Laser Safety Practices Manual

CLASSIFICATIONS

Lasers are divided into a number of classes depending upon the power or energy of the beam and the wavelength of the emitted radiation. Laser classification is based on the laser's potential for causing immediate injury to the eye or skin and/or potential for causing fires from direct exposure or reflection off diffuse and reflective surfaces. Commercially produced lasers have been classified and identified by labels affixed to the laser since August 1, 1976.

- **Class 1 laser or laser system-** cannot emit levels of optical radiation above the exposure limits for the eye under any exposure conditions inherent in the design of the laser product. For visible laser with wavelengths longer than 500 nm, the limit is 0.4 mW. For lasers of wavelengths shorter than 500 nm, the limit is 0.04 mW. There may be a more hazardous laser embedded in the enclosure of a Class 1 product, but no harmful radiation can escape from the enclosure. Class 1 lasers or laser systems are relatively safe, as long as the system is not modified.
    - **Class 1M laser system-** a class 1 laser using magnifying optics. Incapable of causing injury during normal operation unless collecting optics are used.
- **Class 2 laser or laser system**- emits a visible laser beam which by its very bright nature will be too dazzling to stare into for extended periods. Momentary viewing is not considered hazardous. The upper radiant power limit on this type of device is 1 mW which corresponds to the total beam power entering the eye for a momentary exposure of 0.25 seconds. Class 2 lasers or laser system requires no special safety measures other than not staring into the beam.
    - **Class 2M laser system-** a class 2 laser using magnifying optics. Visible lasers incapable of causing injury in 0.25 seconds unless collecting optics are used.
- **Class 3 laser**- can emit any wavelength, but cannot produce a diffuse or scattered reflection hazard unless focused or viewed for extended periods at close range. Safety training must be completed by the laboratory personnel before using these lasers. In addition, the laser should be operated within a well-marked and controlled area. Class 3 is divided into two sub-classes 3R (formally 3A) and 3B.
    - **Class 3R** lasers are "Marginally Unsafe." This means that the aversion response is not adequate protection for a direct exposure of the eye to the laser beam, but the actual hazard level is low, and minimum precautions will result in safe use. This sub-class only allows visible lasers with a maximum continuous wave (CW) power of 5mW and an invisible laser with a CW power of up to 5 times the Class 1 limit. It is also not considered a fire or serious skin hazard. Since the output beam of such a laser is definitely hazardous for intrabeam viewing, control measures must eliminate this possibility.

- **Class 3B** lasers are hazardous for direct eye exposure to the laser beam, but diffuse reflections are not usually hazardous (unless the laser is near the class limit and the diffuse reflection is viewed from a close distance). This sub-class includes continuous wave (CW) or repetitive pulse lasers with a maximum average power of 0.5 W. The maximum pulse energy for a single pulse class 3B laser in the visible and near IR varies with the wavelength. For visible lasers the maximum pulse energy is 30mJ. It increases to 150 mJ per pulse in the wavelength range of 1050-1400 nm. For UV and the far Infrared (IR) the limit is 125 mJ. Class 3B lasers operating near the upper power or energy limit of the class may produce minor skin hazards. Most Class 3B lasers do not produce diffuse reflection hazards. However, single pulse visible or near IR class 3B lasers with ultra-short pulses can produce diffuse reflection hazards at more than a meter from the surface. Eye protection may be needed while the laser is operating.

- **Class 4 laser**- any that exceeds the Annual Exposure Limit (AEL) of a Class 3 device. Class 4 lasers have an average power level greater than 0.5 W. The lower power limit for single pulse Class 4 lasers varies from 0.03 J for visible wavelengths to 0.15 J for some near IR wavelengths. These lasers are powerful enough to be a fire, skin, and diffuse reflection eye hazard. Class 4 lasers require the use of eye protection, facility interlocks, and special safeguards.

