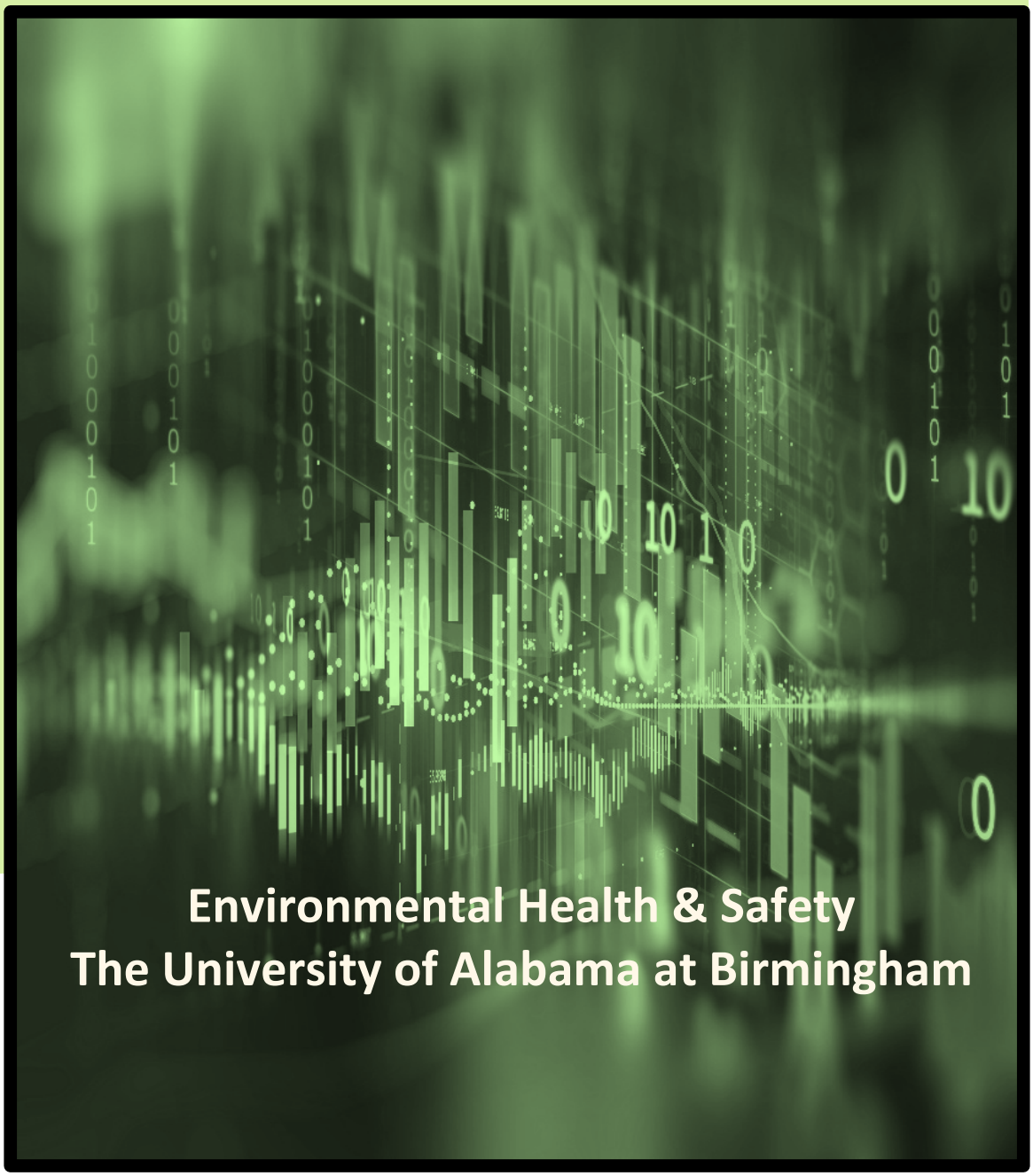
UAB
Laser Safety Manual for UAB Research

2026 Edition



Environmental Health & Safety
The University of Alabama at Birmingham

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Definitions

For the purposes of this manual, the following definitions apply:

ANSI – The American National Standards Institute (ANSI) is a private, non-profit organization that administers and coordinates the U.S. voluntary standards and conformity assessment system. ANSI Z136.1 guides the safe use of lasers and laser systems by defining control measures for each of the seven laser hazard classifications. A practical means for accomplishing this is to (1) classify lasers and laser systems according to their relative hazards and (2) specify appropriate controls for each classification. Once a laser or laser system is properly classified, there should be no need to carry out tedious measurements or calculations to meet the provisions of this standard. However, technical information on measurements, calculations, and biological effects is also provided within the standard and its appendices.

Accessible Exposure Limit (AEL) – The maximum accessible emission level permitted within a particular laser class.

Blink Reflex or Aversion Response – The involuntary closure of the eyelid, movement of the head, or other natural reaction in response to bright visible light. This response generally occurs within 0.25 seconds and provides a measure of protection against accidental exposure to visible laser radiation in certain lower laser classifications, such as Class 2 and Class 2M lasers.

Continuous Wave (CW) – The output of a laser, operated in a continuous rather than a pulsed mode. For purposes of safety evaluation, a laser that is operated with a continuous output for a period of 0.25 seconds or greater is regarded as a CW laser.

Custom Laser Research Laboratory – A laboratory formally approved by the Laser Safety Officer and LSAC to perform custom laser research.

Controlled Area – An area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from laser radiation and related hazards.

Diffuse Reflection – Change of spatial distribution of a beam of radiation when it is reflected in many directions by a surface or by a medium. Diffuse reflections are less hazardous than specular reflections for a given beam.

Energy – The capacity for doing work. Energy content is commonly used to characterize the output from pulsed lasers and is generally expressed in Joules (J).

Export Control – Laws that protect national security interests and foreign policy objectives. These laws govern the transfer/export of sensitive equipment, software, data, technologies, etc. It is important to note that under the context of these laws, an “export” to an individual is considered an export to the individual’s country of citizenship regardless of where the individual is physically located at the time of transfer.

Fail-Safe Interlock – An interlock where the failure of a single mechanical or electrical component of the interlock will cause the system to go into, or remain in a safe mode.

Environmental Health and Safety (EH&S) – The department is charged with implementing and maintaining the laser safety program at the UAB. The Laser Safety Officer is an EH&S staff member and has the authority to enforce laser safety policies to affect the knowledgeable evaluation and control of laser hazards.

Infrared Radiation – Electromagnetic radiation with wavelengths that lie within a range of 700nm to 1mm.

Intrabeam Viewing – The viewing condition whereby the eye is exposed to all of part of a laser beam.

Irradiance (E) – Radiant power incident per unit area upon a surface, expressed in watts per square centimeter W/m² and W/cm.²

Laser – A device that produces an intense, coherent, directional beam of light by stimulated emission of electronic or molecular transitions to lower energy levels. An acronym for Light Amplification by Stimulated Emission of Radiation.

Laser Operator – An individual who has met all applicable laser safety training, medical surveillance, and approval requirements for operating a laser or laser system. The person who sets up the laser and operates the laser console to control the laser parameters under the supervision of the laser user. The operator could be the treating physician, nurse, technician, or anyone who is properly trained in operating the laser equipment.

Laser User: The person employing the laser for its intended purpose within the user's scope of practice, education, and experience.

Maximum Permissible Exposure (MPE) – The level of laser radiation to which a person may be exposed without hazardous effects or adverse biological changes to the eye or skin. MPE is expressed in terms of either radiant exposure (Joules/cm^2) or irradiance (Watts/cm^2). The criteria for MPE are detailed in Section 8 of ANSI Z136.1.

Nominal Hazard Zone (NHZ) – The space within which the level of the direct, reflected, or scattered radiation during normal operation exceeds the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE level.

Optical Density (OD) – Logarithm to the base ten of the reciprocal of the transmittance: OD = log T, where T is the transmittance.

Office of Research Compliance - Responsible for ensuring that research is conducted in full conformity with the provisions of applicable university policies and procedures and all federal, state, and local regulations.

Power – The rate at which energy is emitted, transformed, or received in Watts/second or Joules/second. Also called the radiant power.

