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University of Arizona
Laser Radiation Protection Reference Guide

Research Laboratory & Safety Services

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Research Laboratory & Safety Services (RLSS) is the primary coordinating unit responsible for the radiation safety program at the University of Arizona. The Laser Radiation Protection Reference Guide is maintained at RLSS at 1717 E Speedway Blvd, Suite 1201, Tucson, AZ, and is readily available to anyone via the RLSS website (rlss.arizona.edu).

TABLE OF CONTENTS

Tables and Figures

I. Introduction

The Laser Protection Reference Guide serves to describe the Laser Safety program at The University of Arizona (UA) and to provide information regarding the safe use of lasers. The Laser Safety program primarily addresses hazard Class 3b and 4 lasers and products containing lasers in these classes. The responsibilities Research Laboratory & Safety Services (RLSS), Laser Safety Officer (LSO), Approval Holders, Radiation Safety Coordinators and Radiation Workers are also described.

The program is intended to:

- Provide a basic introduction to ionizing and non-ionizing radiation, lasers, and the hazards associated with laser use;
- Provide guidance to Approval Holders and workers authorized under their approvals;
- Provide instruction on the acquisition, safe use, transfer, and disposal of lasers;
- Maintain regulatory compliance with applicable state and federal regulations, and
- Inform Approval Holders of the resources available to them through Research Laboratory & Safety Services (RLSS).

All personnel working with Class 3b or 4 lasers must complete the Laser Radiation Protection Course prior to use of lasers. Course materials and schedules are available on the RLSS website. Approval Holders and Radiation Safety Coordinators must also complete an Approval Holder- Orientation (provided by RLSS personnel).

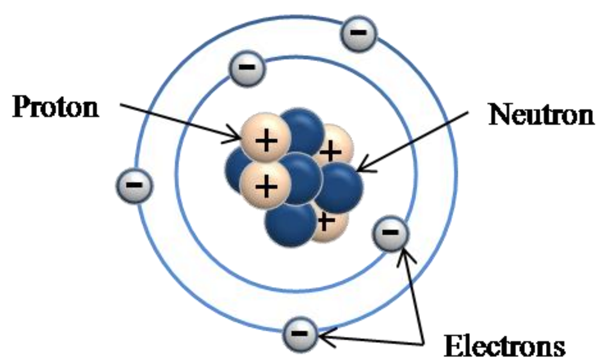
II. Physics

A. Atomic Structure

The basic unit of matter is the atom. The basic atomic model, as described by Ernest Rutherford and Niels Bohr in 1913, consists of a positively charged core surrounded by negatively-charged shells (see Figure 1). The central core, called the nucleus, is held together by nuclear forces.

Protons (p+) are positively charged particles and neutrons (n) are uncharged particles; both are located in the nucleus of the atom. Electrons (e-) are negatively charged particles that travel in structured orbits, or energy shells, around the nucleus.

Figure 1: Atomic Structure



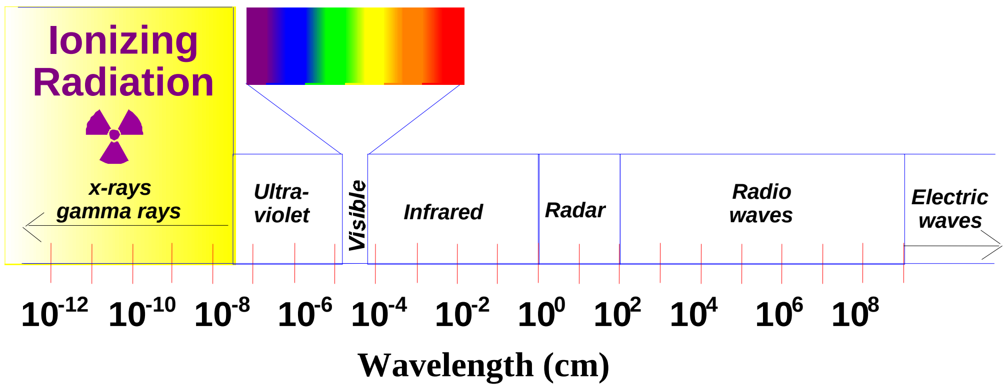
An atom is electrically neutral if the total electron charge equals the total proton charge. The term ion is used to define atoms or groups of atoms that have either a positive or negative electrical charge. Isotopes are forms of an element that have the same number of protons, but different numbers of neutrons. bureau

B. Ionizing and Non-Ionizing Radiation

Radiation is the transfer of energy, in the form of particles or waves, through open space. Radiation with sufficient energy to create ions by physically removing electrons from neutral atoms is referred to as ionizing radiation. Ionizing radiation includes alpha particles, beta particles, electromagnetic waves (gammas and x-rays), and neutrons. Radiation that lacks the energy to cause ionization is referred to as non-ionizing radiation. Examples of non-ionizing radiation include radio waves, microwaves, visible light and lasers.

1. **Electromagnetic Spectrum and Lasers**
   Electromagnetic radiation is traveling wave motion resulting from changing electric or magnetic fields. The energy is distributed across the electromagnetic spectrum (the full range of frequencies that characterizes light). Every electromagnetic wave exhibits a unique frequency and wavelength associated with that frequency. The electromagnetic spectrum (see Figure 2) is divided into two distinct regions: non-ionizing and ionizing radiation. Lasers operate in the ultraviolet, visible, and infrared regions of the non-ionizing spectrum.

Figure 2: The Electromagnetic Spectrum



C. Laser Fundamentals

Laser is an acronym for **L**ight **A**mplification by the **S**timulated **E**mission of **R**adiation.

