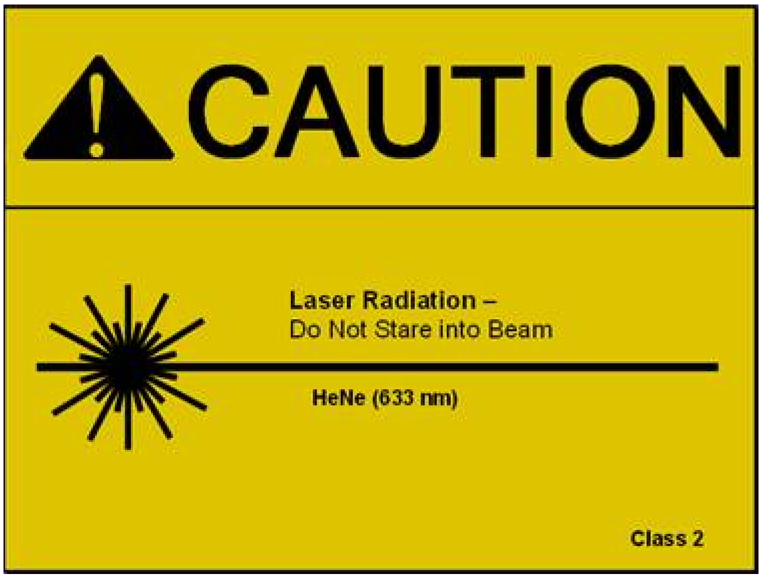
Exceptions to the foregoing, such as cooperative use of UA facilities and equipment by university and corporate researchers or use of university facilities and equipment by visiting scholars, must be approved by appropriate college and university officials, and must be documented by written agreements 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. For specific information, contact the LSO.

Section 4 – Warning Signs and Labels

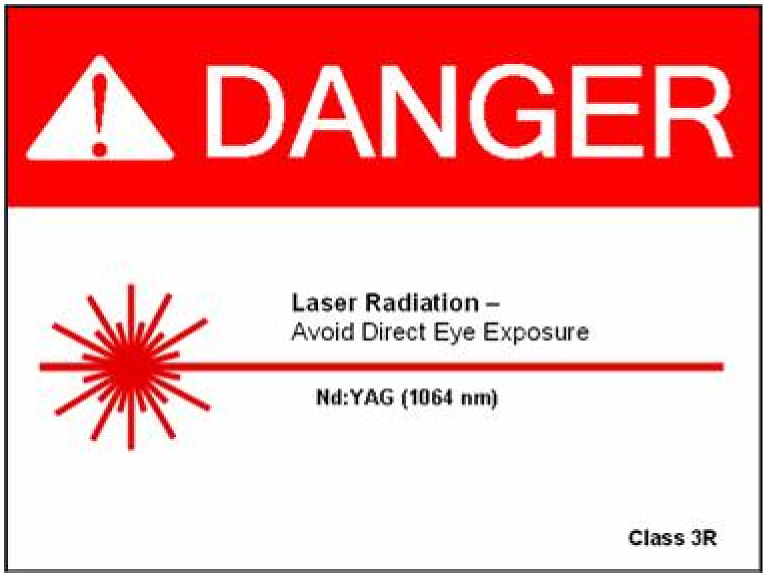
Labels and warning signs should be displayed conspicuously in areas where they would best serve to warn individuals of potential safety hazards. Normally, signs are posted at entryways to laser controlled areas and labels are affixed to the laser in a conspicuous location. All Class 2, 3 and 4 laser 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