Principal Investigator (PI) – The authorized laser user who assumes responsibility for the control and safe use of a laser or laser system.

Pulsed Laser – A laser that delivers its energy in the form of a single pulse or a train of pulses. The duration of a pulse is regarded to be less than 0.25 seconds.

Q-Switched Laser – A laser that emits short (generally ~10–100 nanoseconds), high-power pulses by means of a Q-switch. A Q-switch produces very short, intense laser pulses by enhancing the storage and pumping of electronic energy in and out of the lasing medium, respectively.

Radiant Exposure (H) – Surface density of the radiant energy received. (J/m^2 or J/cm^2).

Radiant Flux (F) – Power emitted, transferred, r received in the form of radiation, expressed in Watts (also called radiant power).

Repetitively Pulsed Laser – A laser with multiple pulses of radiant energy occurring in sequence with a frequency of 1 Hz or higher.

Research Safety and Security – Responsible for the day-to-day operations of the Laser Safety Advisory Committee and for Export Control concerns related to National security and economic interests, etc.

Specular Reflection – A mirror-like reflection typically resulting from a shiny, flat surface. Specular reflections are more hazardous than diffuse reflections for a given beam.

Standard Operating Procedure (SOP) – A set of operating instructions for a particular laser or laser system. The procedure specifies measures that, if followed, will ensure the safe and correct use of the laser or laser system.

Transmittance – The ratio of total transmitted radiant power to the total incident radiant power.

Ultraviolet Radiation (UV) – Electromagnetic radiation with wavelengths smaller than those of visible radiation; for the purpose of laser safety, 180nm to 400nm.

Visible Radiation (Light) – Electromagnetic wavelengths that lie in the range of 400nm to 700nm and can be seen by the human eye.

Watt – The unit of power or radiant flux 1 watt = 1 Joule per second.

Wavelength – The distance between two successive points on a periodic wave that has the same phase.

1.0 UAB Laser Safety Program Administration

The University of Alabama at Birmingham (UAB) Laser Safety Program is designed to provide guidance for the safe use of lasers and to help provide for the safety of all personnel and visitors who may be exposed to the radiation emitted by lasers.

The UAB Laser Safety Program is based on the following ANSI Laser Standards:

- ANSI Z136.1 Safe Use of Laser Standards
- ANSI Z136.2 Safe Use of Optical Fiber Communication Systems Utilizing Laser Diode and LED Sources: Used within the optical fiber industry
- ANSI Z136.3 Safe Use of Lasers in Health Care Facilities: Used within the medical industry
- ANSI Z136.4 Recommended Practice for Laser Safety Measurements for Hazard Evaluation
- ANSI Z136.5 Safe Use of Lasers in Educational Institutions: Used for academic facilities
- ANSI Z136.6 Safe Use of Lasers Outdoors: Used for military and entertainment industries
- ANSI Z136.7 Testing and Labeling of Laser Protective Equipment

These standards apply to all lasers and laser systems, whether purchased, borrowed, fabricated, or brought in for use by others. Many lasers can cause eye injury to anyone who looks directly into the beam. Reflections alone from high-power laser beams can produce permanent eye damage. High-power laser beams can also burn exposed skin. Laser operators must be aware of other potential dangers such as fire, electrical, biological, and chemical hazards.

This manual will provide basic information on laser operation and safety practices, as well as the University policy regarding the safe use of lasers and laser systems.

2.0 Roles and Responsibilities

The Office of the Vice President of Administration, UAB's Environmental Health and Safety (EH&S) department, will hold responsibility for the implementation and maintenance of UAB campus safety programs. The Office of Research Safety and Security (RSS) will assist in ensuring UAB-approved research activities remain compliant with related federal, state, and local laws, rules, regulatory codes and guidelines as described in applicable UAB handbooks, policies, procedures, and safety manuals.

The Executive Directors of UAB Hospital, in conjunction with the Director of Hospital Planning and Management and the Manager of Policies and Standards Resources, are responsible for

ensuring that hospital activities are conducted in conformity with Hospital Standard Policies and Procedures.

2.1 Office of Research

The Office of Research is responsible for:

- Promoting the importance of safety in all research activities
- Endorsing a broad-based research safety program that will protect UAB laboratory personnel, visitors, students, and the community from ill-health effects and injuries associated with the use of lasers and laser systems in UAB facilities.
- Encouraging faculty engagement and service in Research Safety Committees to provide the expertise needed to protect UAB laboratory personnel, visitors, students, and the community from the ill-health effects and injuries associated with the use of lasers and laser systems during UAB-approved activities.
- Supporting the administrative personnel and resources needed to maintain the efficient operation of Research Safety Committees at UAB
- Supporting the administrative personnel and resources needed to maintain appropriate Research Security and Export Controls at UAB.

2.2 Research Safety Committees

The University has established several safety committees tasked with the review of policies or proposals associated with the acquisition, use, handling, and final disposition of potentially hazardous materials. These committees consider available literature, regulations, guidelines, and UAB safety manuals to stipulate the appropriate precautions needed to mitigate risks associated with hazardous material work on campus.

Membership for all committees is composed of UAB researchers and/or faculty, administrators, Environmental Health & Safety (EH&S) staff, and other UAB and/or community stakeholders. Cross-membership with other institutional committees is emphasized to reduce paperwork for PIs and provide coordinated comprehensive review and reporting of research activities (e.g., Institutional Animal Care and Use Committee, Institutional Review Board, Hospital Infection Control).

2.3 The Laser Safety Advisory Committee

The LSAC is responsible for assessing the risk(s) associated with lasers and laser systems that are classified by the ANSI Laser Standard as Class 3B, 3R, and Class 4. LSAC members provide expertise in one or more areas, including laser systems, radiation hazards, hazardous chemicals, public health, law, and UAB policy and procedure. The Vice President for Research or their designee appoints all members of the LSAC, including alternates, the Chair, and Vice-Chair.

Laser Research Investigators must register their equipment with the Laser Safety Officer at EH&S prior to receipt of the laser system. The Laser Safety Program must evaluate the work area, procedures, training, and safety-related equipment prior to the use of the laser.

2.4.1 LSAC Responsibilities

The UAB LSAC's responsibilities include, but are not limited to, the following:

- Endorsement and enforcement of the Laser Safety Program's policies for control and safety of laser hazards within UAB research settings.
- Maintaining an awareness of all applicable laser safety standards
- Making recommendations to improve upon laser safety training programs, materials, and standard operating procedures
- Reviewing the registration and stipulating conditions of approval for research involving Class 3B or 4 lasers
- Facilitating compliance with laser safety standards, including federal and state regulations, and non-regulatory standards, as outlined in UAB's Laser Safety Manual and in the American National Standards Institute (ANSI) Z136 series of laser safety standards.
- Reviewing reports from the Laser Safety Officer (LSO) or other individuals with delegated responsibilities for health and safety practices of the University involving laser radiation sources. Reports may include personnel training records, laser hazard control measures, laser safety inspections, and other matters concerning the use and operational hazards of lasers.
- Assist and investigate alleged infractions of safety rules or improper use of research-related Class 3B or 4 laser equipment brought to its attention.
- Facilitate education for investigators involved in laser research.

2.4 Research Security and Export Control Regulations and Requirements

The University engages in research and academic activities that may be subject to the U.S. export control laws and regulations. While the research being performed at UAB is mostly fundamental research, the controlled export of items, software, technologies, and equipment could impact the conduct of research or teaching. These regulations control what can be shared with foreign nationals, either as tangible items for shipping abroad or as data and information for sharing either in the U.S. or abroad. Listings of export-controlled and embargoed countries and entities are maintained by the Department of State, the Department of Commerce, and the Department of the Treasury. These lists dictate where and to whom transfers may or may not be sent and with whom they may or may not be shared.

To protect national security interests and foreign policy objectives, the U.S. government controls the export of sensitive equipment, software, and technologies. The two sets of export control regulations are the International Traffic in Arms Regulations (ITAR) Munitions List and the Export Administration Regulations (EAR) Commerce Control List (CCL). The ITAR is focused on potential military applications or technologies that are military in nature. The CCL is focused on "Dual Use" technologies having both legitimate commercial purposes and potential military applications. The regulations contain a "catch-all" category (EAR99) that covers any item or technology that is subject to the EAR but that is not found on the CCL. Items categorized as EAR99 may require a license based on embargoes, sanctions, receiving party/end user, or end use.

