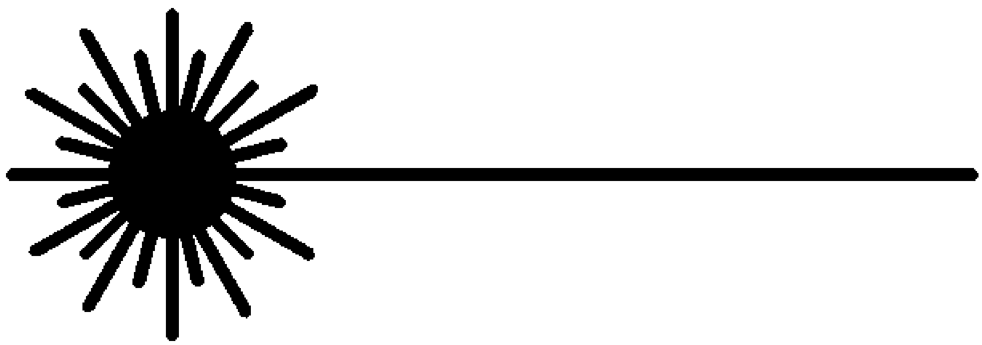
CALIFORNIA INSTITUTE OF TECHNOLOGY



LASER SAFETY MANUAL

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1. INTRODUCTION

INTRODUCTION

This manual describes the Institute's laser safety program. The purpose of this program is to protect Caltech personnel, guests, and property from the hazards associated with lasers and laser systems.

This manual does not describe the theory behind lasers or the various types and uses of lasers. It is assumed that researchers operating lasers have sufficient knowledge in those areas. However, resources are available through the Safety Office which covers these topics.

PRINCIPAL INVESTIGATORS

The primary responsibility for ensuring the safe use of lasers belongs to Principal Investigators (PIs). Specifically, PIs are responsible for ensuring:

- Only authorized individuals operate lasers or have access to controlled areas during laser operations.
- Individuals authorized to use lasers have received adequate training.
- Appropriate personal protective equipment (PPE) is available and worn when necessary.
- Operating procedures include adequate safety measures.
- Lasers manufactured or modified at Caltech are properly classified and labeled.
- Proper laser warning signs are posted.
- All class 3b and 4 lasers have been registered with the Safety Office.

OPERATORS

Persons operating lasers are responsible for following proper operating and safety procedures and only performing operations authorized by the PI. Operators are also responsible for restricting access to controlled areas during operations.

SAFETY OFFICE

Members of the Safety Office are available to provide support in all aspects of laser safety, including:

- Providing training and/or training materials to laser operators.
- Classifying lasers and providing appropriate signs and labels.
- Determining proper protective eye wear and other PPE.
- Reviewing operating and safety procedures.

2. LASER HAZARDS

EYE

Different structures of the eye can be damaged from laser light depending on the wavelength. Retinal burns, resulting in partial or complete blindness are possible in the visible (400 - 700 nm) and near-infrared (700 - 1400 nm) regions. At these wavelengths, the eye will focus the beam or a specular reflection on a tiny spot on the retina. This focusing increases the irradiance of the beam by a factor of about 100,000.

Laser emissions in the ultraviolet (< 400 nm) and far-infrared (> 1400 nm) regions are primarily absorbed by and cause damage to the cornea. In the near-ultraviolet range (315 - 400 nm), some of the radiation reaches the lens of the eye.

SKIN

Skin damage can occur from exposure to infrared or ultraviolet light. For infrared exposure, the results can be thermal burns or excessively dry skin depending on the intensity of the radiation. In the 230 - 380 nm range of ultraviolet light, erythema (sunburn), skin cancer, or accelerated skin aging are possible. The most damaging region of ultraviolet is 280 - 315 nm, also known as UV-B.

ELECTRICAL

Many lasers contain high-voltage components which can present a potentially lethal hazard. Proper lockout procedures should be followed when working on high-voltage components. (See the *Caltech Lockout Program*.)

FIRE

Many class 4 lasers are capable of igniting combustible materials. Care should be taken when choosing beam stops and shielding material.