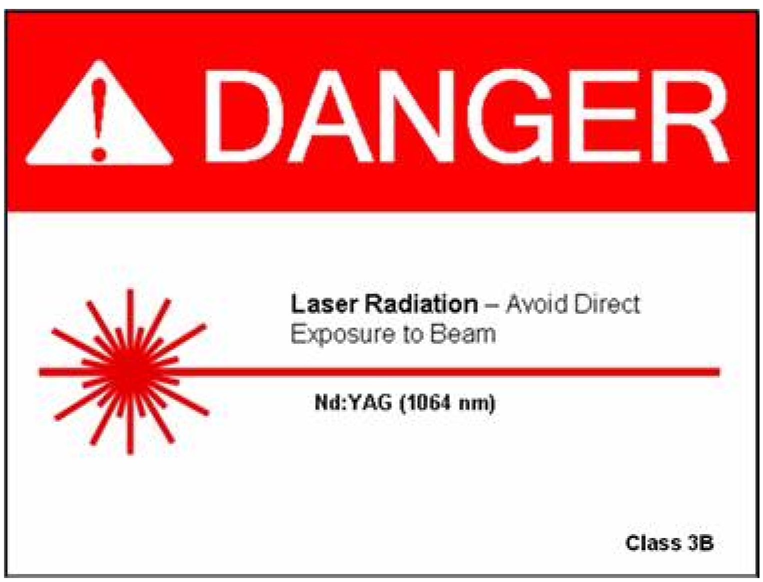


Class 3R laser equipment, below MPE: Danger, Laser Radiation (or laser symbol), Do Not Stare into Beam or View Directly with Optical Instruments

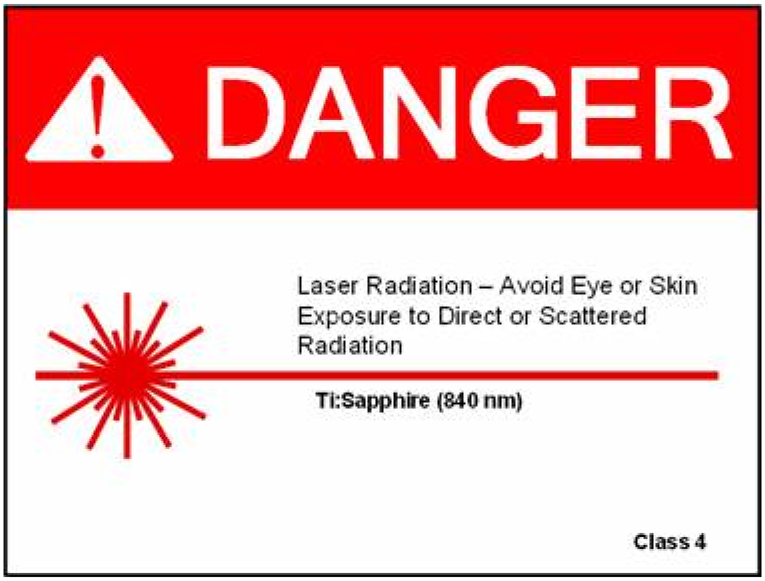
Class 3R laser equipment, above MPE: DANGER, Laser Radiation (or laser symbol), Avoid Direct Eye Exposure



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



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

5.3.1 – 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.

5.3.2 - 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.

5.3.3 – 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 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

To date, more than a dozen electrocutions of individuals from laser-related accidents have been reported in the United States. In 1986, a graduate student working with a CO_2 laser was wiping condensate from the laser tube when he received a 17 kV electrical shock. He suffered cardiac arrest and second degree burns. In 1988, a laser repair technician was electrocuted while working alone on a CO_2 laser. He reportedly defeated the interlock system. In 1983, a serviceman in Ohio was electrocuted while attempting to adjust the power supply of a copper vapor laser. A senior research scientist, working alone, was electrocuted while trying to replace a high voltage regulator tube in a laser power supply. These instances are typical and many other instances could be described. These accidents could have been prevented and need not be fatal to be considered serious. Many electrical fatalities can be prevented if CPR is administered. The principle factors influencing all accidents in order of their frequency are fatigue, hunger, medication, alcohol and other drugs.

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 (except under physician's approval).
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 mouth-to-mouth 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/cm-2, 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 shall complete the University of Alabama Laser Safety Training course. This is an electronically delivered course via the SkillSoft Academy and can be completed at the users convenience. Any laser owner/PI/Sublicensee should submit a user registration for training assignments. Anyone who works with lasers shall receive initial system 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 (other than the Academy 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. 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 change.