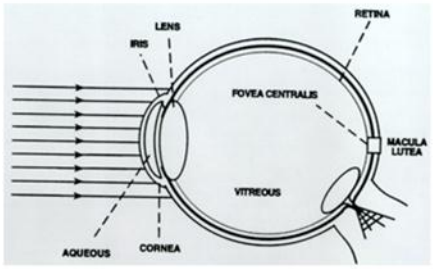
- **Summary:**
  - **Class 1** • Safe.
  - **Class 1M** • Safe provided optical instruments are not used.
  - **Class 2** • Visible lasers. Safe for accidental exposure (< 0.25 s).
  - **Class 2M** • Visible lasers. Safe for accidental exposure (< 0.25 s) providing optical instruments* are not used.
  - **Class 3R** • Not safe. Low risk.
  - **Class 3B** • Hazardous. Viewing of diffuse reflection** is safe.
  - **Class 4** • Hazardous. Viewing of diffuse reflection is also hazardous. Fire risk.

**Optical instruments - binoculars, telescopes, microscopes, magnifying glasses (but not prescription glasses).*

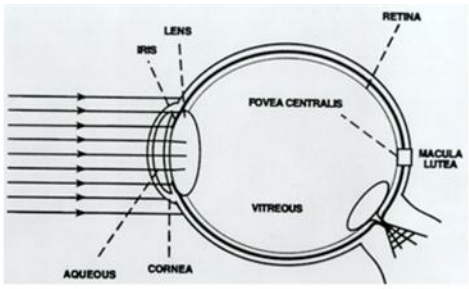
***Diffuse reflection - the reflection of radiation from a matt surface such as a wall.*

LASER HAZARDS

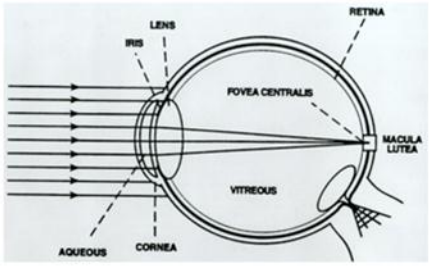
1. **Beam Hazards**- Destruction of tissue can occur to the eye and skin. In the far-UV and far-IR regions of the optical spectrum, the cornea will absorb the laser energy and be damaged. In the near-UV region and near-IR at certain wavelengths the lens may be damaged. The greatest hazards are 400 - 1400 nm wavelengths which can damage the retina. Lasers below the visible spectrum (>1400 nm) are especially dangerous because the eye does not have a natural aversion at these wavelengths. Keep in mind that the light entering the eye from a collimated beam in the retinal hazard region is concentrated by a factor of 100,000 times when it strikes the retina. If the eye is not focused at a distance or if the laser light has been reflected off diffuse surfaces, this hazard is greatly diminished but can still be very dangerous.



