California Institute of Technology

LASER SAFETY MANUAL

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Chapter 1: Introduction

The purpose of the California Institute of Technology's (Caltech or Institute) Laser Safety Manual is to increase awareness of hazards associated with lasers and laser systems, and to provide guidance on recommended practices.

The Laser Safety Manual follows the normative American National Standard for Safe Use of Lasers (ANSI Z136.1) and American National Standard for Safe Use of Lasers in Research, Development, or Testing (ANSI Z136.8).

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.

Chapter 2: Caltech's Code of Conduct

Caltech's Code of Conduct embodies widespread principles for which each worker is accountable for in their work and in their laboratories. As members of the Caltech community, we expect that each one of us will put into practice the high standards that have gained Caltech its worldwide reputation.

The Caltech Code of Conduct is centered on:

- A commitment to excellence, responsibility and accountability.
- Integrity in all we do.
- Open, honest, and respectful discourse.
- Curiosity in research and exploration.
- Dignity and respect.
- Education.
- Stewardship of the Institute's resources.
- Maintaining a safe environment.
- Scrupulousness.
- Leadership.

Chapter 3: Roles and Responsibilities

Principal Investigators

The primary responsibility for ensuring the safe use of lasers belongs to the Principal Investigators (PIs). PIs may delegate the safety duties, but not the responsibility, and must ensure that all safety duties are carried out in a consistent manner.

Specifically, PIs are responsible for ensuring:

- Only authorized individuals operate lasers or have access to laser-controlled areas during laser operations.
- Individuals authorized to use lasers have received training commensurate with the greatest level of potential laser radiation exposure.
- 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 labelled and classified.[1]
- Proper laser warning signs are posted.
- All Class 3B and Class 4 lasers have been registered with Environmental Health and Safety (EH&S).

Laboratory Safety Coordinator

Each PI overseeing a research laboratory may designate one or more Laboratory Safety Coordinator(s). Duties may include but shall not be limited to:

- Communicating safety information to other lab members.
- Provide lab specific information to new lab members, including a job safety walk around pointing out lab specific hazards, the location of the Emergency Response Guide and emergency equipment located in the lab.

Laboratory Laser Safety Officer

Each PI or Laboratory Safety Coordinator may designate a Laboratory Laser Safety Officer (LLSO). Duties may include but shall not be limited to:

- Hazard evaluation of laser-controlled areas.
- Ensuring that local control measures are implemented and maintained.
- Approval of laser standard operating procedures (SOPs) and other procedures that may be part of the requirements for administrative controls.
- Reviewing and updating the wording on area warning signs and equipment labels.
- Laser installation specific training to laser operators.
- Reporting laser accidents to EH&S and assisting in investigating the root cause.

Operators

Personnel operating lasers are required to have detailed knowledge of the potential hazards, control measures and safe practices for the laser they will be working with. Duties may include but shall not be limited to:

- Following proper operating and safety procedures.
- Performing operations authorized by the PI.
- Limiting access to laser-controlled areas during laser operations.
- Coordination of activities when more than one activity is being conducted in a laser-controlled area.
- Reporting laser accidents and near misses to the LLSO, PI, and EH&S.

Environmental Health and Safety

Caltech's Environmental Health and Safety (EH&S) Team is available to provide support in all aspects of laser safety, including:

- Providing basic laser safety training and/or materials to laser operators.
- Hazard evaluation of laser-controlled areas.
- Classifying lasers and providing appropriate warning signs and labels.
- Determining the proper laser eye protection and other personal protective equipment.
- Reviewing operating and safety procedures.
- Review laser laboratory designs.
- Inspect laser laboratories and laser setups.
- Investigate laser accidents and near misses and recommend corrective actions.

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[1] Significant modifications may result in the laser having comply with the radiation safety performance standards in Title 21 Code of Federal Regulations (Subchapter J, Radiological Health) Parts 1010 and 1040. This requires the submission of a report to the FDA.

Chapter 4: Laser Radiation Hazards

Historically because the eye is so much more susceptible to damage from laser radiation, skin damage has been less emphasized. However, repeated, or even a single exposure to certain wavelengths, can cause damage of varying degrees.

The Skin

The skin is the largest organ of the human body. It forms the outer covering for the body and protects the internal tissues from the external environment. The skin consists of two distinct layers: the epidermis, and the dermis. A third layer of tissue, located under the skin, is the hypodermis or subcutaneous layer. The epidermis has a typical thickness of 50 – 150 μm and is where tanning occurs. Tanning is the process where melanin is formed. Melanin acts as a protective pigment as it inactivates the free radicals formed by the high energy photons of UV radiation. Below the epidermis is the dermis with a thickness of 1 – 4 mm. The dermis is a supportive layer that contains collagen and elastin for strength and elasticity, as well as blood vessels and nerve cells. The subcutaneous layer consists of connective tissue, fat cells, blood vessels, and nerves.