Failure to attend or to provide required training will void the privilege to work with lasers and EHS will secure the laser or laser system from unauthorized use until such training is completed

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 University Medical Center for treatment. Students shall complete a non-employee accident/incident report and be sent to Russell Student Health. They should ask for a reference to an ophthalmologist. All forms can be accessed via the EHS website at www.bama.ua.edu/~ehs.
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

Incidents can be such things as stolen materials, lasers in unattended operation, unsafe actions, failure to use personal protective equipment, laser labs left unlocked, warning lights or door signage not operating correctly, and narrowly avoided accidents or near misses. Any laser accident or incident should be reported to the LSO. Reporting and near miss documentation is available on the EHS website, www.bama.ua.edu/~ehs.

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. The Chair of the LSC and the responsible department chair shall be provided a copy of this documentation.
7. In the event of an immediately hazardous violation the LSO or Director of EHS 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 LSC will evaluate the incident to determine appropriate punitive action.
9. 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, pipes, asbestos, or laboratory apparatuses.
- 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 Laser Safety Officer.
- 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 Laser Safety Officer 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

XI. Optical Densities for Protective Eyewear for Various Laser Types
XII. Control Measures for the Four Laser Classes
XIII. Selected ANSI Table Availability
XIV. Registration of Personnel (Sample)
XV. Laser Safety Registry (Sample)
XVI. Laser Purchase Requisition – Sample
XVII. Laser Safety Self Audit – Sample
XVIII. Laser Specs and Hazard Analysis – Sample
XIX. Pre-Usage Check – Sample
XX. Standard Operating Procedures - Sample

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
CO_2 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

II. Control Measures for the Four Laser Classes

Control Measures	Classification						
Engineering Controls	**1**	**1M**	**2**	**2M**	**3R**	**3B**	**4**
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. Selected ANSI Table Availability

The following ANSI tables are available through EHS:

ANSI Table C1: Typical Laser Classification - Continuous Wave Lasers

ANSI Table C2: Typical Laser Classification - Single Pulse Lasers

ANSI Table 5: Maximum Permissible Exposure for Ocular Exposure to a Laser Beam

ANSI Table 6: Parameters and Correction Factors

ANSI Table 7: Maximum Permissible Exposure for Skin Exposure to a Laser Beam

Contact the LSO for copies of these tables.

IV. Registration of Personnel – Sample – current version available at www.bama.ua.edu/~ehs

Registration of Personnel (Continued)

Name	CWID#	Status	Date Active	Date Inactive

V. Laser Registry – Sample – most recent version is posted at www.bama.ua.edu/~ehs

University of Alabama
Environmental Health and Safety

Laser Registry
Laser Safety Program

Note: All lasers in use at The University of Alabama must be registered with the Laser Safety Program at Environmental Health and Safety. All lasers of Class 3B and Class 4 will have additional documentation requirements.

Instructions: Please complete this form for each laser to be used or purchased and submit to Marcy Huey, mhuey@ua.edu, or campus mail at Box 870178.

I. PI Information

PI | Phone

Location | Email

Date Submitted

II. Personnel

A. Please list the people who will be using the laser or laser system

Name | CWID | Status (faculty, staff, UG, G, etc)

B. Please list the people who will be in the laser area but are not laser users

Name | CWID | Status (faculty, staff, UG, G, etc)

III. Laser Usage

A. Please describe the use/experimental purpose:

B. Is there a written SOP available? Y N

If yes, please submit with registration.

IV. Laser System Information

A. System Use Location (Building, Room)

B. System Storage Location (if different from usage)

C. Laser Warning Sign on door? Y N
Wording on sign?

D. Do users wear laser protection eyewear? Y N
   a. Type/Manufacturer

   b. Optical Density

   c. Storage Location

Are they inspected before each use? Y N

E. Is laser protection eyewear available for visitors? Y N
   a. Type/Manufacturer

   b. Optical Density

   c. Storage Location

Are they inspected before each use? Y N

F. Is the laser serviced 'in house'? Y N

G. If no, is there a service contract for the laser? Y N
Service Company Information:

V. Laser Specs

Manufacturer:

Model:

Serial Number:

Class:

Type: Continuous Pulsed

Description (HeNe, CO2, etc):

Wavelength(s):

Maximum Power/Peak Power (Watts or Joules):

Pulse Duration (repetition rate):

Emerging beam dimensions (mm):

Laser Setup: Open Beam Fully Enclosed Fiber Delivery
Other:

VI. Laser Purchase Requisition – Sample – most recent version is posted at www.bama.ua.edu/~ehs

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
Principal Investigator			
Lab Contact			
Other			

Location of Use: ____

Laser Information:

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:

VII. Laser Safety Self Audit – Sample – most recent version is posted at www.bama.ua.edu/~ehs

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. If you have any questions, contact Marcy Huey at mhuey@ua.edu, 348-5912, 561-4789.

PI/Lab Supervisor ____
Inspected by ____
Building/Room ____
Date of inspection ____

General Questions for all Lasers and Laser 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
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
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:

____
____
____
____

VIII. Laser Specs and Hazard Analysis – Sample– most recent version is posted at www.bama.ua.edu/~ehs

Laser Specs and Hazard Analysis

Inventory Number:

Laser Type: Class:

Embedded Laser: y n Class of embedded laser:

Manufacturer:
Model:
Serial Number:

Tunable: y n Wavelength(s):

Power/Energy Output:

CW/Single Pulse/Multiple Pulse/Combination

Pulse Duration: PRF:
Beam divergence: Emergent Beam Diameter:
Lens Focal Length: Beam size at lens:
Numeral Aperture: Model Field Diameter:

Beam Path

Totally Enclosed	y	n
Limited Open	y	n
Totally Open	y	n
Potential for Stray Beams	y	n
Non-reflective surfaces in path	y	n
Flammable/combustible materials	y	n

Laser Control Area: Class 3B Class 4 Temporary (maintenance/alignment/other)

Notes:

MPE1	@time 1	@wavelength 1
MPE2	@time 2	@wavelength 2
MPE3	@time 3	@wavelength 3

Nominal Hazard Zone
Direct Beam ____ @MPE ____________________________
Lens on Laser ____ @MPE ____________________________
Diffuse Beam____ @MPE ____________________________

Reflectivity____________________________________ viewing angle ______________________________

Optical Fiber____@MPE____________________________

Eyewear: Required OD1 __________________________________@MPE___________________________
Eyewear: Required OD2 __________________________________@MPE___________________________

Non-Beam Hazards
(When questions below are answered with a 'T', these items will require further investigation.)

Possible Airborne Contaminants

Base materials of targets:

Laser gases:

Dyes/solvents:

Class 4 laser radiation interacts with target materials in the absence of mechanical ventilation T F
The processes requires mode burns on plastic T F
The process requires periodic change of ventilation filters T F
Secondary containment for dye solvent reservoirs is absent T F
Reactive and/or toxic gases are used to generate laser radiations T F
Laser gases are used in a flow through mode T F

Potential for electrical hazards
The equipment is not listed and labeled by an independent testing lab T F

Employees are not authorized and qualified to work on electrical equipment	T	F
There are bare metal terminal plugs near internal power transformers	T	F
There are bare metal connections in access panels	T	F
There is no provision to discharge, short, or ground capacitors	T	F
Grounding sticks and shorting straps are no in good condition	T	F
There is no emergency ‘off’ switch in the laser electrical circuit	T	F

Potential for exposure to plasma or collateral radiation

The laser has high voltage in excess of 5kV	T	F
The laser has a thyratron switch accessible during service	T	F
The process uses a carbon dioxide laser	T	F
The target material is metal	T	F
The discharge tube is accessible and made of quartz	T	F
The output of the flash lamp is accessible	T	F
The laser is operated with interlocks defeated and protective housings removed	T	F

Potential for noise exposure

The laser is a pulsed excimer laser	T	F
The laser is transversely excited atmospheric (TEA) carbon dioxide laser	T	F
The laser is used to dissociate gas molecules	T	F

Notes:

IX. Pre-Usage Check – Sample – most recent version is posted at www.bama.ua.edu/~ehs

Pre-Usage Check

Laser Eyewear and Interlocks

- All laser eyewear must be inspected to ensure there are no scratches, holes, cracks, discoloration or other damages that would decrease their intended safety level.
- All safety interlocks must be inspected to ensure they are functioning properly.