Near-ultraviolet (100-330 nm)
Possible damage to Cornea

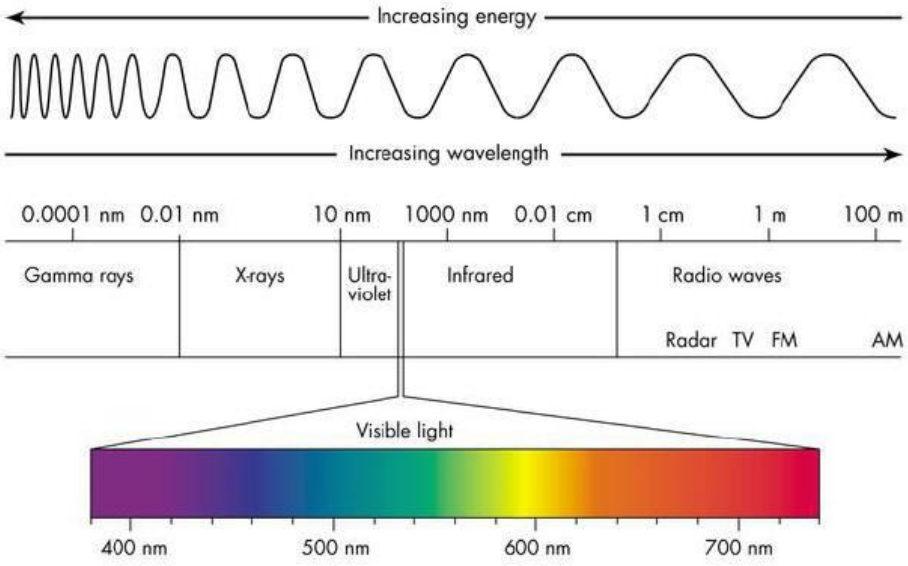


Far-IR (1400-10600 nm)
Possible damage to Lens

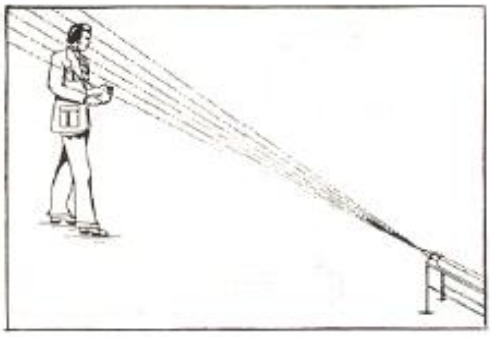


Visible and Near IR (400-700 nm/700-1400 nm)
Possible damage to Retina

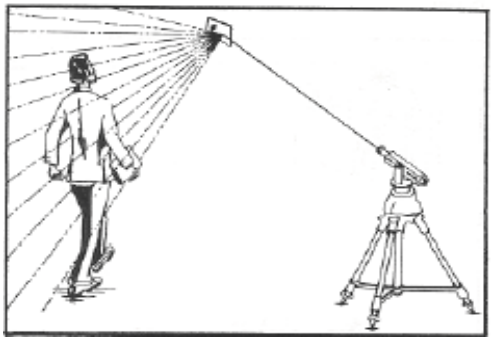
Electromagnetic Spectrum



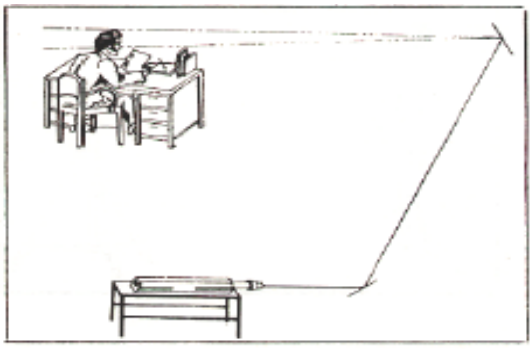
There are a variety of types of beam exposures that are not limited to intrabeam viewing. For high powered laser, the specular or diffuse reflection may be equally as damaging.



Direct Intrabeam exposure.



Diffuse Reflection.



Specular Reflections.

Intrabeam exposure: The skin or eye is exposed directly to all or part of the laser beam resulting in a full exposure to the irradiance of the beam.

Specular reflection: The reflection from a smooth or mirrored surface. Items such as jewelry or cover glass of wrist watches produce specular reflections. These items should be removed prior to operating a laser. Exposure to specular reflections can be as dangerous as an intrabeam viewing.

Diffuse reflections: Reflection off a non-uniform or rough surface. Diffuse reflection scatter the beam and does not carry the full

power of an intrabeam exposure like in specular reflections. However, diffuse reflections from Class IV lasers can contain enough power to initiate a fire.

SAFETY RULES FOR CLASS 3B AND 4 LASER

1. General

- An SOP should be written for all Class 4 Lasers. (See Appendix 1: Class 4 Laser SOP Template) Only trained, authorized personnel may operate lasers. Authorization is received from the laser lab manager.
- NEVER put yourself into any position where your eyes approach the axis of a laser beam (even with eye protection on).
- Keep beam paths below or above standing or sitting eye level. Do not direct them towards other people.
- Do not damage laser protective housings, or defeat the interlocks on these housings.
- Eliminate all reflective material from the vicinity of the beam paths.
- Never use viewing instruments to look directly into a laser beam or its specular reflection. If this is necessary, install an appropriate filter into the optical element assembly.
- Keep ambient light levels as high as operations will permit.
- Do not work alone when performing high power laser operations.
- Visitors should not be permitted to observe a laser experiment without first receiving a laser safety briefing and being issued laser eye protection. They will be escorted by knowledgeable personnel at all times.