A laser produces an intense beam of light that consists of waves that are:

- Monochromatic – of the exact same wavelength and color
- Coherent – exactly in step (phase) with each other in both space and time
- Collimated – parallel, with very low divergence of the beam even over great distances

Lasers can be described by which part of the electromagnetic spectrum is represented:

- Ultraviolet (180-400 nm)
- Visible (400-700 nm)
- Infrared (700 nm–1 mm)

Lasers can also be described by the length of time the beam is active:

- Continuous wave - the laser is continuously pumped and continuously emits light
- Pulsed - lasers which emit light in the form of optical pulses, resulting in high-energy light
- Ultra-short pulsed – pulsed lasers with pulse duration of at most a few tens of picoseconds (1 trillionth of a second)

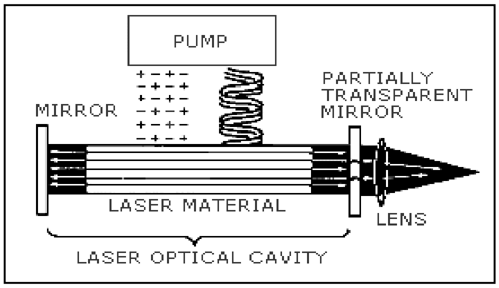
D. Laser Construction

A laser typically is a cavity with mirrors at the ends, filled with a lasing medium (typically a gas, solid, liquid, or semiconductor). Laser production involves moving electrons in the lasing medium from their ground state to an excited state using a high voltage current (an electrical discharge within a gas or gaseous mixture; a.k.a. collision pumping), optical pumping (photons from another source, such as a xenon gas flash tube), or the release of binding energy from chemical reactions. Photons, which are generated as the excited electrons return to a resting state, oscillate (bounce back and forth) between two mirrors; one mirror is partially transparent to allow some of the light out and into a lens. This oscillation (lasing action) results in a laser beam.

Figure 3 shows a typical laser, consisting of an optical cavity, a pumping system, and a lasing medium.

- The optical cavity contains the media to be excited with mirrors to redirect the produced photons back along the same general path.
- The pumping system uses various methods to raise the media to the lasing state.
- The laser medium can be a solid, gas, liquid dye, or semiconductor.

Figure 3: Laser Construction



1. Laser Mediums

The laser medium (a substance capable of emitting coherent radiation when stimulated to an excited state, followed by the release of photons as it returns to a ground state) determines the wavelength that is emitted by a particular laser. Active mediums are grouped into four major classifications:

a. Gas

The molecules in a gas-active-medium environment become excited when an electric current is passed through the gas.

b. Solid

An optically clear type of material composed of a host crystal laced with an impurity called a dopant is the active medium normally used in solid (crystal) lasers. The dopant, when activated by an arc or flash lamp, emits the radiation that results in a laser beam. Most solid lasers are now pumped by diode (semiconductor) lasers.

c. Liquid

The active medium in a liquid laser is an organic dye which is activated by another laser beam and produces a wide range of wavelengths.

d. Semiconductor

Layers of semiconductor crystal material are used as an active medium in semiconductor lasers.

E. Laser Classifications

Lasers are divided into classes based on the potential for causing immediate injury to the eye or skin and/or potential for causing fires from direct or indirect exposure to the beam. Lasers are classified using power, wavelength, and other physical parameters of the laser. Exposure duration is also considered.

1. **Class 1**

   Lasers in this class are incapable of causing eye damage because emissions are less than the maximum permissible exposure (MPE) limit. The MPE is defined as the level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin. Therefore, Class 1 lasers are exempt from regulation and any labeling requirements and Class 1 users are not required to complete RLSS training.

2. **Class 2**

   Lasers in this class operate in the visible portion of the electromagnetic spectrum (400-700 nanometers) and cannot exceed 1 milliwatt total power. Eye damage occurs only if the beam is stared at directly for longer than the normal human aversion response to bright light stimulant (0.25 second). This means a person would naturally turn away from the beam before any damage is done. This laser class is normally not regulated by RLSS and users are normally not required to complete RLSS training unless the use includes intentionally overcoming the aversion response or includes the use of collecting optics (e.g., lenses, telescopes, microscopes, endoscopes, etc.). If collecting optics will be used, controls such as filters, attenuators, interlocks, or the use of cameras to prevent exposures above the MPE would be required. If these types of engineering controls are not practical, standard operating procedures must be developed to address the hazard.

3. **Class 3a**

   Class 3a lasers emit visible or invisible beams and are capable of causing eye damage from short-duration (<0.25 second) viewing of the direct beam. A Class 3a laser produces accessible radiation that is between 1 and 5 times the Class 1 emission limit for invisible beams, or between 1 and 5 times the Class 2 emission limit for visible beams. Most laser pointers are 3a lasers. It is possible to be injured by a Class 3a laser if there is more than brief exposure, but injuries are very uncommon. The more likely hazard associated with a Class 3a laser is flash blindness or "dazzling" that interferes with normal vision and can cause an accident due to the temporary interference with normal vision.

   This laser class is not regulated by the RLSS and users are normally not required to complete RLSS training unless conditions exist where injury can occur, such as intentionally overcoming the aversion response or using viewing optics (e.g., microscopes, telescopes, or endoscopes).

4. **Class 3b**

   Class 3b lasers have an output power greater than that defined for Class 3a, but at levels less than Class 4 output levels. Class 3 laser output cannot exceed 0.5 watts for periods >0.25 seconds or 0.125 joule for periods <0.25 seconds. Danger labels are required and safety controls are necessary to prevent direct or indirect exposure to the beam. Class 3b laser beams are usually not a fire hazard or skin hazard, but are capable of producing acute eye injury. Class 3b lasers are regulated by the Bureau of Radiation Control (BRC) and are required to be registered with RLSS.

5. **Class 4**
   Class 4 lasers are high powered and capable of causing severe eye damage with short-duration exposure to the direct, indirect, or scattered beam. Class 4 lasers also present a skin hazard and fire hazard. Class 4 laser output exceeds 0.5 watts for periods >0.25 seconds and 0.125 joule for periods <0.25 seconds. Class 4 lasers are regulated by the BRC and are required to be registered with RLSS.