Date	Checked By	Eyewear Ok?	Interlocks Ok?

X. Laser Standard Operating Procedures– Sample– most recent version is posted at www.bama.ua.edu/~ehs

PI:____ Sublicense #:______________________

Location:____ Date:___________________________

Email:____ Phone:__________________________

- **This SOP shall be read and signed annually by all persons who use the lasers covered in this SOP.**
- **This procedure shall be reviewed annually by the PI to ensure it reflects current conditions.**

Section 1 Laser Safety Contacts

Title	Name	Email	Office #	Cell #
UA LSO	Marcy Huey	mhuey@ua.edu	348-5912	561-4789
PI				
Lab Contact				

Medical Emergencies: Call 911 from a landline phone OR 348-5454 from a cell phone.
Notify the LSO (above) of all laser-related injuries and near misses ASAP.
Complete accident documentation – OJI for employees, student accident for anyone else. Forms are available at www.bama.ua.edu/~ehs

Section 2 Laser Inventory

Attach most current laser registry that has been submitted to the LSO. Update as required.

Section 3 Laser Safety Program

See the Laser Safety Manual at www.bama.ua.edu/~ehs, under 'Laser Safety' for UA guidelines on:

- Responsibilities of the laser operator, PI, and Laser Safety Officer
- Laser registration requirements
- Maintenance of training requirements
- Laser purchasing procedures
- Laser disposal procedures
- Signage and labeling requirements
- Eyewear requirements
- Inspection schedules

Section 4 Hazards and Controls

Check if applicable	Hazard	Controls in Place
	High Voltage	
	Capacitors	
	Unenclosed Beam/Access to Beam	
	Fumes/Vapors	
	UV Radiation or Blue Light	
	Compressed Gases	
	Hazardous Chemicals/Waste	
	Housekeeping Procedures	
	Reflective Materials in Beam Path	
	Fire	
	Laser at Eye Level of Person Sitting or Standing	

Attach any other applicable safety plans or SOPs to address the control of lab hazards.

Section 5 Additional Controls

Check if applicable	Hazard	Controls in Place
	Entryway – Door Interlocks or Controls	
	Laser Enclosure Interlocks	
	Laser Housing Interlocks	
	Panic Button/Emergency Stop	
	Beam Stops	
	Master Switch (operated by key or computer codes)	
	Laser Secured to Base	

Attach any other applicable safety plans or SOPs to address the control of lab hazards.

Section 6 Personal Protective Equipment

A. Eyewear

Laser Eyewear

For this laser	Wear this eyewear

ID Number	Type Laser	Wavelength (nm)	XXXXX	Wavelength attenuated (nm)	Optical Density (OD)	Remarks
Example 1151511	CO2	10600	XXXXX XXXXX	10600	At least 3.5	Glendale, white frame
			XXXXX XXXXX			
			XXXXX XXXXX			
			XXXXX XXXXX			
			XXXXX XXXXX			
			XXXXX XXXXX			

B. Skin Protection

_____ Long Sleeves
_____ Gloves
_____ Barrier Cream
_____ Lab Coat
_____ Other: ____

C. Other Protective Equipment Required in This Area – attach if more space is needed.

What (item)	And is available from (where):	Which must be worn (when):

Section 7 Operating Procedures

A. Initial preparation of lab environment for normal operation (key position, warning lights activated, interlocks activated, identification of personnel, other):

B. Target area preparation:

C. Operation procedures are as follows:

D. Shutdown procedures for this laser are as follows:

E. Alignment Procedures:

F. Special Procedures (safety tests, interlock bypass, etc):

G. Emergency Procedures:

Section 8 Operator Reviews

I have read this procedure and I understand its contents. I will abide by these guidelines and by all applicable safety and usage policies.

Name (print)	Signature	Date