The UAB Research Safety and Security office monitors embargoed countries and export control laws. Investigators planning to construct or modify a laser, or operate it outside the user manual guidelines, must register and obtain approval beforehand.

Class 3B and Class 4 lasers that are not commercially obtained may be subject to US Export Control requirements and could require a Technology Control Plan (TCP). This affects access to equipment, plans, data, and disposal methods. For questions, contact vpr-researchsecurity@uab.edu.

If any equipment or technology is export-controlled, the Research Safety and Security office will assist in creating or maintaining a TCP to ensure compliance. A TCP outlines procedures to prevent unauthorized exportation of sensitive items. It may apply to equipment, software, data, materials, services, or payments, depending on the specifics involved.

2.5 Office of the Vice President of Administration

The Office of the Vice President of Administration is responsible for:

- Promoting the importance of safety in all activities
- Endorsing a broad-based research safety program that will protect UAB laboratory personnel, visitors, students, and the community from ill-health effects and injuries associated with the use of laser systems in UAB facilities.
- Providing administrative, financial, and operational support to EH&S to ensure the day-to-day operations at UAB remain safe and according to local, state, and federal regulations.
- Ensuring EH&S staff numbers and expertise are sufficient to maintain safe and compliant operations at UAB.

2.6 Environmental Health and Safety (EH&S)

Develops, implements, and maintains UAB safety policies and programs, including the Laser Safety Program. The EH&S Department facilitates the day-to-day operation of the individual safety programs including but not limited to:

- Asbestos Abatement
- Biosafety
- Campus Safety
- Chemical Safety
- Construction Safety
- Controlled Substances
- Environmental Management
- Hospital and Clinic Safety
- Employee Health
- Radiological Health and Safety
- Research Safety

2.7 The Laser Safety Program

The Laser Safety Program, supplies the following services under the Laser Safety Program:

- Maintains the operation of a comprehensive laser safety program to ensure research activities on campus involving lasers meet or exceed regulatory requirements and best practices
- Provides advice to the faculty and staff on laser safety matters.
- Reviews project registrations.
- Provides laser-specific risk assessments and recommendations to the LSAC.
- Provides guidance on practices and procedures for the use of lasers.
- Provides consultation on the purchase of lasers.
- Review plans for new labs and renovations.
- Provides laser safety education and training aids and develops educational and training programs
- Performs periodic audits of facilities with lasers.
- Assists PIs and staff in performing laboratory and project specific risk assessments.
- May facilitate collaboration with other EH&S staff to further promote a university-wide safety environment.

2.8 Laser Safety Officer(s)

The Laser Safety Officer(s) (LSO) is responsible for overseeing the Laser Safety Program and ensuring compliance with the policies, guidelines, and regulations established by University Administration, the Laser Safety Advisory Committee (LSAC), and other regulatory and granting agencies. The specific responsibilities of the LSO include, but are not limited to:

- Maintaining an inventory of all Class 3B and Class 4 lasers and verifying their classifications if necessary.
- Reviewing and approving registrations of laser systems.
- Submitting registrations of laser systems that fall outside the normal use of commercial laser systems to the LSAC for review.
- Reviewing standard operating procedures, alignment procedures, and other control measures.
- Periodically inspecting Class 3B and Class 4 lasers and laser programs to assess compliance with safety requirements. Overseeing the termination or decommissioning of Class 3B and/or Class 4 lasers.
- Assisting in the evaluation and control of hazards.
- Maintaining records of inspections for Class 3B and Class 4 lasers.
- Suspending, restricting, or terminating the operation of a laser or laser system that lacks proper hazard controls.
- Participating in investigations of accidents involving lasers.

2.9 Dean/ Department Chairs/ Directors

Deans, Department Chairs, and Directors are responsible for:

- Taking appropriate measures to ensure that university/department/division activities comply with all relevant safety policies, laws, regulations, and guidelines

- Ensuring that students and staff have had instruction on laser safety and security procedures appropriate for their assignments
- Ensuring that emergency response plans are in place for their areas and facilities of responsibility

2.10 Principal Investigator

The Principal Investigator (PI) is directly and primarily responsible for full compliance with the policies and procedures described in the Laser Safety Manual. Responsibilities include, but are not limited to:

- Notifying the UAB EH&S LSO of the intent to procure, produce, or construct a laser and providing required information for registration and safety reviews for Class 3B and Class 4 lasers
- Notifying UAB EH&S LSO prior to receiving, constructing, or modifying a laser, transferring a laser to another user, sending a laser to another site off campus, or disposing of a class 3 or 4 laser or laser system
- Ensure that lasers are adequately inventoried as required
- Providing laser-specific training for all operators
- Ensuring each assigned laser is operated safely and in accordance with applicable requirements.
- Providing medical surveillance for laser operators and ancillary personnel as described in Section 12, as applicable.
- Ensuring that each laser is stored securely and safely when not in use so that it is not usable by unauthorized personnel or under unauthorized conditions.
- Maintaining a written Standard Operating Procedure (SOP) for all registered lasers and ensuring laser use is commensurate with the requirements of the SOP.
- Training and supervising staff and students in safe practices and incident responses
- Promptly reporting any known or suspected accidents to the UAB LSOs.
- Ensuring that a hazard assessment for personal protective equipment (PPE) and specific PPE training is provided for all laser users for whom PPE will be required.
  Performing an initial ITAR and/or CCL review to determine any export control requirements and contacting the Research Safety and Security office to develop required Technology Control Plans

2.11 Laser Operator

The Laser Operator is responsible for:

- Completing all applicable requirements including training and medical surveillance, as applicable, before operating a laser.
- Operating lasers safely and in a manner consistent with safe laser practices, requirements, and approved SOPs. This includes the use of personal protective equipment and maintaining a safe environment/area during the operation of a laser.

2.12 Laboratory Staff

Laboratory staff members (faculty members, students, interns, visiting scholars, or volunteers) are the most critical element in maintaining a safe working environment. Each person must consider their own safety and that of their co-workers. The laboratory staff's responsibilities include, but are not limited to:

- Attentively follow lab-specific laser safety and security practices and approved SOPs
- Understand all protocols used in the laboratory
- Know all emergency procedures established by the principal investigator
- Complete training and ensure documentation of that training
- Follow all appropriate laboratory practices as outlined in the Laser Safety Manual and all additional practices outlined in the protocol and lab-specific safety plan.
- Report to the PI, LD, or lab supervisor all problems, violations in procedure, or accidents as they occur
- Report to the LSO any violations in laser safety policy, practices, or procedures. No adverse action shall be taken against any person for reporting real or perceived problems or violations of procedures.

2.13 Students and Visitors

Students and visitors must have:

- Site-specific training for students
- Visitors who work with lasers shall complete training appropriate to their assigned activities. When required, visitors may be provided temporary University access credentials to complete applicable online training and shall receive site-specific training before performing laser-related activities.
- Non-laser workers who work in laser areas (while the laser is inactive) do not require training.
- Visitors who are also foreign nationals must be pre-screened and cleared by the Office of Global Affairs and the Research Safety and Security Office.
- Guests who are also foreign nationals must be pre-screened and cleared by the Research Safety and Security Office.

3.0 Principles of Laser Safety

3.1 Basic Operation of a Laser

The term LASER is an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation. Lasers operate by the excitation of a medium through the introduction of energy. As electrons in this medium return to their ground state, they stimulate the release of light of a certain wavelength. This chain reaction continues until a certain number of photons reach a totally reflective mirror (see Figure 3-1). This reverses the direction of the beam, and the beam continues to intensify until it passes through a partially transmissive mirror, constituting the laser beam. Laser radiation will continue to be produced as long as energy is applied to the lasing medium. Laser radiation differs from normal light in that it is coherent, electromagnetic radiation characterized by one or

more specific wavelengths. The wavelengths are determined primarily by the composition of the lasing medium.