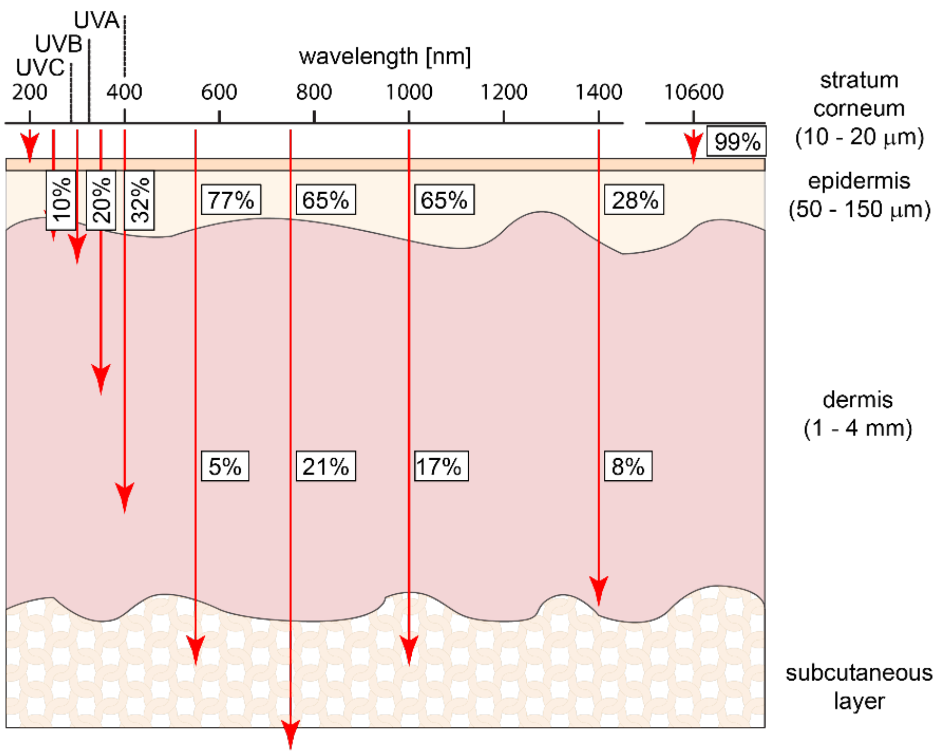

Figure 1. Schematic cross section of the skin. The percentage figures indicate fractions of absorbed radiation.

The optical properties of the skin are strongly wavelength dependent. Wavelengths in the far UV are mainly absorbed in the outermost layer of the epidermis, known as the stratum corneum. As the wavelength increases the absorption coefficient decreases so that the radiation penetrates deeper into the skin, up to the near infrared, where at around 800 nm a maximum is reached with a penetration depth of about 10 mm. At wavelengths longer than 800 nm then absorption coefficient increases so that the penetration depth decreases. There is also a strong absorption peak at a wavelength of about 3 μm and absorption are very high for wavelengths longer than 5 μm, where radiation is absorbed by the stratum corneum.

Thermal effects are the principal cause of tissue damage. Thermal damage occurs when the absorbed laser radiation causes the skin temperature to increase. The elevated skin temperature causes the tissue proteins to be altered. This reaction most closely resembles that of a deep electrical burn. Tissue damage can also occur because of photochemical effects. Photochemical damage is caused by exposure to UV radiation (200 – 400 nm) for any exposure duration.

UVC radiation is absorbed in the stratum corneum. UVA radiation causes pigment darkening but excessive exposure will cause sunburn. UVB radiation poses the greatest health risk as it can cause sunburn, accelerated skin ageing, and skin cancer.

The Eye

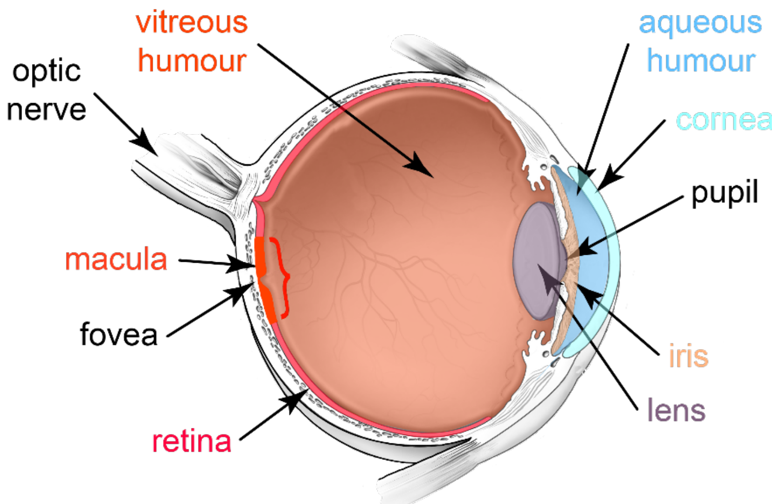

Figure 2. The human eye. Image credit: National Eye Institute

The eye has three distinct layers. The outermost layer is the sclera and is popularly referred to as the white of the eye. The choroid forms the second layer of the eye. This layer contains the blood vessels that nourish the eye. The retina is the innermost layer of the eye. In this layer are embedded the photoreceptors used in seeing.

The cornea is the transparent cover in front of the sclera and acts like a window. The cornea is the primary refracting element of the eye. The colored part of the eye is the iris and lies just behind the cornea in the choroid layer. The iris controls the amount of light entering the eye by causing the pupil to expand or contract. The pupil is the clear center part of the iris. The lens is located directly behind the pupil and focusses the light entering the eye onto the retina. The volume between the cornea and the lens is the aqueous chamber, which contains a clear watery fluid called the aqueous humour. Behind the lens, the eye is filled with the vitreous humour which gives the eye its shape and body.