2. Laser Entryway Controls

- *Class 3b Laser Only Labs*
  - Doors must be closed and locked during laser operations.
  - Doors must be properly posted and the warning light energized during operations.
  - Door windows and labs windows must be covered to prevent the escape of a laser beam, unless an interlocked laser beam path enclosure is provided.
- *Class 4 Laser Labs*
  - Including controls listed for Class 3b.
  - All Class 4 lasers laboratories must have either an interlocked entry way or laser enclosure system.
  - Overriding any safety controls is considered a serious violation of safety rules. Overriding actions include, but are not limited to the following: defeating of interlocks; removal of external shutter from the laser beam path; rewiring laser interlock connectors.
- Personnel requiring entry to a laser lab with laser operations in progress shall knock and verbally request permission to enter. Enter with care, following any laser operator's instructions that are given.

3. Turn-on Procedures

- Follow any pertinent safety precautions listed in the laser manufacturer's published owner's manual.
- Prior to lasing, perform a "countdown" or make an announcement to warn others that you are about to lase.

4. Review Design and Set-up of New Experiments

- Before a newly acquired laser is put into operation.
- Upon a major rearrangement to a new lab.
- Whenever a new experiment within a lab results in a new beam path for which the prior safety requirements or controls no longer apply. NOTE: Minor changes to experiments are made quite often in a research environment. Minor changes that do not affect the overall safety recommendations for a lab do not require review.

5. Shared Laser/Non-Laser Space

- *Class 3b and 4 Laser Labs*. Labs will be arranged so that non-laser personnel will not have to pass through laser areas to enter or leave the lab. This can be done through lab design, or the use of movable partitions or interlocked curtains .

6. Use of Laser Eye and Skin Protection

- Laser protective eyewear must be worn whenever you are within the Nominal Hazard Zone (NHZ). The NHZ is defined as that area within which the laser beam power exceeds maximum permissible exposure levels. During maintenance or alignment operations, the N HZ extends to the entire lab or to the partitioned laser use area. Once the laser beam path is well defined and contained to a specific area, the NHZ may be reduced in size to the area where the experiment is taking place. Note that Class 4 lasers can p roduce hazardous diffuse reflections, and that the NHZ for laser experiments must be extended to account for diffuse reflection hazards from your experiment.
- Eyewear must be of the correct optical density and offer protection at the wavelength(s) of the laser(s) being used.
- Eyewear will only protect your eyes for short time periods, depending on the laser power. Therefore do not look directly into any laser beam, even with laser eye protection on.
- Periodically inspect and replace damaged or defective eyewear.
- Exposure to direct or diffuse reflections from ultraviolet lasers (particularly excimers) can result in short and long term skin hazards. Cover your exposed skin areas when working near these lasers (use long sleeve shirts or lab coats, cloth gloves , etc. as necessary).
- Exceptions:

    - Lower optical density eyewear may be used when a laser beam must be seen. This eyewear is chosen to eliminate the diffuse reflection hazard.
    - If a diffuse reflection must be observed, do this after the beam path is well defined and away from the area that the diffuse reflection will be viewed from.

During viewing, your eyes may not come within the diffuse reflection hazard distance.

7. Laser Alignment Practices

- Never look directly into a laser beam. Do not bring your eyes near the axis of any beam to perform an alignment (or any other operation).
- Wear laser skin and eye protection (see section 6 above).
- Use a low power laser for alignments. If this is not possible, adjust your laser to minimum power levels and/or use a filter to bring down the power to safe levels.
- Use viewers or viewing cards to sight where an invisible beam is. To sight where a visible beam is, use lower optical density laser protective eyewear (see below) or sight beams with a non-specular, dark colored viewing card.