Mediums can be solids, liquids, or gases. Laser radiation may be emitted in the visible portion of the electromagnetic spectrum (wavelengths of 400 – 700 nm) or the invisible infrared (700 – $3x10^6$ nm) and ultraviolet (180 – 400 nm) regions.

Laser radiation transmits energy that can be transmitted, absorbed, or reflected after striking a specific material. If a material transmits a laser beam, it is said to be transparent. If the beam is not transmitted, the material is said to be opaque, and the incident radiation is absorbed or reflected.

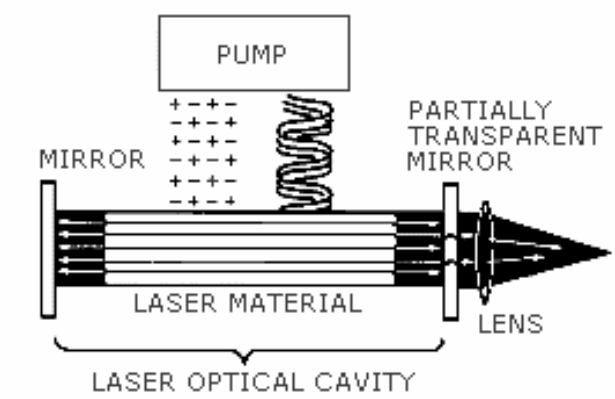


Figure 3 - 1 Simplified Diagram of a Laser

Parts: partially transmissive mirror, high reflectance mirror, laser material = medium, excitation mechanism (power) and laser beam

3.2 Absorption

Absorbed laser energy appears in the target material as heat. Absorption and transmission are functions of the chemical and physical characteristics of the target material and the wavelength of the incident radiation. At visible wavelengths, laser radiation impinging upon the eye is focused on the retina and, if sufficient energy is absorbed, can cause tissue destruction. At longer and shorter wavelengths, such as the far infrared and the ultraviolet, radiation striking the eye is absorbed in the cornea and the lens rather than being focused on the retina. Although these structures are less easily damaged than the retina, excessive energy absorption can cause cell damage and impairment of vision.

3.3 Reflection

Reflection is a function of the physical character of the surface of the target material. A smooth polished surface is generally a good, or specular, reflector. A rough, uneven surface usually is a poor reflector producing a diffuse reflection. A reflector such as a flat mirror changes the direction of an incident beam with little or no absorption. A curved mirror or surface will change

the divergence angle of the impinging laser beam as well as its direction. For a diffuse reflection, the reflected energy is scattered in all directions thereby reducing the energy or power density. Generally, diffusely reflecting surfaces are favored when designing laser experiments since their use reduces the likelihood of a specular reflection and hence enhances the safety of the experiment.

3.4 Transmission

Most visible light laser beams, such as those generated by HeNe, Nd:YAG, and Krypton lasers are transmitted through clear objects such as a room window or water. Use of these types of lasers often requires the use of window coverings that absorb the beam and prevents the laser hazard from existing outside of the immediate work area. It is important to note that these coverings will need to be fire resistant for use with higher powered lasers. Some lasers, such as CO2, are not transmitted through glass, and therefore do not require the use of windows coverings.

3.5 Pulsed vs. Continuous Wave

The output of a laser can be pulsed or continuous depending on the type of excitation strategy used to excite the gain medium. Pulsed lasers typically have pulse durations in the nanosecond (ns) range, although some of them can go down as far as femtoseconds (fs). While the power output of the laser may be small, the short pulse duration can offer a tremendously concentrated delivery of power and can cause significant damage to the eyes if proper care is not taken. Continuous wave lasers deliver prolonged concentrated power and will cause severe damage to the eyes.

4.0 Laser Classification

To provide a basis for laser safety requirements, all lasers and laser systems in the United States are classified according to the ANSI Z136.1 Standard and the Federal Laser Products Performance Standard (FLPPS). The manufacturer is responsible for determining the laser classification. The builder must classify custom built and/or modified lasers. The UAB LSO can assist with the classification of such lasers.

The following sections describe the classification for continuous wave lasers. The same hazard levels also apply to pulsed laser with pulse duration of less than 0.25 seconds, but classification is more complex. See ANSI Z136.1 for details of the classification. Copies of the ANSI Z136.1 can be purchased from the Laser Institute of America and are also available for review at the UAB EH&S Radiation Safety Office (CH19, Room #445).

4.1 Embedded Lasers

Embedded lasers are found in laser products with lower class ratings. When such a laser system is used as intended (embedded), the lower laser class applies. When such a system is opened (e.g., for service or alignment) and the embedded laser beam is accessible, the requirements of the higher class of the embedded laser shall be implemented. Examples include some laser

pointers, CD players, and laser welders that may have Class 3b or Class 4 lasers in their protective and interlocked housings.

4.2 Class 1 Lasers

Class 1 lasers are low powered and do not emit hazardous radiation under normal operating conditions because they are completely enclosed. **These lasers are exempt from any control measures and include equipment such as laser printers and laser disc players as examples.** These lasers may present hazards if the housing is breached for maintenance (see Embedded Lasers section 4.6). Use of these lasers do not require control measures, specified training, an LSO or engineering controls.

Class 1M Lasers

Considered to be incapable of producing hazardous exposure conditions during normal operation unless the beam is viewed with collecting optics (e.g., telescope) and is **exempt from any control measures other than to prevent potentially hazardous optically aided viewing.** The use of M in the laser classification indicates there is Magnified Class 1 risk. Use of these lasers do not require control measures, but may require specified training, an LSO and engineering controls depending on its application.

4.3 Class 2 Lasers

Class 2 lasers are visible continuous wave (CW) and repetitive pulse lasers or laser systems which can emit accessible radiant energy exceeding the appropriate Class 1 AEL but less than 1 mW. The human eye blink index, which occurs within 0.25 seconds, provides adequate protection for Class 2 lasers. However, it is possible to overcome the blink response and stare into a Class 2 laser long enough to damage the eye. Class 2 lasers are typically exempt from control measures other than having a protective housing and label. Equipment such as visible continuous wave Helium-Neon lasers and some laser pointers are examples of Class 2 lasers. **Use of these lasers does not require control measures, specified training, an LSO and engineering controls.**

Class 2M Lasers

Emits in the visible portion of the spectrum (400 nm to 700 nm) and eye protection is normally afforded by the aversion response for unaided viewing. However, Class 2M is potentially hazardous if viewed with collecting optics (e.g., telescope). The use of M in the laser classification indicates there is Magnified Class 2 risk. **Control Measures are required for this class of lasers, but training, an LSO and engineering controls may be appropriate depending on the application.**

4.4 Class 3R Lasers

Class 3R lasers are systems with power levels of 1 to 5 mW that normally would not produce a hazard if viewed for only momentary periods with an unprotected eye. These lasers can pose severe eye hazards when viewed through optical instruments such as microscopes, binoculars,

or other collecting optics. Examples include visible continuous wave Helium-Neon lasers and some solid-state laser pointers.

Class 3R lasers must be labeled. The warning label shall be placed on or near the laser in a conspicuous location and caution users to avoid staring into the beam or directing the beam toward the eye of individuals. It is highly recommended that no laser pointers over Class 3R be used at UAB. The use of R in the laser classification indicates there is a Reduced Risk Class 3 risk. Use of these lasers does not require control measures, specified training, an LSO, or engineering controls. An evaluation of the application of this laser is encouraged.

4.5 Class 3B Lasers

Class 3B lasers are systems with power levels of 5 to 500 mW for continuous wave lasers or less than 10 J/cm^2 for a 0.25-second pulsed laser. These lasers will produce an eye hazard if viewed directly. This includes intrabeam viewing or specular reflections. Higher power lasers in this class will also produce hazardous diffuse reflections. Use of these lasers requires control measures, specified training, and an LSO or engineering controls.

4.6 Class 4 Lasers

Class 4 lasers are systems with power levels greater than 500 mW for continuous wave lasers or greater than 10 J/cm^2 for a 0.25-second pulsed laser. These lasers will produce eye, skin, and fire hazards. This includes intrabeam viewing and specular or diffuse reflections. Use of these lasers requires control measures, specified training, and an LSO or engineering controls.