HAZARDOUS MATERIALS

Laser laboratories contain many of the same hazards found in many chemical laboratories and therefore the same precautions should be taken. (See the *Caltech Chemical Hygiene Plan*.) In addition, most laser dyes are considered to be hazardous materials and should be handled accordingly. Laser interactions with certain materials may produce toxic fumes which must be properly vented.

3. LASER CLASSIFICATION (2007)

Lasers and laser systems are classified by potential hazard according to a system described in the American National Standards Institute (ANSI) standard Z136.1, and in 21 CFR part 1040. A laser's classification is based on several factors including its wavelength, power output, accessible emission level, and emission duration. The level of hazard associated with each class of lasers is listed below.

The ANSI Z136.1 standard was updated in 2007 and current classifications are as follows:

CLASS 1	These are low-power lasers and laser systems that cannot emit radiation levels greater than the maximum permissible exposure (MPE). Class 1 lasers and laser systems are incapable of causing eye injury under normal operating conditions. This class may include lasers of a higher class whose beam are confined within a suitable enclosure so that access to laser radiation is physically prevented.
CLASS 1M	Class 1M lasers produce large-diameter beams, or beams that are divergent. The MPE for a Class 1M laser can not normally be exceeded unless focusing or imaging optics are used to narrow down the beam. If the beam is refocused, the hazard of Class 1M laser may be increased and the product class may be changed.
CLASS 2	A Class 2 laser emits in the visible region. It is presumed that the human blink reflex (<0.25 seconds) will be sufficient to prevent damaging exposure, although prolonged viewing may be dangerous. Class 2 lasers are limited to 1 mW when operating in the continuous wave mode, or more if the emission time is less than 0.25 seconds.
CLASS 2M	A Class 2M laser emits in the visible portion of the spectrum in the form of a large diameter or divergent beam. It is presumed that the human blink reflex will be sufficient to prevent damaging exposure, but if the beam is focused down, damaging levels of radiation may be reached and may lead to a reclassification of the laser.
CLASS 3R	A Class 3R laser is potentially hazardous under some direct and specular reflection viewing condition if the eye is appropriately focused and stable, but the probability of an actual injury is small. This laser will not pose either a fire hazard or diffused-reflection hazard. Class 3R visible

lasers (0.4 to 0.7 um) are limited to 5 mW when operating in continuous wave mode. For other wavelengths and pulse lasers, other limits apply.

CLASS 3b	Class 3b lasers are capable of causing eye damage from short-duration (< 0.25s) viewing of the direct or specularly-reflected beam. Diffuse reflections from these lasers are generally not hazardous, except for intentional staring at distances close to the diffuser.
CLASS 4	Lasers in this class are high powered and capable of causing severe eye damage with short-duration exposure to the direct, specularly-reflected, or diffusely-reflected beam. They are also capable of producing severe skin damage. Flammable or combustible materials may ignite if exposed to the direct beam.
LASER CLASSIFICATION (Prior to 2007)	**All lasers purchased before 2007 may still display the former classifications.**
CLASS 1	Lasers in this class are incapable of causing eye damage. These lasers are exempt from labeling requirements.
CLASS 2	Lasers in this class emit visible light only. They are only capable of producing eye damage if the beam is stared at directly for longer than the normal human aversion response time to bright light (0.25 second). This means a person would naturally turn away from the beam before any damage is done.
CLASS 2a	This is a special category of class 2 lasers which are not hazardous if viewed directly for up to 1000 seconds. Supermarket barcode scanners are in this class.
CLASS 3a	Lasers in this class are capable of causing eye damage from short-duration (< 0.25s) viewing of the direct beam.
CLASS 3b	No change
CLASS 4	No change
EMBEDDED LASERS	A laser system of one class may contain a laser of a higher class. For example, a class 3a system might contain a class 4 laser in an interlocked protective housing which incorporates design features to limit the accessible emission level to the class 3a level.

4. CONTROL MEASURES

GENERAL	This section describes administrative, procedural and engineering measures which can reduce the chance of a laser-related incident. These measures should be considered when evaluating a class 3 or 4 laser facility. Although some items are appropriate for all facilities (e.g. posting proper warning signs), others may not be practical for some operations.
BEAM CONTROL	Enclose as much of the beam path as possible. If practical, the entire beam path should be enclosed. As a minimum, beam stops must be used to ensure no direct or specularly reflected laser light leaves the experiment area. Laser beams should be limited to a horizontal plane which is well below or well above normal eye level. Securely fasten the laser and all optics on a level, firm, and stable surface.
REFLECTIONS	Remove unnecessary reflective items from the vicinity of the beam path. Do not wear reflective jewelry such as rings or watches while working near the beam path. Be aware that lenses and other optical devices may reflect a portion of the beam from their front or rear surfaces. Avoid placing the unprotected eye along or near the beam axis. The probability of a hazardous specular reflection is greatest in this area.
POWER LEVEL	Operate a laser at the minimum power necessary for any operation. Beam shutters and filters can be used to reduce the beam power. Use a lower power laser when possible during alignment procedures.
SIGNS AND LABELS	The entrance to a class 3b or 4 laser facility must be posted with the appropriate warning sign. Each laser must be labeled as required by 21 CFR part 1040. These labels show the classification of the laser and identify the aperture(s) where the laser beam is emitted. Signs and labels may be obtained through the Safety Office.
WARNING DEVICES	Class 4 laser facilities where the beam is not fully enclosed should have a visible warning device (e.g. a flashing red light) at the outside of the entrance which indicates when a laser is in operation.

CONTROL OF AREA

Except for fully enclosed and interlocked systems, an authorized user must be present or the room kept locked during laser operations.

INTERLOCKS

Many laser systems have interlocked protective housings which prevent access to high-voltage components or laser radiation levels higher than those accessible through the aperture. These interlocks should not be bypassed without the specific authorization of the Principal Investigator. Additional control measures must be taken to prevent exposure to the higher radiation levels or high voltage while the interlock is bypassed.

PERSONAL PROTECTIVE EQUIPMENT

Eye protection designed for the specific wavelength of laser light should be available and worn when there is a chance that the beam or a hazardous reflection could reach the eye. Protective eye wear should be marked by the manufacturer with the wavelength range over which protection is afforded and the minimum optical density within that range. Eye wear should be examined prior to each use and discarded if there is damage which could reduce its effectiveness.

Protective eye wear generally will not provide adequate protection against viewing the direct beam of a high-powered laser. Wearing protective eye wear should not be used as an excuse for performing an unsafe procedure.

TRAINING

All operators must receive training in the safe and proper use of lasers by the PI (or a person designated by the PI) before being allowed to operate a laser.

OPERATING PROCEDURES

Written operating procedures should be available which include applicable safety measures.

MAINTENANCE/SERVICE

Maintenance, servicing, or repair of a laser should be performed only by a knowledgeable person who has been specifically authorized by the PI to perform such work. Whenever such work involves accessing an embedded laser of a higher class, the controls appropriate to the higher class must be applied.

Any laser which is significantly modified must be reevaluated to determine its classification.

5. EMERGENCY/INCIDENT PROCEDURES

EMERGENCIES

For any emergency:

Call x5000 and follow the CALTECH EMERGENCY RESPONSE GUIDE posted in the laboratory.

EMERGENCIES OR INCIDENTS INVOLVING LASERS

In the event of an accident or unusual incident involving a laser:

1. TURN OFF THE LASER.

2. If there is a serious injury or fire, call x5000 and request paramedics or the fire department.

3. Notify the Safety Office (x6727). If after working hours, call x5000 and have the operator contact a Safety Office representative.