8. **Laser Beam Termination**

- Terminate laser beams at the end of their useful path with immovable, non-specular, fire retardant beam stops or targets.
- Do not allow open beams to cross aisle ways.
- Choose target materials that partially absorb the laser beam.
- Unused secondary beams emerging from alternate laser apertures will be terminated.
- Terminate all unused beams.
- Every time that a beam hits an optical element in your beam path, a portion of the beam will be reflected. This is of particular concern with an invisible beam and when a prism or angled optical element is used. Block all reflections and pr event them from leaving the experimental area. Even a 1% reflection from a high power YAG laser beam can cause instantaneous eye damage.

9. **Non-Beam Hazards**

- *Electrical Safety*
  - Practice Lock-Out/Tag-Out procedures where appropriate.
  - Do not defeat laser housing interlocks or come into contact with energized electrical circuits.
  - Do not wear jewelry or metallic objects when working near a high voltage source.
  - In case of emergency, press the Emergency Power Off button in your lab to turn off the electricity to your lab.
- *Chemical Safety*
  - Follow the precautions in your Lab Safety Plan when working with chemicals in your lab. Before working with chemicals you must have attended Hazard Communication training.
  - Work shall be performed in hoods where required. Use appropriate personal protective equipment, including safety glasses/goggles, gloves, respirators, etc., as required.
  - Follow the precautions listed on the Material Safety Data Sheets for your chemicals.
  - Many dyes and dye solvents are either known or suspected carcinogens. In addition to the above, you must have a containment tray or system to contain any dye spill which may occur within your laser.

- *Gas Safety*
  - Store hazardous gases in vented gas cabinets. Provide laser housing ventilation for those lasers (e.g. excimers) that use hazardous gases.
- *Airborne Contaminants*
  - High power lasers interacting with a target or sample may cause airborne contaminants to be released to the air. Use a hood or other ventilation system to remove these contaminants from the ambient air.
- *Noise Safety*
  - Wear hearing protection when in the vicinity of a laser that generates noise levels exceeding 85 dB.

- *Cryogenic Safety*
  - Wear protective gloves, face shields, and clothing, as required when handling cryogenic materials.
- *X-Ray Safety*
  - Power supplies operating at potentials above 15 kV may produce X-rays. Leave interlocked power supply doors in place. Do not defeat the door interlocks and open these doors when the power supply is on.

10. **Service and Maintenance Procedures**

- Wear laser skin and eye protection (see section 6 above).
- Set up a temporary controlled area that restricts access to the nominal hazard zone. Post warning signs as required.
- When access cannot be adequately restricted, use partitions or curtains to prevent the beam from leaving the area.
- Work carefully. Take the time needed to service the laser properly.
- Remove only the minimum number of protective housings required to do the work. Replace the housings promptly when done.
- Use the lowest possible laser power.
- Use indirect viewing instruments or targets to align the beam. Do not look directly at a potentially hazardous beam or specular reflection.
- After servicing, reactivate all safety features.

11. **Accident/Emergency Procedures**

- In case of an emergency, dial 911 for assistance.
- Emergency response personnel will be directed to you as necessary.
- An Emergency Power Off button is located in the lab to shut down power to the lab.
- Notify the lab manager and the site Laser Safety Officer.

Appendix 1
Laser Safety Standard Operating Procedure (SOP)

Department/Laboratory:_____ Date:_____

Procedure #:_____ Revision Number:_____

Author:_____

- **This procedure shall be read and signed annually by all persons who use lasers listed in the SOP.**
- **This procedure shall be reviewed every two years by the LASER owner to ensure it reflects the most current conditions.**

1. **LASER SAFETY CONTACTS**

   - Laboratory Laser Safety Supervisor (LSS)_____

     Phone number_____
   - University Laser Safety Officer Tom Bialke

     Phone number 330-672-4996 **24 hour on call 330-671-6352**
   - Maintenance/Repair_____

     Phone number_____
   - Medical Emergencies
     1. **911**
     2. Notify the Laboratory LSS and University LSO of all laser-related injuries and near misses as soon as possible.