These classifications help ensure that lasers are used safely in various applications. The use of B M and R in the classifications help define the potential hazards and necessary precautions. The letter M is used to indicate “Magnified” and indicates that a laser can be hazardous when viewed with optical instruments that can focus the beam and increase the risk of eye injury. The letter R is used to indicate “Reduced Risk”. These lasers are designed to be safer for use in some applications.

Table 4 - 1 Requirements by Laser Class

Class	Control Measures	Training	LSO	Engineering Controls
1	Not Required	Not Required	Not Required	Not Required
1M	Required	Application Dependent (2)	Application Dependent (2)	Application Dependent (2)
2	Not Required (1)	Not Required (1)	Not Required (1)	Not Required (1)
2M	Required	Application Dependent (2)	Application Dependent (2)	Application Dependent (2)
3R	Not Required (1)	Not Required (1)	Not Required (1)	Not Required (1)
3B	Required	Required	Required	Required

4	Required	Required	Required	Required

(1) Not required except for the condition of the interventional intra-beam exposure application
(2) Certain uses for Class 1M or 2M lasers or laser systems that exceed Class 1 or Class 2 because they do not satisfy Measurement Condition 1 may require hazard evaluation and/or manufacturer information (See Section 4.1.1.3 from ANSI Z136.1)

5.0 Laser Safety Hazards

5.1 Hazard Evaluation

The total laser hazard evaluation is influenced by several aspects of the laser or laser system that also influence the application of control measures:

- The laser or laser system's capability of injuring personnel or interfering with task performance.
- The environment in which the laser is used, including access to the beam path (considering enclosures, baffle, beam, etc.)
- The personnel who may use or be exposed to laser radiation

The laser hazard class is based on the laser's capability of injuring personnel. All lasers or lasers systems shall be classified according to their accessible radiation during operation. The total hazard evaluation procedure shall consider all aspects, although only aspect I. influences the control measures that are applicable. Classification shall be based on the maximum output power or radiation energy available for the intended use. Only personnel trained in laser safety, optical engineering, physics, or a related field are suited to perform the detailed hazard evaluation or the classification determinations of a laser.

5.2 Laser Beam Hazards

The nature of laser beam damage and the threshold levels at which each type of injury may occur depends on several parameters. These include wavelength of light, energy of the beam, divergence, and exposure duration. For pulsed lasers, parameters also include the pulse length, pulse repetition frequency, and pulse train characteristics. The ANSI Z136.1 Standard establishes maximum permissible exposure (MPE) limits for laser radiation. MPEs need to be determined for each specific hazard so that a nominal hazard zone (NHZ) can be established. The NHZ is the area around a laser in which the applicable MPE is exceeded. When an MPE is exceeded, damage can occur to the skin, retina, lens, cornea, and conjunctiva tissue surrounding the eye. For lasers over 500 mW, the beam can ignite flammable materials and initiate a fire.

5.3 Damage to the Eye by Laser Beam

Thermal burn, acoustic damage, and photochemical damage to the retina may occur from laser light in the near ultraviolet (UV), visible, and near infrared (IR) regions (from below 400 nm to 1400 nm). Damage occurs as the laser light enters the eye and is focused on the retina. Normal focusing of the eye amplifies the irradiance by approximately 100,000; thus, a beam of 1 mW/cm^2 results in an exposure of 100 mW/cm^2 to the retina. Energy from the laser beam is absorbed by the tissue in the form of heat which can cause localized intense heating of sensitive tissues. The

most likely effect of excess exposure to the retina is a thermal burn that destroys retinal tissue. Since retinal tissue does not regenerate, the damage is permanent. This may result in the loss of sight in the damaged area.

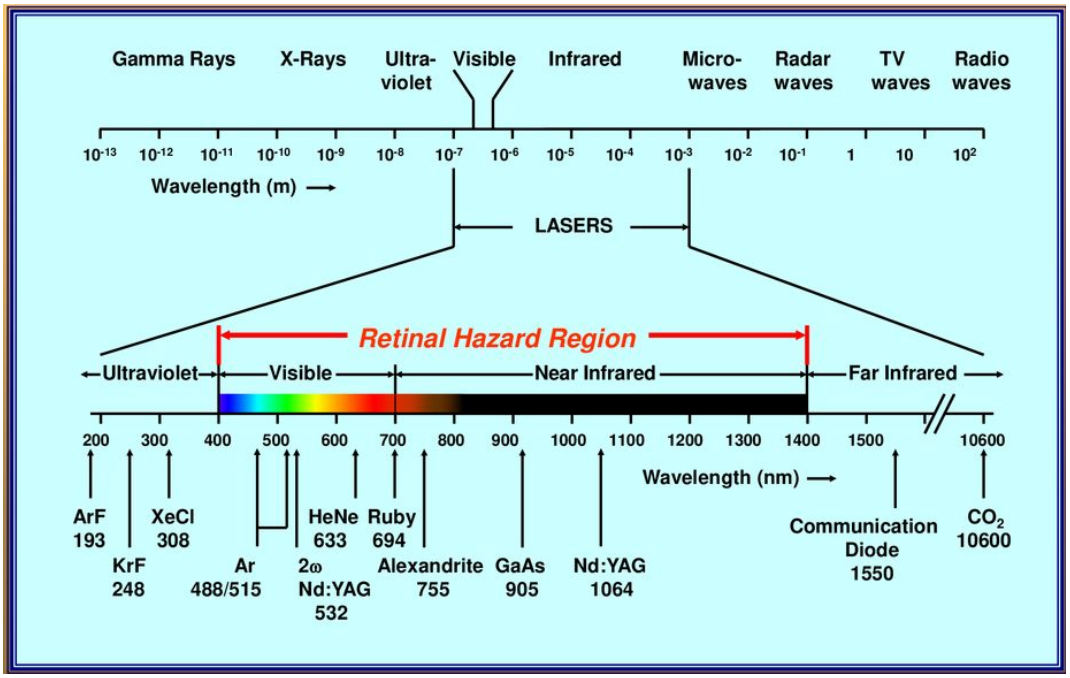


Figure 5 - 1. Retinal Hazard Region (UW-Madison.)

5.3.1 Effects on Eye Structures

Different structures of the eye can be damaged from laser light depending on the wavelength.

- Retinal burns causing scotomas (blind spots in the fovea or other retinal area) resulting in partial or complete blindness is possible in the visible (400 – 700 nm) and near-infrared (700 – 1400 nm) range.
    - At these wavelengths, the eye will focus the beam or a specular reflection on a tiny spot on the retina. Thus the wavelength range is known as the retinal hazard region (**Table 5-1**).
    - This focusing increases the irradiance of the beam by a factor of about 100,000.
- Laser emissions in the ultraviolet (290 – 400 nm) and far-infrared (1400 – 10600 nm) regions are primarily absorbed by and caused damage to the cornea.
- In the near-ultraviolet range (315 – 400 nm), some of the radiation reaches the lens of the eye.
- Photo-acoustic retinal damage may be associated with an audible “pop” at the time of exposure. Visual disorientation due to retinal damage may not be apparent to the operator until considerable thermal damage has occurred.

5.3.2 Symptoms of an Eye Injury

- Exposure to an invisible carbon dioxide laser beam (10,600 nm) can be detected by a burning pain at the site of exposure on the cornea or sclera.
- Exposure to a visible laser beam can be detected by a bright color flash of the emitted wavelength and an after-image of its complementary color (e.g., a green 532 nm laser light would produce a green flash followed by a red after-image).
- The site of damage depends on the wavelength of the incident or reflected laser beam.
    - When the retina is affected, there may be a difficulty in detecting blue or green colors secondary to cone damage and pigmentation of the retina may be detected.
    - Exposure to the Q-switched Nd:YAG laser beam (1064 nm) is especially hazardous and may initially go undetected because the beam is invisible, and the retina lacks pain sensory nerves.