6. **Class 1 Laser Products**
   Some scientific equipment, such as flow cytometers and mass spectrometers, contain Class 3b and 4 laser components. Even though one or more high power lasers are incorporated in the equipment, it can be assigned a Class 1 approval because engineering features limit the accessible emissions to below the MPE. In this manual, the term "Class 1 laser product" will apply only to products where a Class 3b or Class 4 laser is accessible during service or maintenance operations specified by the manufacturer.

   RLSS does not track Class 1 laser products classified by the manufacturer. Unless a potential for users to be exposed to a Class 3b or Class 4 laser housed within the laser product exists. Users of Class 1 laser products who may access Class 3b or Class 4 lasers within the unit must notify RLSS.

   During service of a Class 1 laser product (when exposure to Class 3b or 4 lasers is possible), a temporary laser controlled area (an area under the control of the Approval Holder) must be designated and appropriate signs posted ("NOTICE – Laser Service – Do Not Enter") to warn individuals of the potential for laser exposure.

Note: The above classifications follow current BRC regulations. However, a new classification system was approved by the American National Standards Institute (ANSI) Z136 Committee and published in ANSI Z136.1-2007. The classification system was changed to harmonize it with International Electrotechnical Commission standard IEC-60825-1. As of mid-2010, the updated classification system has not yet been adopted in BRC regulations.

III. Biological Effects and Other Hazards

Biological effects can be categorized as direct or indirect based on how cellular damage occurs. An indirect effect occurs when free radicals produced by the ionization of water molecules in the body, interact with other molecules or intracellular structures. Most of the time, free radicals interact with molecules that cells can easily survive without.

Radiation that deposits energy directly into intracellular structures (including DNA) results in a direct effect. Changes to DNA can produce cell death, the inability to reproduce, the inability to function, or a change in the function of the cell (mutation), which could lead to cancer. DNA has the ability to repair itself, reverting to its original state or mutating, depending on the type and extent of the damage.

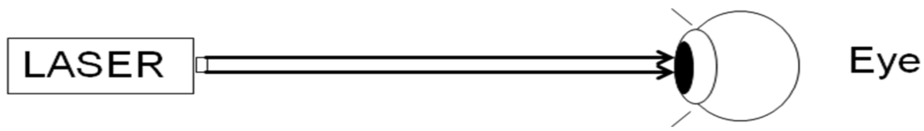
A. Laser Induced Eye Effects

The type and severity of damage to the eye is contingent upon the conditions under which the laser radiation is viewed and which area of the eye absorbs the most radiant energy per volume of tissue.

1. **Viewing Conditions**

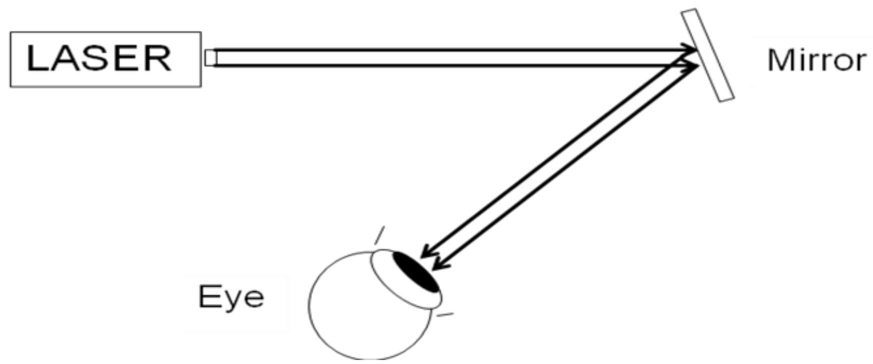
   a. Intrabeam Viewing (direct viewing of the beam)
   Intrabeam viewing of a primary beam or the alignment of a laser by looking along the axis of a beam is prohibited. Controls (e.g., filters or eyewear designed to reduce exposure to below the applicable MPE) are mandatory. Intrabeam viewing is very hazardous because of exposure to the full energy of the beam (see Figure 4).

Figure 4: Intrabeam Viewing



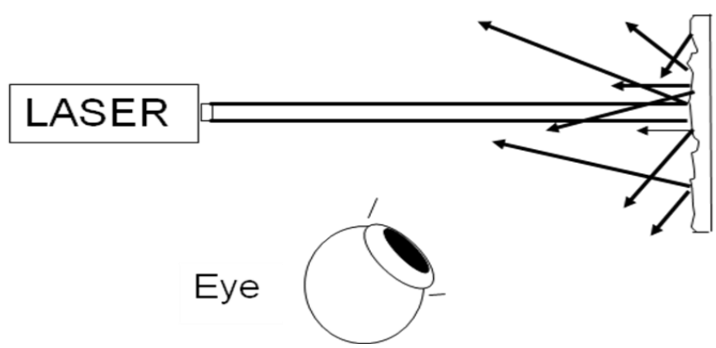
   b. Specular Reflection (viewing the reflection of the beam off a mirror-like surface)
   Direct viewing of the specular reflection of the beam is prohibited. Depending on the nature of the beam, this can be as hazardous as intrabeam viewing (see Figure 5).

Figure 5: Specular Refraction



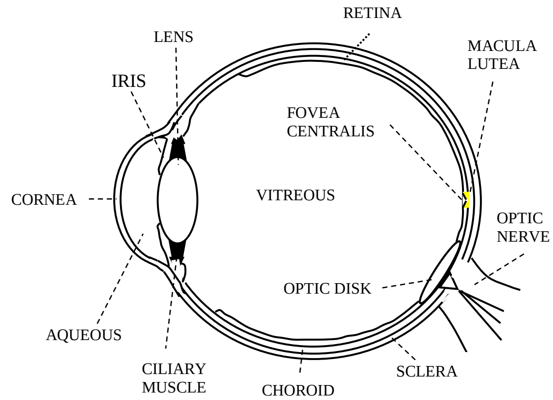
   c. Diffuse or Scattered Reflection (viewing the reflection of the beam off of a rough surface that scatters the energy)
   This is usually not hazardous except when using powerful Class 4 lasers (see Figure 6).

Figure 6: Diffuse or Scattered Reflection



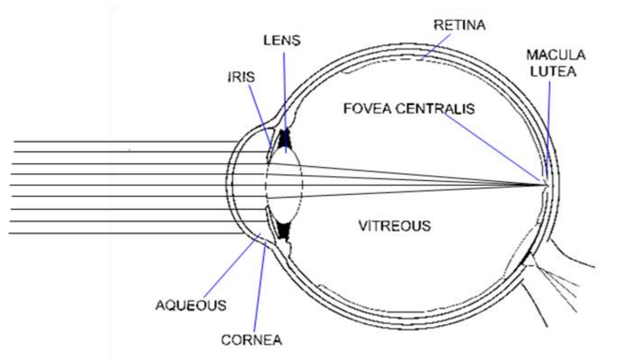
2. **Physiology of the Eye**
   A diagram of the human eye is shown below (see Figure 7). Damage to any of the labeled structures can result in impaired vision, varying from minor irritation to complete blindness.

Figure 7: The Human Eye



   a. Visible and Near-Infrared Light (400-1400 nm)
      This light is transmitted through the eye with little loss of intensity and is focused to a spot on the retina, making this the retinal hazard region of the spectrum (see Figure 8).

Figure 8: Effect of Visible and Near-Infrared Light



b. Mid-Infrared and Far-Infrared Light (1400-1000 nm); Far-Ultraviolet Light (180-315 nm)
Light in these regions of the spectrum effects the cornea, leading to some types of cataracts. The mid-ultraviolet region is responsible for "welder's flash", a type of burn to the cornea (see

Figure 9: Effect of Mid/Far Infrared and Far-Ultraviolet Light

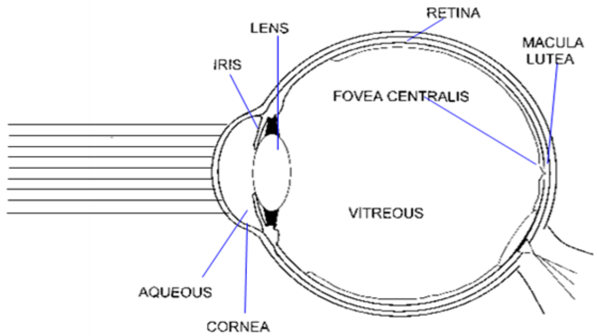
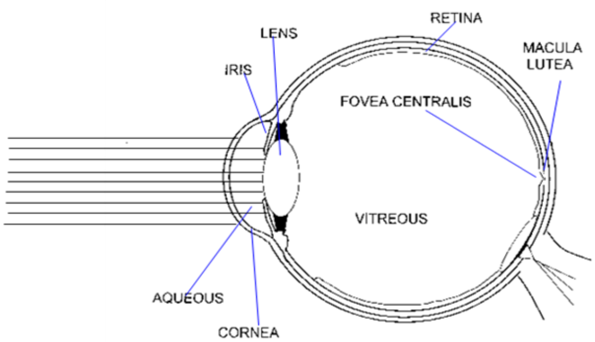


Figure 9).

c. Near-Ultraviolet Light (315-390 nm)
Radiation in the near-ultraviolet region is absorbed in the lens, promoting possible cataract formation (see Figure 10).

Figure 10: Effect of Near-Ultraviolet Light



B. Laser Induced Skin Effects

Skin damage can occur with exposure to ultra-violet (UV) and high-power lasers. The most common effect from acute exposure to high power lasers is skin burns. Skin damage can also be caused by chronic exposure to scattered UV laser radiation. Chronic exposure to even scattered UV light can cause sunburn, skin cancer, and accelerated aging, particularly at UV-B wavelengths (280–315 nm). Increased pigmentation (tanning) occurs in the 280–400 nm range. Photosensitive reactions are possible in the near-UV (310–400 nm) and visible (400–600 nm) ranges. Damage in the infrared region (700–100 nm) can lead to excessively dry skin or skin burns.

Because of these chronic exposure effects, it is important to not only protect personnel from intrabeam exposure and specular reflection of low power beams, but from chronic exposure to diffuse reflection of UV light. Light sensitivity from industrial chemicals or medications can make individuals more susceptible to these effects.

C. Non-Beam Hazards

Many non-beam hazards may be present in a laser laboratory. It is the responsibility of the Approval Holder to take proper precautions to prevent injury due to these hazards. The UA Risk Management & Safety Department is available to assist with evaluation of these hazards. Additionally, RLSS is available to assist with hazard evaluation involving ionizing or non-ionizing radiation. Non-beam hazards may include:

1. **Electrical Hazards**
   High-voltage power supplies used for Class 3b and 4 lasers are of sufficient voltage to cause injury or death during accidental contact. In particular, power sources of 15 kV or more have the potential to emit x-rays, which can cause injury if not appropriately managed.

2. **Fire Hazards**
   High powered Class 4 lasers can easily cause flammable materials (such as, paper or flammable liquids) to ignite. Class 3 lasers, in some situations, can also cause flammable liquids to ignite.

3. **Laser Generated Air Contaminants (LGAC)**
   The interaction between the laser beam and the target material can result in the production of toxic chemicals, contaminating the air. During surgical procedures, biologically hazardous aerosols containing blood borne pathogens may be created. To prevent personnel from inhaling the LGAC and to prevent the release of LGAC into the environment, exhaust ventilation with special filters may be required.

4. **Chemical Hazards**
   Lasers use a variety of lasing mediums and some of these are comprised of toxic chemicals (such as dyes, solvents and hazardous gases). Many laser dyes and solvents are toxic and can cause cancer. The Material Safety Data Sheet (MSDS) for each of the dyes or solvents in use should be reviewed. Toxic gas hazards, such as those associated with some excimer lasers, and cryogenic hazards may also exist and need to be addressed.

5. **Noise**
   Hearing protection may be required if a laser system generates noise that is at 90 decibels or higher.

D. Protection Against Radiation Exposure

Though risk of skin and eye damage may be present when using lasers, steps can be taken to greatly reduce or eliminate exposures. The ANSI standard describes specific controls that are recommended or required for each laser classification.

1. **Nominal Hazard Zone (NHZ) and Laser Controlled Area (LCA)**
   When the beam path of a Class 3b or 4 laser is not completely enclosed, there exists an area within which the level of direct, reflected or scattered radiation may exceed the Maximum Permissible Exposure (MPE) Limit. This area is known as the Nominal Hazard Zone (NHZ). Generally, the NHZ for a laser is assumed to be the entire room in which the laser is used, but the NHZ can be reduced using appropriate engineering and administrative controls.

   The Laser Controlled Area (LCA) is that area which is controlled by the Approval Holder for the purpose of protecting individuals from laser radiation. Warning signs and lights are generally located at the entrance to the LCA in order to warn people about the potential for laser hazards.

The LCA and the NHZ are assumed to be the same unless engineering or administrative controls are applied to reduce the area of the NHZ. Entryway controls or curtained alcoves in Class 4 laser labs are examples of controls used to reduce the size of the NHZ within the LCA.

a. Beam Control

Laser beam paths and any potentially hazardous reflections should be enclosed, if possible. If the enclosure material is not obviously opaque material, the Approval Holder must document the optical density of the material for the wavelength(s) of the laser being used. If enclosing the beam is not practical, other beam control measures must be used, including:

- Confining the beam path to the optical bench, if possible. The beam should not traverse populated areas or traffic areas. If traversing traffic areas is necessary, access to the area must be restricted through the use of chains, ropes or other barriers.
- All windows leaving the Laser Controlled Area must be covered with non-reflective or diffuse reflective material.
- The laser must be turned off or beam shutters/caps utilized when laser is not in use.
- Beam path must be well defined and uncluttered.
- All extraneous reflective material must be removed from the potential beam path.
- Optics, optical mounts and the laser must be secured.
- The beam must be terminated at the end of its useful path. Beam stops should be secured with strong mechanical mounts to avoid the possibility of beam blocks dropping and exposing individuals to high intensity beams.
- The beam path must be located so that it is not at eye level for any person standing or sitting.
- The beam must not be directed toward any doors.
- The beam must not be directed upward at any time during alignment or operation.
- Vertical beams must be totally enclosed or shielded with a periscope (the beam should never be inclined).
- The lowest power or attenuator should be used (especially during alignment).
- The beam should be kept parallel to the table and preferably at one common height.

b. Administrative Controls

RLSS may apply alternate engineering to obtain equivalent laser safety protection when certain engineering controls are inappropriate. This substitution will be based on a laser hazard evaluation performed by RLSS personnel. When necessary, these alternate methods may be administrative controls, including a written Standard Operating Procedure (SOP). Each SOP is reviewed by RLSS prior to being adopted for use by the Approval Holder.

A SOP is a concise set of instructions regarding operation and safety that is specific to a system. It must be available at the laser control panel or legibly posted at a position clearly visible to the laser operator. RLSS may require that safeguards against non-beam hazards be included in the SOP. The SOP shall be evaluated annually by the Approval Holder and will be briefly reviewed during RLSS audits.

2. Alignment Safety Measures

A significant number of laser eye injuries occur during alignment. Alignment procedures must be designed to minimize the possibility of accidental specular or diffuse reflection of a laser beam toward a worker's eye or skin with power level exceeding the MPE. Alternative viewing methods may be required to achieve a satisfactory level of safety for invisible wavelengths. For alignment of a class 3b or class 4 laser system, the following requirements apply:

- If at all possible, a class 2 or 3a laser should be used to align the optical system.
- If the condition above cannot be met, and if the laser emits only visible continuous wave radiation, then the laser output should be reduced to the lowest power possible.
- If the alignment laser must be operated at a high power, the user should obtain appropriate eyewear to provide protection during alignment.

3. Additional Requirements for Class 4 Laser Laboratories

Intrabeam exposure to class 4 lasers can be extremely damaging to the eyes and skin. Class 4 lasers are especially hazardous in that both specular and diffuse reflections can be an eye, skin or fire hazard. Therefore, the following additional control measures are applied to personnel and the use area for Class 4 laser labs.

a. Eyewear

Laser safety eyewear is required for class 4 lasers. The operator must maintain sufficient eyewear to accommodate all personnel in the NHZ. If eyewear is not available, use of the Class 4 laser must cease until appropriate eyewear is obtained.

b. Entryway Controls

Controls must be established at all entryways to either reduce the laser hazard to below the MPE or to allow an individual entering the laser controlled area to don laser protective eyewear prior to entering the NHZ (the area in which direct or scattered laser light is above the MPE).

One of these three types of entryway controls must be established at all entrances to the work area:

- Barrier or blocking screens - allows individuals to don eyewear before they enter the nominal hazard zone. This control is used in conjunction with “Laser In Use” lights.
- Non-defeatable door interlocks – “Laser In Use” lights are not required if this method of entryway control is used.
- Defeatable door interlocks – used when normal usage requires operation without interruption and it is clear that there is no laser hazard at the point of entry. “Laser In Use” lights are not necessary if this method of entryway control is selected.

Because implementation barriers or blocking screens can be problematic, RLSS allows labs to provide barriers at the optical bench to shield the source or place barriers in the room to create a maze effect so that individuals entering the rooms have an opportunity to don eyewear before entering the nominal hazard zone. A barrier at the optical table or placement of barriers away from the doorway and closer to the source allows some flexibility in storage location for eyewear.

If barriers are erected to satisfy the entryway requirements, the material used must be selected to withstand all direct and diffusely scattered beams produced by the highest power laser system. The barriers must be constructed of a material that is not flammable and does not release toxic fumes if exposed to a laser.

E. Hazard Evaluation to Identify Exposure Risk

Hazard evaluations are performed by RLSS staff in order to identify the hazards associated with a laser's use. The initial hazard evaluation takes place upon arrival of the laser (if its use is known) or just prior to use (if details of use are not known at the time the laser is acquired). The hazard evaluation is used to determine what controls are needed to prevent accidental exposure above the MPE. Hazard evaluation is based on:

- Laser and laser system specifications
- Description of use
- Environment in which it is used, including access to beam path
- The individuals using the system

A hazard evaluation is repeated:

- When RLSS is notified by the laser user, Approval Holder, or Radiation Safety Coordinator that the hazard associated with the laser operation has changed significantly
- When the laser's status is changed from "storage" to "use"
- At the semiannual laser approval audit conducted by RLSS staff

F. Personal Protective Equipment

1. Eye Protection

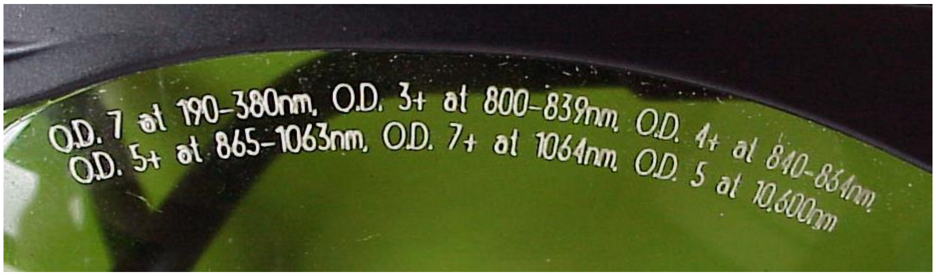
A significant number of laser eye injuries occur because laser safety eyewear is available, but not used. Appropriate eyewear must be available for all individuals (users and guests) present in the Nominal Hazard Zone when a class 4 laser is in use and the laser beam is not completely enclosed or contained. Although not required, eyewear for class 3b lasers is highly recommended. The need for eyewear for class 3b lasers is evaluated by RLSS on a case-by-case basis.

The BRC requires that eyewear be examined for defects at no greater than six month intervals. Eyewear is examined for damage by RLSS during the semiannual laser approval audit. It is important that users also examine eyewear prior to each use.

Protective eyewear shall meet the following requirements:

- Have an optical density (OD) adequate for the worst case irradiance or radiant exposure to be encountered
- Have the wavelengths and the optical densities for those wavelengths legibly and permanently marked on the eyewear (see Figure 12)
- Be able to protect from hazardous peripheral radiation exposure
- Be maintained such that its protective properties are retained
- Transmit enough visible light so that the experiment may be conducted safely
- Be comfortable to wear and fit appropriately
- Be listed in the eyewear inventory maintained by RLSS

Figure 11: Eyewear Optical Density and Wavelength Markings



Optical Density

$$OD = \log_{10}(H_p / MPE)$$

Where:
H_p = potential eye exposure
MPE = maximum permissible exposure limit

Note: Above values must be in the same unit of measure.

The optical density is a measure of the effectiveness of the eyewear and the required optical density for a laser can be calculated by using the equation above. The required optical density is based on a number of factors (including the power, pulse energy, beam diameter, pulse repetition frequency and duration of exposure). Laser vendors, eyewear vendors and RLSS can calculate OD requirements for a particular laser. If eyewear will be used for wavelengths other than those designated by the manufacturer, the OD and applicable wavelength must be permanently marked on the eyewear or OD information must be readily available at the point of use.

Prior to each use, eyewear must be checked for defects (cracks, holes, scratches, discoloration) and to verify that it is appropriate for the wavelengths of the laser in use (since some areas use multiple lasers, all eyewear may not be appropriate for all lasers in the area). Additionally, when using goggles, the elastic headband must ensure a snug fit or be replaced prior to use. Laser eyewear is assigned an inventory number and tracked by RLSS. It is the responsibility of the Approval Holder to inform RLSS when new eyewear is obtained, eyewear is discarded or no longer in use, or when previously “out of service” eyewear will be used again (RLSS must examine the eyewear prior to use).

2. Skin Protection

Skin protection is generally not required unless unenclosed ultraviolet lasers are in use or when there are other special circumstances. Acute exposure to high levels of laser radiation may cause skin burns. The intent of the hazard evaluation and the application of control measures is to minimize the possibility of acute exposure. Chronic exposure to high levels of some UV wavelengths may be hazardous to skin, so face shields and garments that cover all bare skin may be appropriate.

IV. Laboratory Practices

All individuals working with lasers should be aware of the location of the necessary documents, records, and guidelines that pertain to laser use approvals. A visiting RLSS or state inspector may ask to view this information at any time.

A. Education and Training

Individuals may not work with Class 3b or 4 lasers until they have received appropriate training. This includes on-the-job, laser specific training and completion of the Laser Radiation Protection Course.

Course schedules and registration information are located on the RLSS website. RLSS training is required before an individual begins working in a new laboratory or under an additional approval.

Class 2 and Class 3a laser users are normally not required to complete RLSS training unless use includes intentionally overcoming the aversion response or collecting optics (e.g., lenses, telescopes, microscopes, endoscopes, etc.).

B. Approval to Use Lasers

An 'Approval to Use Lasers' is granted to an individual after RLSS reviews and approves an Application for Laser Approval. The Application for Laser Approval includes general information about the Approval Holder (and Radiation Safety Coordinator if applicable), hazards associated with proposed use, use categories, previous laser experience, and formal/on-the-job training.

To change approved laser use or locations, add or remove lasers or workers, or change configurations that may impact laser-associated hazards, contact RLSS.

In addition to RLSS approval, proposed experiments may require additional regulatory approvals from the Institutional Animal Care Use Committee (IACUC), the Institutional Review Board (IRB) at the Human Subjects Protection Program office, or the Institutional Biosafety Committee (IBC).

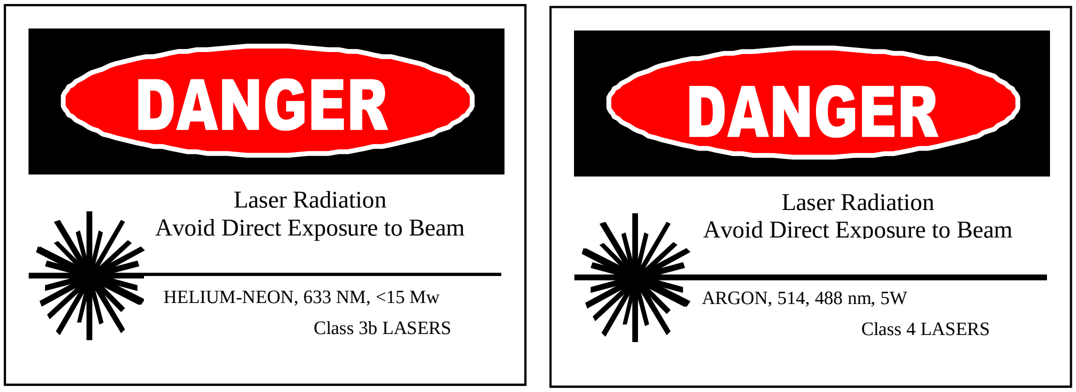
C. Posting and Labeling for Lasers

Once a room is approved for laser use or storage, RLSS will post the required signs. No work involving lasers may be initiated until the signs have been posted.

1. Room and Laser Controlled Area Entrances

Signs must warn of the presence of a laser hazard and indicate the type and wavelength of laser in use, output power, and class of laser. If multiple lasers are available for use in the area, a single sign may be posted at the entrance with instructions to ask the laser operator for information about the laser in use. Examples of Class 3 and Class 4 laser signs are shown below (see Figure 1).

Figure 123: Sample Entrance Warning Signs



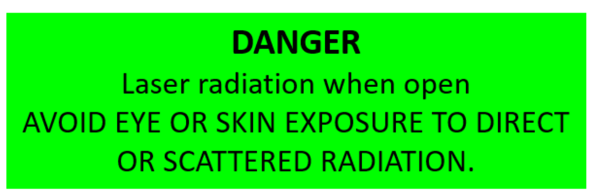
2. Laser Labels

All lasers must have laser hazard labels (indicating the class of the laser and potential safety hazards) and tracking number/registration labels attached. RLSS monitors laser labeling and will replace any missing or damaged labels. Examples of labels that may be found on lasers are shown below (see Figure 1).

Figure 134: Sample Laser labels

3. Labeling of Enclosures

The following label is required on each non-interlocked or defeatable interlocked portion of the protective housing or enclosure that permits human access to laser or collateral radiation hat exceeds the applicable accessible emission limit for a Class 3 laser.



D. Activation, Recordkeeping and Security of Lasers

All incoming and outgoing lasers must be routed through RLSS.

1. **Activation**

   After approval for a proposed laser use is obtained, all purchased or fabricated lasers must be inspected by RLSS prior to initial use, when significant changes to planned operation are made, and at six month intervals.

2. **Recordkeeping**

   RLSS must be notified prior to transfer of any laser, whether internally to another Approval Holder, or externally to another institution. RLSS will update inventory records and may perform a hazard evaluation for internal transfers.

3. **Security**

   It is the responsibility of the Approval Holder to ensure that lasers are secure from unauthorized use or theft. All individuals who are authorized to enter a laser use area have the responsibility to adhere to laser security measures. These individuals may include radiation workers, non-radiation workers or others who are authorized to enter the laser use laboratory (including University support personnel).

   Unless determined otherwise by RLSS or the Radiation Safety Committee, unattended lasers must be secured by:

   - removing the activation key (if activated by a key) from the console and locking the key in a cabinet or storage area, or by locking the approved laser use or storage area/laboratory.

   Note: If it is necessary to operate a laser while unattended, the Approval Holder should contact RLSS to discuss appropriate additional control measures.

   Any known or suspected loss or theft of lasers must be reported immediately to RLSS.

V. Emergency Procedures

Radiation workers should familiarize themselves with the location of supplies that may be needed in an emergency. The Radiation Safety Coordinator is the designated person, other than the Approval Holder, who can provide information about laser use in the laboratory in case of an emergency.

A. Common Causes of Accidental Exposures

- Eye exposure during alignment
- Available eyewear not used
- Misaligned optics or upwardly directed beam
- Improper handling of high voltage sources
- Unfamiliarity with laser equipment or standard operating procedures
- Failure to follow standard operating procedures

B. Actions and Notifications

If an injury is suspected as a result of an exposure to laser/collateral radiation;

- Stop work and turn off laser.

- Warn others in the area if a hazard still exists.
- Do not alter the configuration of the laser unless required to turn off the laser. The configuration of the laser is helpful for RLSS to evaluate the incident and properly determine if a potential over exposure has occurred.
- For severe injuries such as total loss of vision, bleeding from the eye, 2nd or 3rd degree burns to the skin, call 911 and request transport to a nearby hospital emergency room (University of Arizona Campus Health Center or Banner UMC Urgent Care.).
- For any exposures resulting in potential injury to the eye or skin (i.e. headaches, photophobia, or some visual disturbance) seek medical attention. Not all eye injuries will have pain; laser retinal burns may be painless while laser burns to the cornea may have burning pain at the site of exposure. When seeking medical attention, state the type and extent of the injury or suspected injury, and clearly request any assistance you might need.

After the immediate medical needs of an individual suffering from potential injury to laser/collateral radiation have been met, the Approval Holder or the operator of the laser must contact Research Laboratory & Safety Services as soon as possible. RLSS will notify the ARRA within 24 hours of any incident that may have caused;

- Permanent loss of eye sight in either eye; or
- Third-degree burns of the skin involving more than 5 percent of the body surface as estimated by the rule of nines.

RLSS will notify the ARRA within 5 working days of any incident that has or may have caused;

- Any second-degree burn of the skin larger than one inch (2.54 centimeter) in greatest diameter; or
- Any third-degree burn of the skin; or
- An eye injury with any potential loss of sight.

RLSS shall file a written report to the ARRA of any known exposure of an individual to laser or collateral radiation within 30 days of its discovery describing;

- Each individual’s exposure to laser or collateral radiation exceeding the MPE; or
- Any laser incident requiring notification to the ARRA.

The written report filed with the ARRA will include;

- An estimate of the individual’s exposure,
- The level of laser/collateral radiation involved,
- A summary of what caused the exposure,
- The corrective measures to prevent a recurrence.

RLSS will perform an investigation of the incident and present those results to the Approval Holder and the NRSC. The Approval Holder or laser operator must also report to potential injury to the UA Risk Management & Safety office within 7 calendar days to maintain compliance with Worker’s Compensation rules.

C. Fire Emergencies Involving Lasers

- In case of fire, call ‘911’ from a University telephone, notify dispatcher that lasers are present, pull the nearest fire alarm, and vacate the building.
- Call RLSS (if after business hours or if no answer at RLSS telephone number, call University Police).

D. Loss or Theft of Lasers

Suspected loss or theft of lasers must be reported immediately to the Radiation Safety Coordinator and/or Approval Holder, and RLSS. If after business hours or if no answer at the RLSS telephone number, call University Police.

VI. Responsibilities By Role

The responsibility for ensuring laser radiation doses to workers and members of the general public stay below the MPE is shared by RLSS, the Approval Holder, the Radiation Safety Coordinator, and each radiation worker.

A. Approval Holder Responsibilities

Approval Holders are the individuals ultimately responsible for the safe use of lasers under their control and listed on their approval. Approval Holder Orientation is provided by RLSS at the time of approval, during audits, and/or at a minimum of every three years. Approval Holders have the responsibility to:

- Comply with the rules and regulations administered by the Non-Ionizing Radiation Safety Committee, the Laser Safety Officer, RLSS, and the BRC;
- Register all Class 3b and 4 lasers (whether fabricated or purchased) with RLSS upon arrival at The University of Arizona or prior to first use (initial RLSS notification of intent to obtain a laser or intent to initiate use of a laser may be made via email or telephone);
- Properly train radiation workers to handle, secure, and dispose of lasers under their approval.
- Provide in-house, system-specific training;
- Ensure that RLSS is notified of newly proposed radiation;
- Provide adequate supervision of authorized radiation workers;
- Respond to information requests by RLSS in a timely manner;
- Notify RLSS immediately if an exposure has occurred or is suspected;
- Maintain all required postings, labeling, and warning lights for lasers and laser use/storage areas;
- Provide and ensure proper use of personal protective equipment, if required (including a sufficient number of appropriate eyewear for workers and visitors);
- Notify RLSS prior to decommissioning, relocation or transfer of lasers (to internal or external sites);
- Notify RLSS if the Approval Holder will be absent from the institution for an extended time that will reduce the effective oversight of laboratory operations. If an extended absence is planned, an agreement must be reached with an appropriate substitute to oversee the use of lasers while the Approval Holder is away.

B. Radiation Safety Coordinator Responsibilities

Some Approval Holders may not have the time or resources to personally monitor the day-to-day operation of a laboratory. Therefore, Approval Holders may appoint a Radiation Safety Coordinator to operate under their Approval, but the ultimate responsibility for use of the laser remains with the Approval Holder. The Radiation Safety Coordinator, in addition to attending the Laser Radiation Safety Course will receive an Approval Holder Orientation from RLSS personnel initially, during audits, and/or at a minimum of every three years. At the direction of the Approval Holder, the Radiation Safety Coordinator may be assigned extra responsibilities such as those in the above list.

C. Radiation Worker Responsibilities

Radiation Workers have the responsibility to:

- Complete the Laser Radiation Safety Program and any other required training prior to beginning work;
- Work under the direct supervision of another knowledgeable radiation worker until competence with the laser system is demonstrated;
- Comply with all required Standard Operating Procedures established by the Approval Holder for setting up, aligning, operating and shutting down the laser;
- Notify RLSS if transferring to a new Approval Holder's group or laboratory;
- Comply with the requirements for the safe use, disposal and security of lasers;
- Report all accidents and exposures (known or suspected) to the Radiation Safety Coordinator and/or Approval Holder, and to RLSS.

D. Research Laboratory & Safety Services (RLSS) Responsibilities

RLSS has responsibility to:

- Carry out the Laser Safety Program and ensure compliance with the laser control measures as developed by the LSO and the Non-Ionizing Radiation Safety Committee;
- Provide training (e.g., Laser Radiation Protection Course, Approval Holder's Orientation);
- Provide technical staff to assist the Laser Safety Officer;
- Maintain a current inventory of all sources of laser radiation;
- Evaluate hazards and installations of lasers prior to initiation and at regular intervals;
- Maintain laser registrations with the BRC for The University of Arizona;
- Calibrate survey instruments;
- Provide signs for entrances to laser use and storage areas;
- Maintain exposure records for Radiation Workers;
- Perform audits and laboratory inspections (at least every six months);
- Investigate, document and report (if required) incidents and accidents involving laser use;
- Assist the LSO with enforcement of compliance standards as set out by the Non-Ionizing Radiation Safety Committee.

VII. Obtaining a Laser

It is recommended that RLSS be notified of the intent to obtain (purchase, fabricate, or receive through transfer or donation) a laser. It is required that RLSS be notified prior to initial use of a laser.