2. **LASER DESCRIPTION**

Laser SOP

4. HAZARDS & CONTROLS

HAZARDS AND CONTROLS		
Check if applicable	**HAZARD**	**CONTROL(S)**
☐	High Voltage	
☐	Capacitors	
☐	Unenclosed Beam Access to Beam	
☐	Fumes/Vapors	
☐	Ultraviolet Radiation or Blue Light	
☐	Compressed Gases	
☐	Hazardous Chemicals/Waste	
☐	Housekeeping	
☐	Reflective Material in Beam Path	
☐	Fire	
☐	Laser at eye level of person sitting or standing	
☐	Infrared Lasers	
☐	Correct Eyewear	

COMMENTS:

ADDITIONAL CONTROLS		
Check if applicable	**CONTROL**	**COMMENTS**
☐	Entryway (door) Interlocks or Controls	
☐	Laser Enclosure Interlocks	
☐	Laser Housing Interlocks	
☐	Panic Button Emergency Stop	
☐	Beam Stops	Infrared Laser must terminate in fire-resistant material and the absorber must be inspected at least quarterly[1]
☐	Master Switch (operated by key or computer code)	
☐	Laser Secured to Base	
☐		
☐		
☐		
☐		

COMMENTS:

5. PERSONAL PROTECTIVE EQUIPMENT

A. Eyewear

LASER EYEWEAR

For this Laser… …Wear this Eyewear

Acquisition date	Type	Wavelength (nm)	Wavelength Attenuated (nm)	Optical Density (OD)	Remarks
(example) Aug 99	CO2	10,600	10,600	At least 3.5	Glendale-white frames

Identify each set of laser protective eyewear with a unique designation (name or number).

The following check shall be done annually. Discard unfit eyewear.

Item	Comments	Date/Initial
Adequate pairs of eyewear for all needs.		
Eyewear specific to wavelength		
OD appropriate for full range of power; alignment to power ops		
Fit snugly		
Labeled for wavelength and OD		
Free of damage excessive scratches		

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

6. OPERATING PROCEDURES

A. Initial preparation of lab environment for normal operation (key position, warning light on, interlock activated, identification of personnel, other)

B. Target area preparation

C. Operation procedures are as follows:

D. Shutdown procedures for this laser are as follows:

E. Special procedures (alignment, safety tests, interlock bypass, emergency, etc.)

7. **OPERATOR REVIEW (General Laser Safety Training Certificate, System specific training by Laboratory LSO)**

I have read this procedure and understand its contents.

Name (print)	Signature	Date

Appendix 2

LASER ALIGNMENT GUIDELINES

Preface: Laser alignment is a challenge and rarely has a standardized methodology to adhere to. **It is also the most likely time for a laser-induced injury/accident to occur!**

- Follow all laser-specific operating requirements stipulated in the designated Standard Operating Procedure (SOP).
- No unauthorized personnel will be in the room or designated laser control area during the alignment procedure.
- Only appropriately trained personnel shall perform, or be physically present during laser alignment operations.
- If applicable, laser safety curtains/partitions shall be put in place.
- Remove all wristwatches, jewelry, I.D. badges, etc. that may cause unintended stray reflections.
- Clear the laser optic table of any unnecessary equipment and or materials.
- Ensure beam blocks and stray beam shields are in place and securely mounted.
- Designated protective eyewear shall be worn. For visible-wavelength-lasers, this may involve designated "laser alignment" eyewear intended to allow the researcher to view the beam while providing a reduced level of eye protection.
- Use the lowest practical power during the alignment process.
- If possible use an alignment laser (e.g. HeNe).
- Utilize appropriate alignment tools (e.g. fluorescence cards, alignment scopes, etc.).
- Avoid having beams cross aisle ways – if this is unavoidable ensure the accessible aisle way is appropriately marked and barricaded during laser operations.
- Avoid beam alignment out of the horizontal plane.
- Establish beam path(s) at safe height(s), below eye level when standing or sitting.
- Whoever moves or places an optical component on an optical table is responsible for identifying and terminating each and every stray beam coming from that component.