5.4 Ways in Which a Laser Beam Can Be Accidentally Viewed

- Intrabeam viewing of direct (primary) beam (this type of viewing is the most hazardous)
- Intrabeam viewing of a specularly reflected (secondary) beam from a *flat* surface reflector (specular reflections are most hazardous when the reflecting surface is flat).
- Intrabeam viewing of a specularly reflected (secondary) beam from a *curved* surface reflector is less hazardous than that of a flat source reflection.
- Intrabeam viewing of the direct beam and the specularly reflected beam are most hazardous when the secondary reflector is a flat and polished surface.
- Secondary reflections from rough, uneven surfaces produce more diffuse reflections and are usually less hazardous. Extended source viewing of normally diffuse reflections is not normally hazardous except for very high-power lasers such as a Class 4 laser.
- Extra care should be taken with infrared lasers since diffuse reflectors in the visible spectrum may reflect IR radiation differently and produce greater exposures than anticipated. Diffuse reflections are not normally hazardous except with very high-power Class 4 lasers.

5.5 Damage to the Skin by Laser Beam

Skin damage can occur from exposure to infrared or ultraviolet light. Exposure of the skin to high power laser beams (1 or more watts) can cause burns. Risks from infrared lasers include thermal burns and blistering or charring of the skin are directly related to the intensity of the radiation.

Risks from UV lasers include sunburn, skin cancer, skin aging, and photosensitization:

- UV laser wavelengths may also lead to skin carcinogenesis.
- In the 230 – 380 nm range of UV light, erythema (sunburn), skin cancer, or accelerated skin aging are possible.
- The most damaging region of UV is 280 – 315 nm, also known as UV-B.

At power levels under 5-watts, the heat from the laser beam will cause a flinch reaction before any severe damage occurs. The sensation is similar to touching any hot object. You tend to pull your hand away rapidly or drop it before any major damage occurs.

With higher-power lasers, a burn can occur even though the flinch reaction may rapidly pull the affected skin out of the beam. These burns can be quite painful as the affected skin can be cooked and form a hard lesion that takes considerable time to heal.

5.6 Laser Generated Airborne Contaminants (LGAC)

LGAC are air contaminants associated with the use of Class 3B and Class 4 lasers. LGAC results from the interaction of the laser beam with target or other materials and can include metallic fumes and dust, chemical fumes, and aerosols containing biological contaminants. LGACs are generally only formed with target irradiance reaches 10^7 W/cm^2. Local area ventilation must be adequate to keep airborne contaminant levels below worker exposure limits.

5.7 Electricity

Many lasers contain high-voltage components that can present a potentially lethal hazard. The most lethal hazard associated with lasers is the high-voltage electrical system required to power the systems. Several deaths have occurred when commonly accepted safety practices were not followed by persons working with high-voltage sections of laser systems. Proper lockout/tagout procedures must be followed when working on high-voltage components. The following is a list of recommended electrical safety practices:

- Do not wear rings, watches, or other metallic apparel when working with electrical equipment.
- When working with high voltages, regard all floors as both conductive and grounded.
- Do not handle electrical equipment when hands or feet are wet or when standing on a wet floor.
- Prior to working with electrical equipment, de-energize the power source. Lock out and tag out the disconnect switch.
- Check that each capacitor is discharged and grounded prior to working in the area of the capacitors.
- Use shock-preventing shields, power supply enclosures, and shielded leads in all experimental or temporary high-voltage circuits.

Allow the fire department or proper authority to determine the type of fire suppression system required for the high-voltage areas. Water may not be recommended. Perhaps sapphire or other.

5.8 Flammables

Many Class 4 lasers are capable of igniting combustible materials and represent a fire hazard. Depending on the construction material, beam enclosures, barriers, stops, and wiring are all potentially flammable if exposed to high beam irradiance for more than a few seconds. Care should be taken when choosing beam stops, shielding material, and flammable material storage

sites. Gas cabinets may be required for some systems (determined by the LSO on a case-by-case basis).

5.8.1 Flammable Liquids

All flammable liquids in or out of solution with a flash point of greater than 140C must be stored in a flammable-proof refrigerator or freezer. These must never be stored in a common household refrigerator or in an ultra-lower freezer (40C or less). Otherwise, all flammable liquids must be used, handled, stored, and disposed of in accordance with all applicable rules and regulations.

5.9 Explosion Hazards

High-pressure arc lamps, filament lamps, and capacitors may explode violently if they fail during operation. These components are to be enclosed in a housing that will withstand the maximum explosive force that may be produced. Laser targets and some optical components also may shatter if heat cannot be dissipated quickly enough. Consequently, care must be taken to provide adequate mechanical shielding when exposing brittle materials to high-intensity lasers.

5.10 Hazardous Materials

Laser laboratories contain many of the same hazards found in chemical laboratories and therefore the same precautions should be taken (see the UAB EH&S Chemical Hygiene Plan). For example, most laser dyes are considered to be hazardous materials and must be handled accordingly. These dyes used as lasing media are either toxic, carcinogenic, corrosive, flammable, all the above, or a combination.

A safety data sheet (SDS) must accompany all hazardous chemicals. The SDS will supply appropriate information pertaining to the toxicity, PPE, and proper storage of the hazardous materials.

5.10.1 Gases

Gases might be exhausted by lasers or produced by targets. Proper ventilation is required to reduce exposure levels of the gas products below acceptable limits. Gas cabinets may be required for some systems at the discretion of the LSO. Consult with UAB EH&S before purchasing lasers with toxic or pyrophoric gases.

5.10.2 Cryogenic Fluids

Cryogenic fluids are used in the cooling systems of certain lasers. As these materials evaporate, they replace the oxygen in the air. Adequate ventilation must be ensured. Cryogenic fluids are potentially explosive when ice collects in valves or connectors that are not specifically designed for use with cryogenic fluids. Condensation of oxygen in liquid nitrogen presents a serious explosion hazard if the liquid oxygen comes in contact with any organic materials. Although the quantities of the liquid nitrogen used are small, protective clothing and face shields must be used to prevent freeze burns to the skin and eyes.

5.10.3 Compressed Gases

Compressed gases used in lasers also present potential health and safety hazards. Problems may arise when working with unsecured cylinders, cylinders of hazardous materials not maintained in ventilated enclosures, and when gases of various categories (toxins, corrosives, flammables, and oxidizers) are stored together.

5.11 Collateral Radiation

Radiation other than that associated with the primary laser beam is called collateral radiation. Examples include X-rays, plasma, radio frequency emissions, and ionizing radiation.

5.11.1 X-rays

X-rays could be produced from two main sources in a laser laboratory:

- Electric-discharge lasers
- High-voltage vacuum tubes of laser power supplies, such as rectifiers, thyratrons, and crowbars

Any power supplies that require more than 15 kilovolts (kV) may produce enough X-rays to cause a health hazard. Interaction between X-rays and human tissue may cause a serious disease such as leukemia or other cancers, or permanent genetic effects that may show up in future generations. Any use or production of X-rays must be reviewed by the Office of Radiation Safety prior to the procurement and/or use of such equipment.

5.11.2 UV and Visible

UV and visible radiation may be generated by laser discharge tubes and pump lamps. The levels produced may exceed the MPE limit and thus cause skin and eye damage.

5.11.3 Plasma Emissions

Interactions between very high-power laser beams and target materials may, in some instances, produce plasmas. The plasma generated may contain hazardous UV emissions.

5.11.4 Radio Frequency (RF)

Q switches and plasma tubes are RF-excited components. Unshielded components may generate RF fields that exceed federal guidelines.

6.0 Laser Safety Practices

The following measures are recommended as a guide for safe laser use. Some additional measures may be required for a specific laser. See ANSI Z136.1.4 for additional details or contact the UAB LSO for additional information.

6.1 Work Area Safety Practices

- The laser should be isolated from public areas.
- Doors should be closed or locked to keep out unauthorized personnel.

- The proper warning signs should be posted.
- Illumination in the area should be as bright as practical in order to constrict the pupils of users.
- The laser should be set up so that the beam path is above or below the normal eye level of a seated or standing person (below 4.5 feet or above 6.5 feet).
- Where practical, the laser system or beam should be enclosed to prevent accidental exposure to the beam.
- The potential for specular reflections should be minimized by shields and by the removal of all unnecessary shiny surfaces.
- Windows to hallways or other outside areas must be covered with adequate shades or covers when necessary to keep the nominal hazard zone within the room.
- The main beams and reflected beams should be terminated or dumped. This is required for any accessible laser for which the MPE could be exceeded.
- Electrical installation must meet electrical safety standards. The active laser never should be left unattended unless it is a part of the controlled environment.
- Warning devices must be installed for lasers with invisible beams to warn of unintended operation.
- The laser work area should be maintained as free of clutter as possible to minimize the chance of accidentally igniting something or causing an unintended reflection.
- Ensure the laser(s) is secured to the work surface to prevent a stray beam.