4. Notify the laboratory supervisor or Principal Investigator.

5. Report all injuries to the Workers' Compensation Administrator (x4577).

APPENDIX A. LASER REGISTRATION FORM

California Institute of Technology

Class 3b and Class 4 Laser Registration Form

Date			
Principal Investigator (PI)	Department	Mail Code	Extension
Laser Safety Contact Person (if other than PI)	Mail Code	Extension	

Manufacturer	Model		ANSI Classification ☐ 3b ☐ 4
Type (Laser Medium)	Operational Wave Length(s)	☐ CW ☐ Pulsed	Maximum Power (W) or Energy (J)
Location	☐ In Active Use ☐ In Storage		☐ System Contains Separate Aiming Laser

Manufacturer	Model		ANSI Classification ☐ 3b ☐ 4
Type (Laser Medium)	Operational Wave Length(s)	☐ CW ☐ Pulsed	Maximum Power (W) or Energy (J)
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APPENDIX B. GLOSSARY

Accessible Emission Level	The magnitude of laser radiation to which human access is possible. Usually measured in watts for continuous wave lasers and in joules for pulsed lasers.
Accessible Emission Limit (AEL)	The maximum accessible emission level permitted within a particular class.
Aperture	An opening through which laser radiation can pass. This term usually refers to the opening on the laser (or a protective housing) where the beam is emitted.
Aversion Response	Movement of the eyelid or the head to avoid exposure to a bright light. For laser light, this response is assumed to occur within 0.25 second.
Continuous Wave (CW) Laser	A laser which has a continuous output for greater than or equal to 0.25 second.
Controlled Area	An area where the occupancy and activity of those within are subject to control and supervision for the purpose of protection from hazards.
Diffuse Reflection	A reflection where different parts of the beam are reflected over a wide range of angles, such as when hitting a matted surface.
Embedded Laser	A laser with an assigned class number higher than the classification of the laser system in which it is incorporated, where the system's lower classification is appropriate because of the engineering features limiting accessible emission.
Enclosed Laser System	Any laser or laser system located within an enclosure which does not permit hazardous optical radiation emission from the enclosure.
Erythema	Redness of the skin caused by distention of the capillaries with blood.
Fiber Optics	A system of flexible quartz or glass fibers with internal reflective surfaces that passes light through thousands of glancing (total internal) reflections.
Fluorescence	The emission of light of a particular wavelength resulting from absorption of energy typically from light of shorter wavelengths.
Infrared Radiation (IR)	Invisible Electromagnetic radiation with wavelengths which lie within the range of 0.70 to 1000 micrometers.
Irradiance	The optical power per unit area reaching a surface (W/cm^2).
Laser	A device which produces an intense, coherent, directional beam of light. Also an acronym for *L*ight *A*mplification by *S*timulated *E*mission of *R*adiation.

Laser System	An assembly of electrical, mechanical, and optical components which includes a laser.
Optical Density (OD)	A logarithmic expression for the attenuation produced by an attenuating medium, such as an eye protection filter. $OD = \log_{10} (I_i/I_t)$ where I_i is the incident irradiance and I_t is the transmitted irradiance.
Protective Housing	A device designed to prevent access to radiant power or energy.
Pulsed Laser	A laser that delivers its energy in the form of a single pulse or a train of pulses, with a pulse duration of less than 0.25 s.
Scanning Laser	A laser having a time-varying direction, origin or pattern of propagation with respect to a stationary frame of reference.
Specular Reflection	A mirror-like reflection. The exact definition of a specular surface is one in which the surface roughness is smaller than the wavelengths of the incident light.
Tunable Laser	A laser system that can be "tuned" to emit laser light over a continuous range of wavelengths or frequencies.
Ultraviolet (UV) Radiation	Electromagnetic radiation with wavelengths between soft X-rays and visible violet light, often broken down into UV-A (315-400 nm), UV-B (280-315 nm), and UV-C (100-280 nm).
Visible Radiation (light)	Electromagnetic radiation which can be detected by the human eye. It is commonly used to describe wavelengths which lie in the range between 400 nm and 700 nm.
Wavelength	The length of the light wave, usually measured from crest to crest, which determines its color. Common units of measurement are the micrometer (micron) and the nanometer (nm).

APPENDIX C. REFERENCES

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University of Illinois at Urbana-Champaign
Radiation Safety Section
Laser Safety
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University of Pennsylvania
Office of Environmental Health & Safety
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