Light transmitted through the eye is absorbed at the retina. The retina contains photoreceptors known as rods and cones. Rods are very sensitive and control vision in dim light. Rods are color blind; thus night vision consists of varying shades of brightness and darkness. Cones are active in bright light and are responsible for color perception in the brain. The most sensitive region of the retina is the fovea, which lies in an area of the retina called the macula.

The wavelength of the laser radiation determines which layer of the eye absorbs it. For ultraviolet (UV) wavelengths, those from 180 nm to 400 nm, the absorptance of the cornea and lens is strongly wavelength dependent. For wavelengths between 180 nm and 280 nm, referred to as UV-C, the absorption is very high, and all the radiation is absorbed by the surface layers of cornea. In the 280 nm to 320 nm range, referred to as the

UV-B, the absorption coefficient is a little lower and the rays penetrate a little deeper to be absorbed by the cornea and lens. Lens damage leads to clouding of the lens which is known as a cataract. For wavelengths between 320 nm and 400 nm, known as the UV-A, the absorption by the cornea is small and the absorption by the lens, high.

Wavelengths between 400 nm and 1400 nm are focused onto and absorbed by the retina. At these wavelengths, the irradiance incident on the eye is magnified by a factor of 100000 when it reaches the retina. For this reason, the 400 nm to 1400 nm region of the electromagnetic spectrum is known as the retinal hazard region.

Wavelengths between 1400 nm and 1000 μm are absorbed by the cornea.

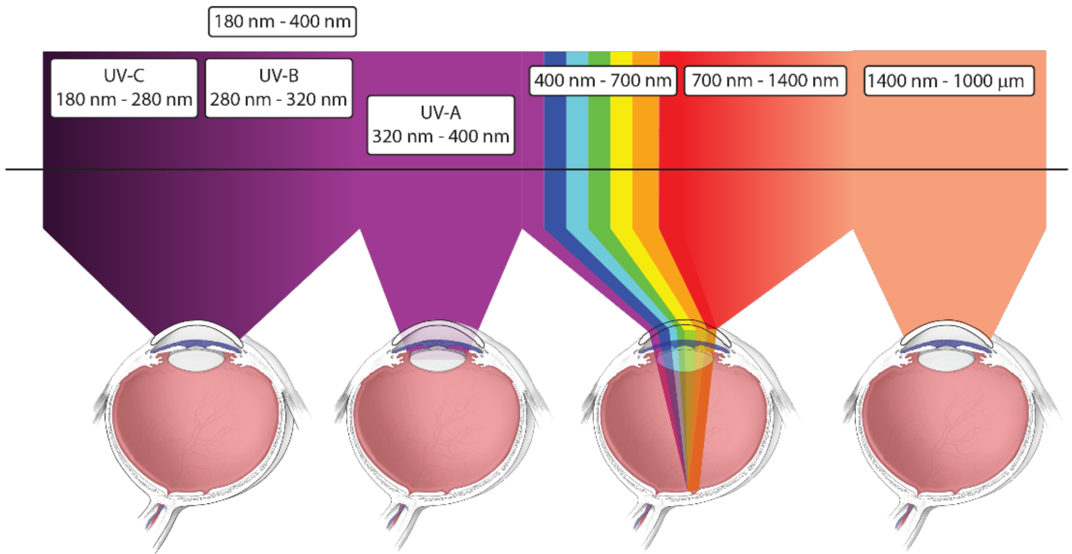

Figure 3. Absorption of laser radiation in the human eye.

Chapter 5: Laser Classifications and Hazards

A laser's hazard class is based on its ability to cause biological damage to the eye or skin. All lasers are classified based on their maximum output power or radiant energy. Factors such as its wavelength, output power, and emission duration are taken into consideration. The four classes and two sub-classes of lasers and the hazards associated with each are listed below:

ANSI Classifications

Class 1

A Class 1 laser presents no risk to the eyes, including the use of optical viewing instruments, and no risk to the skin.

These are low power lasers and laser systems that cannot emit accessible radiation levels during operation that are greater than the maximum permissible exposure (MPE). Class 1 lasers and laser systems are incapable of causing an eye injury under normal operating conditions. This class may include an embedded laser of a higher class whose beam is confined within a suitable enclosure that prevents physical access to any laser radiation.

Class 1M

A Class 1M laser presents no risk to the naked eyes and no risk to the skin. It may present a risk to the eyes when instruments such as a pair of binoculars or a microscope are used.

Class 2

A Class 2 laser presents no risk to the eyes for a short time exposure, including the use of optical viewing instruments, and no risk to the skin.

A Class 2 laser emits in the visible (400 – 700 nm) and can have a greater accessible emission limit (AEL) than the Class 1 AEL but no more than the Class 1 AEL based on a 0.25 s pulse duration. It is assumed that the aversion response time (< 0.25 s) will be sufficient to prevent any biological damage, although prolonged exposure may be dangerous. A CW Class 2 laser has an AEL of 1.0 mW.

Class 2M

A Class 2M laser is no risk to the naked eye for short time exposures and no risk to the skin. It may present a risk to the eyes when instruments such as a pair of binoculars, a telescope, or microscope are used.

Class 3R

A Class 3R laser is a low risk to the eyes and no risk to the skin. Class 3R lasers and laser systems have an accessible output between 1 and 5 times the Class 1 limit for invisible lasers and 5 mW for visible lasers.

Class 3B

A Class 3B laser is a medium risk to the eyes and a low risk to the skin. Class 3B lasers have an accessible output between the Class 3R AEL and 0.5 W.

Class 4

A Class 4 laser is a high risk to the eyes and skin.

Class 4 lasers and laser systems are those that have accessible radiant power that exceeds the Class 3B AEL (0.5 W).

CDRH Classifications

Prior to the adoption of the ANSI Z136.1 standard for classification of lasers, lasers were classified according to a standard set by the Food and Drug Administration's Center for Devices and Radiological Health (CDRH). The approximate equivalence between the ANSI and CDRH laser classes is summarized in Table 1.

CDRH	ANSI
Class I	Class 1
Class IIa	Class 2
Class II	Class 2
Class IIIa	Class 3R
Class IIIb	Class 3B
Class IV	Class 4

Table 1. ANSI and CDRH equivalent laser classes.

Class I

A Class I laser cannot emit radiation at known hazard levels.

Class IIa

A special designation based on a 1000 s exposure duration and applies only to lasers that are not intended for viewing. The upper power limit of a Class IIa laser is 0.4 μW. The emission from a Class IIa laser is defined such that the emission does not exceed the Class I limit for an emission duration of 1000 s.

Class II

A Class II laser is a visible laser that emits above the Class I level but at a radiant power less than 1 mW. The assumption is that the human aversion response to bright light will protect a person.

Class IIIa

An intermediate output power laser (1 – 5 mW CW). Only hazardous for intrabeam viewing.

Class IIIb

A moderate output power laser (5 – 500 mW CW, 10 $J.cm^{-2}$ pulsed or the diffuse reflection limit, whichever is lower). In general, a Class IIIb laser is not a fire hazard or a hazardous diffuse reflection.

Class IV

A high-power laser (greater than 500 mW CW, 10 $J.cm^{-2}$ or the diffuse reflection limit) that is hazardous to view under any condition. A Class IV laser is a potential fire hazard and skin hazard.

Chapter 6: Non-beam Hazards

Other hazards apart from those of exposure to laser radiation, may be present with many lasers and their applications. These additional hazards are often linked to the use of Class 4 lasers. However, it should be noted that additional hazards may be present with any class of laser. All potential additional hazards combined with those associated with the use of a laser, should be taken into account as part of a risk assessment. In some cases, these additional hazards may pose a more serious risk than working with the laser. Control of these additional hazards should be done at the source by elimination, if possible, followed by engineering controls, administrative controls, and personal protective equipment.

Electrical Hazards

Many lasers, especially high-power lasers, use high voltage and high current electrical power that represent an electric shock or electrocution hazard. Contact with electrical components should be avoided.

Radiation Hazards

Power supplies and other electrical equipment associated with the use of lasers may be capable of generating intense electromagnetic fields. Some lasers may have components that use radiofrequency (RF) fields. Examples of which are RF excited CO_2 lasers and RF electro-optic modulators. Some lasers may emit ultraviolet radiation from gas discharge tubes. These components should be shielded.

Fire Hazards

Class 4 laser beams represent a fire hazard. A fire can occur when a laser beam strikes combustible or flammable material such as paper, plastic, and articles of clothing. On table laser screens must be used to prevent beams from exiting the optical table. Laser barriers must also be used to block beams from exiting the nominal hazard zone. Both laser screens and laser barriers should be made from a flame-resistant material. Fabric based laser barriers must bear the California State Fire Marshal certification.

Equipment items, signal cables and plastic tubing may catch on fire when exposed to direct or scattered laser beams.

Chemical Hazards

Hazardous compressed gases are used in some laser applications, especially those involving excimer lasers. Dye lasers may use dyes that may be carcinogenic or are irritants to the eyes and skin. Solvents used for cleaning optical components can be flammable. Workers should read the Caltech Chemical Hygiene Plan for advice on chemical hazards.

Airborne contaminants may be generated when laser beams of sufficient irradiance interact with matter. These laser-generated airborne contaminants may be gaseous or particulate in nature and may pose a health concern. The size of laser generated aerosols varies in size from nanometers (10^{-9} m) to a few micrometers (10^{-6} m). Particles with diameters less than 100 nanometers are termed nanoparticles. Nanoscience is an emerging field which involves work with nanoparticles. Nanoparticles are building blocks to new materials and because of their high surface area to volume ratio are highly reactive and toxic. They can be inhaled, and may be able to pass through the skin, through the lungs and into the blood stream.

Miscellaneous Hazards

Work that involves using high pressure arc lamps, filament lamps, vessels under pressure, and capacitor banks may be an explosion hazard.

Small lengths of optical fiber material or cleaving an optical fiber may represent a sharps injury hazard.

A large optical table may represent an ergonomic hazard because of the need to reach long distances to perform alignment tasks or manipulate equipment items. Painful hand, wrist, arm, and back injuries may result from repetitive motions that occur whilst working over an optical table.

Chapter 7: Control Measures

This section describes some engineering, administrative, and procedural measures which can reduce the likelihood of a laser related incident. These measures should be considered when evaluating a facility that uses a Class 3 or Class 4 laser. Although some items are appropriate for all laser facilities, for example the posting of proper warning signs, others may not be practical for some operations.

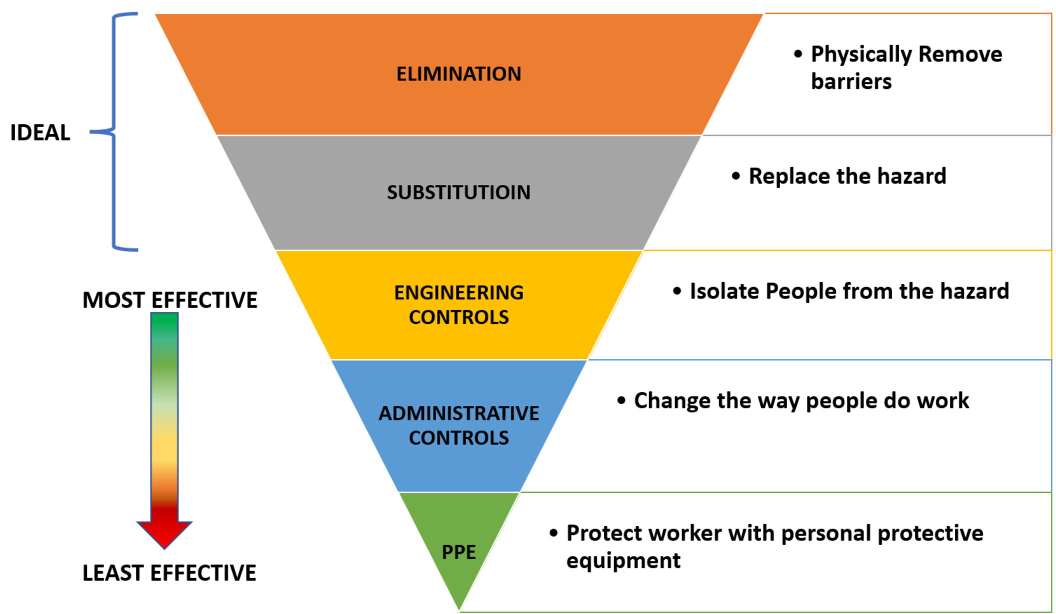

Figure 4. The hierarchy of controls in decreasing order of preference.

Beam Control

Enclose as much of the beam path as possible. If practical, the entire beam path should be enclosed. At a minimum, beam traps must be used to ensure no direct or specular reflection exits the NHZ. Beam traps must have a power handling capability suitable for the beam they are blocking.

Interlocks

Many lasers and laser systems have interlocked protective housings which prevent access to high voltage levels or laser radiation levels higher than the accessible emission limit. These interlocks are not to be bypassed without the specific authorization of the PI. Additional control measures must be taken to prevent exposure to hazards when the interlock is bypassed.

Access Control

Some form of entryway safety control must be implemented. This may be a non-defeatable entryway interlock, a defeatable entryway interlock, or by procedure. A procedure can be used when interlocks are not feasible.

Operating Procedures

Written procedures should be available which include applicable safety measures.

Warning Devices

A laser-controlled area containing a Class 3B or Class 4 laser should have an area warning device that is visible prior to entering the area. The purpose of the area warning device is to ensure that personnel entering the area are aware that a laser is in operation.

Signs and Labels

Appropriate warning signs must be posted at entryways to laser-controlled areas.
All lasers must be labelled as required by 21 CFR 1040.10. Alternatively, the lasers may be labelled in accordance with IEC 60825-1 and IEC 60601-2-22.[2] These labels indicate the class of laser, the maximum output power of the laser, and the output wavelength. In addition, aperture labels indicating each aperture where a laser beam in excess of the Class 1 accessible emission limit must be affixed in close proximity to the aperture.

Power Level

Operate the laser at the minimum power level necessary for the operation. Beam attenuators can be used to reduce the beam power. Beam traps and shutters can be used for blocking the beam. Make sure that the beam traps and shutters are rated for the laser power incident on them.

Always reduce the laser power to the minimum when performing alignment procedures.

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.

Good Work Practices

Use beam blocks or beam shields to prevent the beam from leaving the confines of the optical table if a component was accidentally removed.

[2] https://www.fda.gov/regulatory-information/search-fda-guidance-documents/laser-products-conformance-iec-60825-1-ed-3-and-iec-60601-2-22-ed-31-laser-notice-no-56

Remove unnecessary reflective items from the vicinity of the beam. Do not wear reflective jewellery such as rings and watches while working on or around the beam path.

Lenses and other optics devices may reflect a portion of the beam from either their front or rear surface. This should be considered when working with a Class 4 laser.

Keep the beam height well above or well below eye level.

Maintenance Service

Maintenance, servicing, or repair of a laser should only be performed 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 control measures appropriate to the higher class of laser must be implemented. A temporary laser-controlled area may be required.

Any laser that has been significantly modified must be re-evaluated to determine its classification.

Personal Protective Equipment

Enclosure of the laser system or the beam path is the preferred method of control since the enclosure will isolate or minimize the hazard. When other control measures do not provide adequate means to prevent access to laser radiation at levels above the MPE, it may be necessary to wear PPE such as laser eye protection, or skin protection such as clothing or gloves, in addition to equipment such as laser barriers.

Factors in addition to the required optical density that should be considered when choosing laser eye protection include the style and fit of the frame, and the visible light transmission of the eyewear.[3]

Chapter 8: Medical Examinations

Medical examinations for those working with Class 1, Class 1M, Class 2, Class 2M, and Class 3R lasers or laser systems are not required. Medical examinations for those working with Class 3B and Class 4 lasers are advisory and is left to the discretion of the PI.

Emergency and Incident Procedures

Emergencies

For any emergency at any time, call x5000 ((626) 395-5000 from an external phone) and follow the Caltech Emergency Response Guide.

Incidents Involving Lasers

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

- Turn off the laser.
- If there is an injury, call x5000 and obtain medical attention as necessary.
- If there is a fire, call x5000.
- Notify EH&S (x6727). If after hours, call x5000 and have the operator contact an EH&S representative.
- Notify the laboratory supervisor or Principal Investigator.
- Report all injuries to the Disability and Leave Administration (x4577) within 24 hours of the incident.

[3] EH&S has some sample frames available for evaluating the style and fit of available laser eye protection.

Appendix A: Laser Laboratory Layouts

EH&S is always available for consultation when it comes to setting up a laser laboratory, from layout, signage, choice of laser barrier curtains, to appropriate laser eye protection.

Laser laboratories, or laser-controlled areas, should incorporate entryway features to minimize the risk of inadvertent exposure to a laser beam when a door to the area is opened. Example layouts are illustrated below.

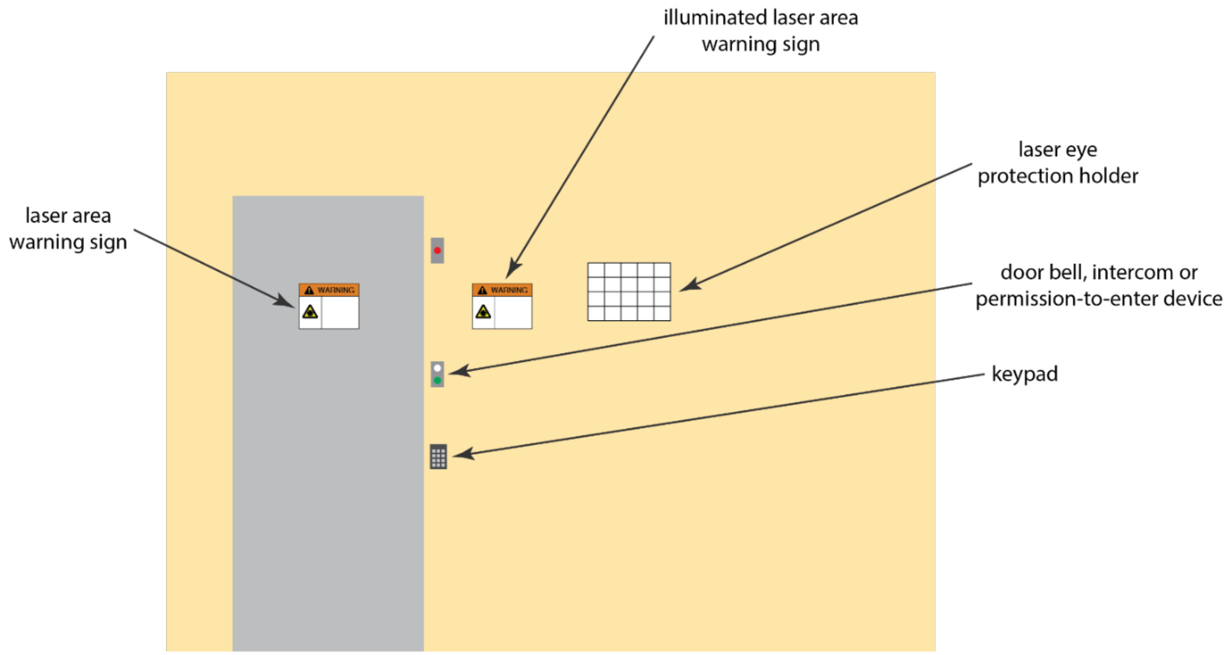

Figure 5. A Class 4 laser controlled area entrance that uses entryway interlocks. (Image credit: Fashioned after Figure 2a, Z136.8-2012).

Elements of a Class 4 laser-controlled area entryway are shown in Figure 5. These include:

- Printed laser warning sign on the door.
- Illuminated laser warning sign by the side of the door, near eye height, not more than 6 ft. from the floor.
- A laser eye protection holder.
- A keypad for interlock bypass or authorized user entry.
- A doorbell, intercom or permission to enter device.

An example floor plan that incorporates the elements of Figure 5, is shown in Figure 6. Beyond the entryway is a barrier to protect workers upon entry. It also can serve as a place to store laser eye protection, and other PPE. The barrier also prevents any stray beam from exiting the room. Beams should remain on the optical table and beam blocks should be placed at the end of beam paths.

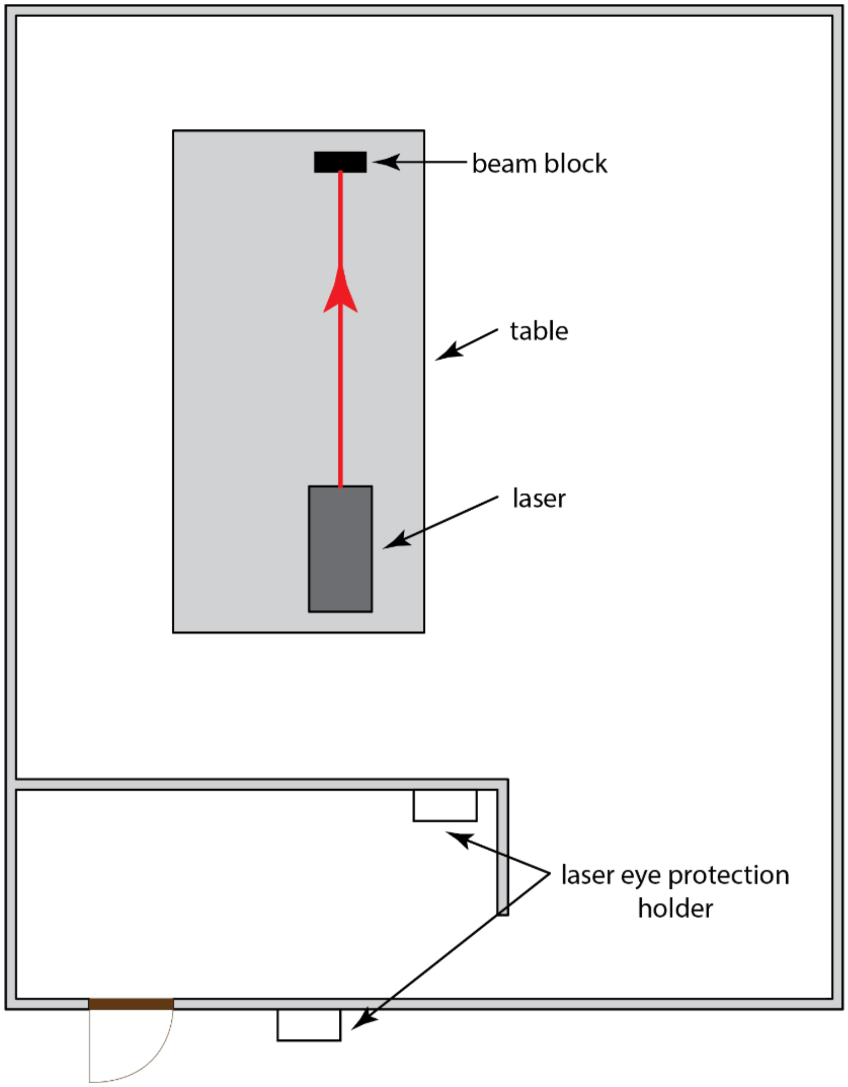

Figure 6. Entryway controls for a Class 4 laser. (Image credit: Fashioned after Figure 2c, Z136.8-2012).

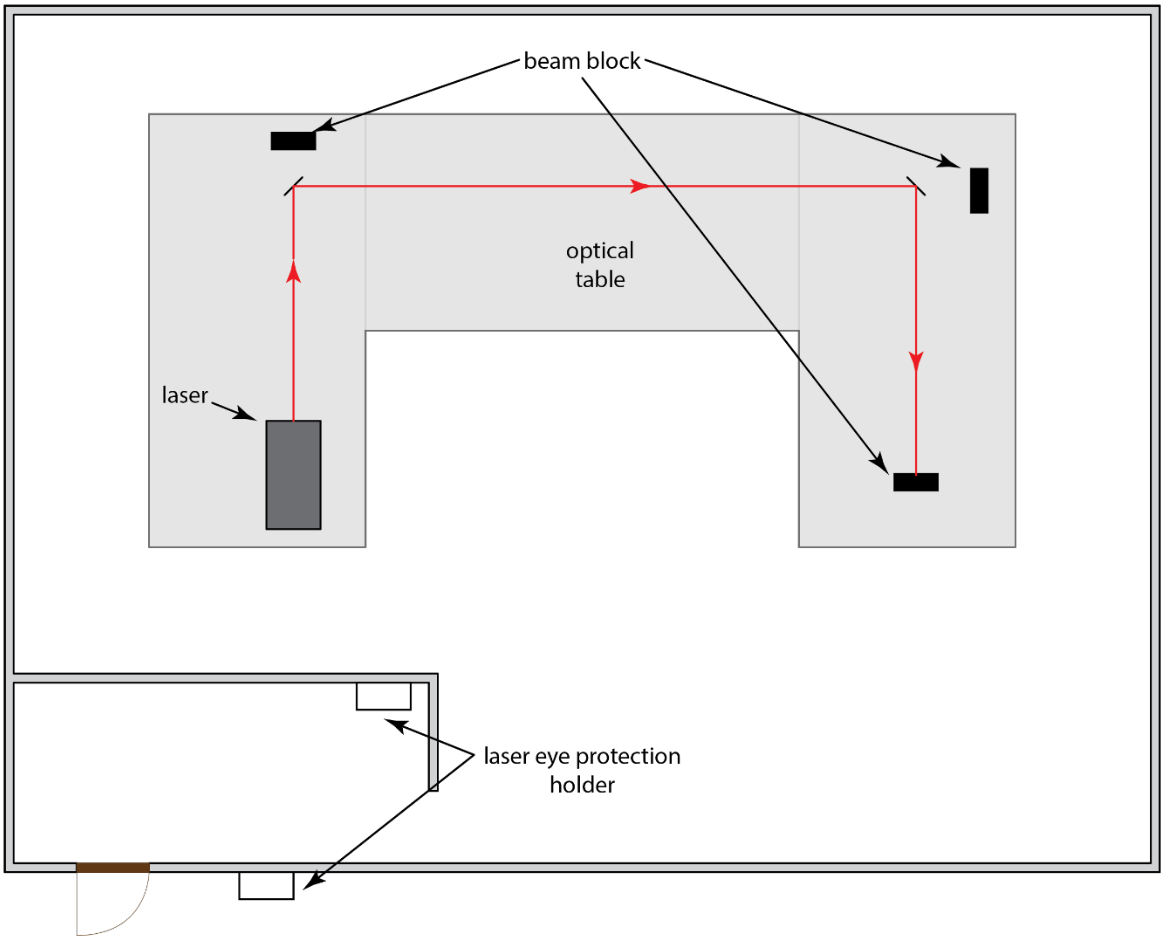

Figure 7. Another example of a Class 4 laser controlled area. (Image credit: Fashioned after Figure 2d, Z136.8-2012). Beams should be aimed away from the entryway. Beam blocks should be placed at the end of all beam paths and behind turning optics.

Appendix B: Useful Information

This appendix contains some information that may be useful and should be considered when setting up a laser laboratory.

Acronyms

AEL	Accessible emission limit
CDRH	Center for Devices and Radiological Health
CW	Continuous wave
FDA	Food and Drug Administration
FLPPS	Federal Laser Product Performance Standard
LCA	Laser controlled area
MPE	Maximum permissible exposure
NFPA	National Fire Protection Association
NHZ	Nominal Hazard Zone
NOHD	Nominal Ocular Hazard Distance
OSHA	Occupational Safety and Health Administration
PPE	Personal Protective Equipment

Chemicals

For information related to the handling and storage of chemicals, please consult the Chemical Hygiene Plan. This appendix section contains a brief reference for some general information related to chemicals and commonly encountered solvents such as acetone, isopropanol, and methanol.

- Quantities of flammable chemicals up to a total of 10 gallons (38 liters) may be kept outside a flammable storage cabinet.
- Storage of flammable liquid chemicals outside of a flammable storage cabinet should be stored in an approved flammable liquid container.
- Keep working quantities of chemicals stored to a minimum.
- Do not store flammable liquids with oxidizers or acids.

Disposal of Containers

For information about what to do with empty containers such as Winchester bottles and paint tins, please consult the Empty Container Decision Tree.

Egress

A means of egress is a continuous and unobstructed way of travel from any point in a room to an emergency exit route. The means of egress should be free and unobstructed (NFPA 101 Life Safety Code). For this reason, it is important to practice good housekeeping and not block doors (NFPA 80 Standard for Fire Doors and Other Opening Protectives).

Electronic waste

Electronic waste or e-waste pick-up services are the first and third Thursday of each month. If there is any uncertainty as to whether or not an item is classified as e-waste, please consult EH&S.

Extension cords

Do not daisy chain power cords (NEC 110).
Do not daisy chain a power cord and a power strip.

Extension cords are only meant for temporary use. Any cords in place over 90 days are considered to be permanent (OSHA 1910.305(a)(2)(i)(C)).

Fire sprinkler obstruction

Care must be taken that the spray pattern of fire sprinklers is not blocked. This becomes an issue with shelving over an optical table or optical table enclosures over 4 ft (1.2 m) in length or width.

Hazardous waste

For information related to hazardous waste, please consult the Hazardous Waste Management Guide.

The following is a non-exhaustive list of examples of hazardous waste:

- Solvents (for example acetone, toluene, ethanol, and methanol).

Laser barriers and curtains

Laser barriers and curtains must be able to withstand direct and diffusely scattered beams. They must be made from a non-flammable material, display their 100 s damage threshold level, and the California Fire Marshal certificate of flame resistance.

Hyperlinks

The following hyperlinks referred to in this document are hosted on the EH&S website www.safety.caltech.edu.

Chemical Hygiene Plan	https://safety.caltech.edu/documents/13874/Chemical_Hygiene_Plan.pdf
Empty Container Decision Tree	https://safety.caltech.edu/documents/13882/Empty_Container_Decision_Tree.pdf
E-Waste Pick-Up Services	https://www.safety.caltech.edu/root-pages/ewaste-roundup
Hazardous Waste Management Guide	https://safety.caltech.edu/documents/16478/Hazardous_Waste_Management_Guide.pdf

References

[1] ANSI Z136.1-2022 American National Standard for Safe Use of Lasers
ISBN 978-1-940168-28-9

[2] ANSI Z136.8-2021 American National Standard for Safe Use of Lasers in Research, Development, or Testing
ISBN 978-1-940168-23-4

[3] Laser Safety Tools and Training
Ken Barat
CRC Press
ISBN 978-1-4200-6854-2

[4] Safety with Lasers and Other Optical Sources A Comprehensive Handbook
David Sliney and Myron Wolbarsht
Plenum Press
ISBN 0-306-40434-6

[5] Laser Safety
Roy Henderson and Karl Schulmeister
Taylor & Francis
ISBN 978-0-7503-0859-5

[6] Laser Safety Guide
Laser Institute of America
ISBN 978-0-912035-06-2

[7] Lasers
Anthony E. Siegman
ISBN 978-0935702118

[8] Laser Electronics
Joseph T. Verdeyen
ISBN 978-0135237380

[9] Solid State Laser Engineering
W. Koechner
ISBN 978-8132204022