6.2 Laser Usage Safety Practices

- Avoid looking into the primary beam at all times.
- Do not aim at the laser with the eye. Direct reflections could cause retinal damage.
- Avoid looking at the pump source.
- Clear all personnel from the anticipated path of the beam.
- Before operating the laser, warn all personnel and visitors of the potential hazard and ensure all safety measures are satisfied.
- Be extremely cautious around lasers that operate at frequencies not visible to the human eye.
- Do not wear bright, reflective jewelry or other similar objects, in particular on hands and wrists.
- Use proper eye protection when working with a Class 3B or Class 4 laser.
    - Remember that safety glasses provide no protection unless they are worn.
    - Safety glass lenses may shatter or melt when the lens specifications are exceeded.
    - Scratched or pitted lenses may offer no protection. Frequent inspection of protective eyewear is required.
    - Eye protection is specific to the type of laser and may not protect at different frequencies or powers.

7.0 General Requirements for Lasers

Class 1 and Class 2 lasers may be used for the intended purposes defined by their manufacturer without restrictions. Any direct eye exposure to these types of lasers should be avoided.

Class 1M and Class 2M require user training, restricted viewing, or engineering controls to prevent harmful, optically-aided viewing.

Class 3R, Class 3B, and Class 4 lasers shall carry a warning label containing the laser classification, type, and any other warnings required by ANSI Z136.1, consistent with the classification assigned by the manufacturer. These requirements also apply to non-commercially built lasers that are used on UAB's campus.

Each Class 3B and Class 4 laser must be assigned to a Principal Investigator (PI) who is responsible for the safe storage and use of that laser.

Class 3B and Class 4 lasers must be registered with the UAB Laser Safety Officer (LSO) and the UAB EH&S office. The EH&S office must be consulted whenever a laser is acquired, constructed, modified, reassigned to a new PI, transferred off campus, or disposed of. Please contact the UAB LSO at (205)934-2487 prior to initiating any of these ownership activities.

All laser operators must complete training specific to the type of laser they operate. This training requirement will be reviewed during LSO safety inspections. All lasers must be operated according to the applicable ANSI Z136.1 safety standards and in a manner consistent with safe laser practices. Laser safety SOPs are required and should be posted for Class 3B and Class 4 lasers.

Each Class 3B and Class 4 laser shall be used in a controlled area that restricts access to unauthorized personnel. The controlled laser areas must be identified with appropriate warning signs.

Each operator of a Class 3B or Class 4 laser must wear PPE (e.g., eyewear and clothing) as appropriate when inside the controlled laser area.

The UAB LSO will perform periodic unannounced inspections to assess the efficacy of the laser safety program. Any required corrective action resulting from the inspection will be communicated to the PI in a timely manner.

Operating a laser in a manner other than specific in the User Manual supplied by the manufacturer requires registration with the LSO and pre-approval by the LSAC.

All research involving these lasers or laser systems conducted at UAB by its employees and/or involving use of its facilities or resources must be reviewed and approved by the LSAC before initiation. Investigators who wish to perform activities under the purview of the LSAC must

register their project with Research Safety and Security prior to receipt, construction, and/or modification of the laser system. The work area, procedures, training, and safety-related equipment must be reviewed and approved prior to the use of the laser.

Class 3B and Class 4 lasers that are not commercially obtained and operated per manufacturer guidelines are likely to be governed by US Export Control requirements and MAY require a Technology Control Plan. These requirements impact who can have access to the equipment, plans, data, software, etc., during development, during use, while stored, and how the equipment is disposed. Contact vpr-researchsecurity@uab.edu with any questions.

8.0 Laser Controls

8.1 Engineering Controls

A protective housing that can block the emitted radiation shall be provided for all classes of lasers or laser systems, except as noted in ANSI Z136.1 Section 4.3.1.1. If a user-created enclosure does not meet the requirements of a protective housing (e.g., a non-interlocked cover), it shall be considered only as a barrier or curtain, and therefore other controls will be required. The protective housing may require interlocks and labels. Special safety procedures may be required when protective housings are removed (e.g., for beam alignment). The use of appropriate protective eyewear is recommended at such times.

8.1.1 Controls for Standard Commercial and Custom-Built Lasers

All Class 3B and Class 4 lasers should be engineered and equipped with safety features that inhibit direct injury. Commercially purchase lasers may be designed with these features already incorporated. Custom-Built lasers should also be designed to incorporate the same safety features:

- Protective housing interlock system that prevents emission of laser radiation when the housing is open.
- Viewing windows in the protective housing must be equipped with optical filters and attenuators that keep escaping light below the MPE limit.
- Optical devices for viewing the laser system must be equipped with filters, attenuators, and interlocks to keep exposures below the MPE for all conditions of operation and maintenance.
- Class 4 lasers shall also be equipped with a removable master key switch if provided by the manufacturer. The laser shall not be operable when the key is removed.
- The lasers should be equipped with electrical connections that allow for an access control system and remote shut-off devices. When the terminals are open-circuited, the laser must not emit any radiation in excess of the MPE.
- Class 4 laser systems must be equipped with an integral and permanently attached beam stop or attenuator capable of preventing the emission of laser radiation in excess of the MPE limit when the beam is not required.

The construction of a Class 3B or Class 4 laser requires registration with the LSO and pre-approval by the LSAC.

8.2 Laser Control Areas

8.2.1 Class 3B Laser Control Areas

The following items are required for Class 3B laser-controlled areas:

- Appropriate warning sign(s) is posted at access point(s) to the area
- Lasers are operated by qualified and authorized personnel
- Operators work under the direct supervision of an individual knowledgeable in laser safety
- Potentially hazardous beams terminate in a beam stop of an appropriate material
- Only diffused reflective materials are in or near the beam path, where feasible
- Personnel within the controlled area are provided with the appropriate eye protection if there is any possibility of viewing the direct or reflected beam(s)
- Whenever feasible, the laser is secured in such a way that the beam path is above or below the eye level of a person in any standing or seated position, except as required for research or medical use.
- All windows, doorways, open portals, etc. of an indoor facility must be either covered or restricted in such a manner as to reduce the transmitted laser radiation to levels at or below the appropriate ocular MPE.
- Storage or disabling (e.g., removal of the master key) of the laser system is required when not in use to prevent unauthorized use.

8.2.2 Class 4 Laser Control Areas

In addition to the items listed for Class 3B lasers above, the following additional measures are required for Class 4 lasers:

- Personnel who enter a Class 4 laser-controlled area during laser operation must be trained, provided with appropriate PPE, and follow all applicable administration and procedural controls.
- Entryway safety controls shall be designed to allow:
    - Rapid egress by laser personnel at all times
    - Admittance to the laser-controlled area under emergency conditions
- Area or entryway safety controls must be used to deactivate the laser or reduce the output to the appropriate MPE levels in the event of an unexpected entry into the laser-controlled area.
- The entryway controls may be non-defeatable, defeatable, or procedural as determined by the LSO.

8.2.3 Temporary Laser Controlled Areas

A temporary laser-controlled area must be set up when:

- Panels or protective housings are removed
- Protective housing interlocks are over-ridden

- Entry into the NHZ becomes necessary (such as for service)
- The accessible laser radiation exceeds the applicable MPE

The temporary laser-controlled area shall be indicated by a notice sign posted outside the area. Appropriate warning sign (Class 3B or Class 4) shall be posted inside the controlled area to warn of the potential hazard.

9.0 Personal Protective Equipment (PPE)

In addition to engineering and administrative controls, PPE for skin and/or eyes is often necessary when working with Class 3B or Class 4 lasers.

9.1 Eye Protection

Eye protection suitable to the laser must be provided and worn within the laser control area if there is a potential for exceeding the MPE limit if the beam is viewed. Protective eyewear may include goggles, face shields, spectacles, or prescription eyewear using special filter materials or reflective coatings. Exceptions may be approved in the written SOPs if the eyewear produces a greater hazard than when the eye protection is not worn.

No single type of eyewear will provide protection against all wavelengths of laser radiation; therefore, eye protection should:

- Provide enough visibility to move about safely.
- Be able to withstand the maximum power of laser radiation likely to be encountered.
- Be able to absorb the specific wavelength of radiation that is being used.
- Be clearly labeled with wavelengths that they are designed for including the optical density at wavelength together with the maximum power rating.
- Be inspected periodically by the laser operator to ensure that pitting, cracking, and other damage will not endanger the wearer.

Lasers that can be tuned through a range of wavelengths present special problems. Broadband laser goggles may provide the level of protection required but they must be chosen with great care. If there is any doubt regarding the suitability of a particular type of eye protection, contact the LSO for guidance.

9.1.1 Optical Density

Optical density designates the transmission of light at a certain frequency. The light transmission of a specific laser wavelength is the ability to filter out as much as possible of that specific wavelength. Optical density can be found using the following equation:

Optical Density (OD) = OD = log10(1 / T), where T is transmittance.

The relationship between the light transmission and the optical density at a specific wavelength can be described in **Table 9-1**.

Table 9-1 Light Transmission and Optical Density at a Specific Wavelength

Table 2 Light Transmission and Optical Density at a Specific Wavelength

Optical Density	Light Transmission
0	1
1	0.1
2	0.01
3	0.001
4	0.0001
5	0.00001
6	0.000001

For example, an optical density of six allows only one-millionth of the original light to be transmitted through the filter lens. This high level of protection is often needed because of the power of the laser as well as the human eye's ability to further focus the power of the beam on the retina. Generally, an OD of five or higher is recommended for laboratory use with a Class 4 laser. Note that none of the protective goggles shield you from visible range entirely as they must allow light for the user to see.

9.2 Skin Protection

Skin injuries from lasers primarily fall into two categories: thermal or photochemical. Thermal injury (burns) from acute exposure to high-power laser beams are usually not serious (although they are painful) and are normally easy to prevent through proper beam management and hazard awareness.

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

Clothing such as gloves and covers for the forearms may be required to protect the skin if laser intensity and/or wavelength warrant such protection. These protective types of covers are especially important if the laser is running in UV. Exceptionally large peak-powered lasers with pulsed UV can be particularly dangerous. For these types of lasers, contact the UAB LSO for specific information regarding the appropriate PPE.

By OSHA regulation, all laser users who are required to wear PPE must undergo a hazard assessment for PPE usage and must receive specific PPE training. Forms for completing each of these are included in this manual. The PI is responsible for managing the completion of these two forms for each laser operator.

10.0 Warning Labels and Signs

ANSI Z136.1 requires that lasers and laser systems have appropriate warning labels and that the areas in which they operate be posted with appropriate warning signs. All lasers, except Class 1, shall have appropriate warning labels affixed to a conspicuous place on the laser housing or control panel. Laser area warning signs and equipment labels are available from the UAB EH&S and/or some safety supply companies including the Laser Institute of America.

11.0 Laser Safety Training

All Class 3B or Class 4 laser operators are required to take basic laser safety training. The EH&S Laser Safety training course can be found on the Campus Learning System website. Go to the Campus Learning System to complete this training course. To access transcripts, log into Learning Locker. In addition to online training, all laser operators must be trained in the usage of each specific laser to be used in the laboratory. The PI, vendor, or other qualified individual may provide this training. Records of this training must be maintained for review by UAB EH&S, the UAB LSO, and/or regulatory agencies.

Before operating a Class 3B laser, a Class 4 laser, or a Class 1 laser system containing an embedded Class 3B or Class 4 laser (when the protective housing is removed), the operator must:

- Review of the UAB Laser Safety Manual
- Receive a thorough review of the laser equipment to be used and the administrative requirements, alignment procedures, and SOPs from the PI.
- Review the operating and safety instructions provided by the manufacturer.
- Review and utilize appropriate PPE provided by the PI.

Along with the requirements listed above, students shall receive on-site training from the PI. This training must be documented and be available upon request. **Copies of all training should be sent to the UAB LSOs.**

12.0 Medical Surveillance and Exposure Incidents

12.1 Medical Surveillance

Medical surveillance is managed as a function of the individual labs. Medical surveillance is encouraged but not required. Supplemental documentation can be provided for labs that wish to document surveillance through programs of UAB's Employee Health.

12.2 Medical Examinations Following Suspected or Known Laser Injury

Any employee with an actual or suspected laser-induced injury should be evaluated by a medical professional as soon as possible after the exposure. Referral for medical examinations shall be consistent with the medical symptoms and the anticipated biological effect based on the laser system in use at the time of the incident. For laser-induced injury to the retina, an ophthalmologist shall perform the medical evaluation. Employees with skin injuries should be seen by a physician.

If an exposure incident occurs, employees must do the following:

Follow the UAB Exposure Response Flowchart

File a report with the UAB On-the-Job Injury & Illness Program.

12.3 Access to Records

The results of medical surveillance examinations should be discussed with the employee and be furnished upon request to their private physician. All non-personally identifiable records of the medical surveillance examinations should be made available on written request by authorized physicians or by medical consultants for epidemiological purposes.

12.4 Epidemiologic Studies

Animal experiments with both laser and narrow-band radiation indicate the potential for chronic damage from both subacute and chronic exposure to radiation at certain wavelengths. Lens opacities have been produced by radiation in the 295 to 450 nm wavelength range and are also theoretically possible from 750 to 1400 nm. Photochemical retinitis appears to be inducible by exposure to 350 to 500 nm radiation. If laser systems are developed that require chronic exposure of laser workers to even low levels of radiation at the above-noted wavelengths, it is recommended that such workers be included in long-term epidemiologic studies and have periodic examinations of the appropriate eye structures.

13.0 Laser Removal

13.1 Laser Decommissioning or Disposal

When decommissioning, transferring, or disposing of a laser care must be taken. Some lasers contain hazardous materials or could be re-activated by an unsuspecting person(s) causing danger. UAB Laser Safety Program requires that all laser transfer and disposal be approved by this program. Contact the laser safety program for more information. The transfer or disposal of a Class 3B or 4 lasers that are built or modified at UAB will likely be subject to Export Control. These requirements impact who can have access to the equipment, plans, data, software, etc., during development, during use, while stored, and how the equipment is disposed. Contact vpr-researchsecurity@uab.edu before transferrin or disposing of any laser that was not commercially obtained and operated per manufacture specifications.

13.2 Laser Waste

Proper waste disposal of contaminated laser-related material, such as flue and smoke filters, organic dyes, and solvent solutions shall be managed in conformance with appropriate federal, state, and local guidelines. Contact the laser safety program for more information.

Appendix

Laser System Standard Operating Procedure (SOP)

Include a diagram of the laser system layout and attach it to this SOP.

Contacts

Department		Laser Location	
Primary Investigator	Phone: Email:	Primary Operator	Phone: Email:
LSO	Phone: Email:	Maintenance	Phone: Email:

Laser Information

Date	
Laser Type/Class	
Wavelength (nm)	
Beam Diameter (mm)	
Beam Divergence (mrad)	

Mode

Continuous Wave		**Pulsed or Q-Switched**	
Average Power (Watts)		Pulse Length (sec)	
		Repetition Rate (Hz)	
Max Power (Watts)		Avg. Joules/pulse	
		Max Joules/pulse	

Laser Hazard Information

List all hazards for this laser system such as unenclosed beams, invisible beams, scatter potential, hazardous materials (dyes, solvents), fumes/vapors, electrical hazards, ergonomic concerns, etc.:

Hazard Control

List all controls in place for the hazards listed above:

Personal Protective Equipment

List the PPE needed for the procedure. Include eyewear Mfg./model, wavelength attenuated, optical density, storage location, etc.:

Alignment Procedures

List the alignment procedures to be followed for the laser system.

Custom Lasers

Is this laser purchased commercially and being operated under manufacturer specifications?

General Operation Procedures

	Warning signs posted
	Warning light turned on
	Doors secured
	Target area preparation
	Protective equipment on (including correct eyewear)
	Beam stops in place

Operation Sequence: