LASER SAFETY MANUAL

UC SANTA CRUZ

DEPARTMENT OF ENVIRONMENTAL HEALTH AND SAFETY

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§1. INTRODUCTION

Lasers have become a prominent tool in many research areas at UC Santa Cruz. If improperly used or controlled, class 3B and 4 lasers can produce severe injuries, such as blindness and burns, to operators and other personnel, including uninitiated visitors to laboratories, and can cause significant damage to property.

Class 3B and 4 laser operators must be adequately trained to ensure full understanding of the safety practices outlined in the UC Santa Cruz Laser Safety Program and the State regulations. All class 3B and 4 lasers must be registered with the EH&S office. The requirements in this Handbook only apply to class 3B and 4 lasers.

The laser safety program shall be ANSI compliant. A current copy of the standard is available for review at the Environmental Health and Safety (EH&S) office.

Each investigator who uses a class 3B or 4 laser system is encouraged to obtain a copy of the ANSI standard to keep in the laboratory. The standard contains useful charts, tables and sample calculations to help with hazard evaluations in the lab. One source for the standard is Laser Institute of America, 13501 Ingenuity Drive, Suite 128, Orlando, FL 32826.

§2. PROGRAM ORGANIZATION AND RESPONSIBILITIES

The University has established a Laser Safety Committee responsible for formulating policy related to the safe use of lasers. The Committee is also charged with monitoring the University's compliance with regard to federal and state regulations for the safe use of laser radiation. The Laser Safety Officer (LSO) is responsible for ensuring that the policies and guidelines established by the Committee are implemented. The LSO is also responsible for informing the Committee of any compliance issues at the University.

As the overall manager of the laser safety program, the LSO is responsible for monitoring laser safety practices and informing responsible persons of situations where recommended safety practices are not being followed. Monitoring is through the laser safety inspection program, which involves the LSO performing periodic inspections in all the laser laboratories. The LSO is authorized to terminate any activity or process that presents an immediate danger to life or health.

The LSO provides basic laser safety awareness training and maintains training resources and some supplies (signs, labels, etc.) to assist laser owners and operators. The LSO also maintains copies of current standards and regulations, which may be reviewed by any interested individual.

It is the policy of UC Santa Cruz that the principal investigator (PI), or faculty member in charge of a laboratory, is responsible for safety associated with laser use in his or her area.

For class 3B and 4 lasers, this responsibility includes, but is not limited to:

1. Developing written operating, safety and emergency procedures.
2. Training operators in operating, safety and emergency procedures (see §5).
3. Procuring protective eyewear appropriate for the wavelength of the laser radiation and requiring its use (see §6).
4. Proper posting of signs and warnings.
5. Registering each new laser system with EH&S.
6. Notifying EH&S when a laser system is permanently taken out of service.

Each laser operator shall follow the standard operating procedure for that specific laser. Also, he or she must inform the PI of any departure from the established procedure, including any exposure incident involving an injury from direct or reflected laser radiation. The operator and PI share responsibility for ensuring that required training is performed annually.

§3. LASER REGISTRATION

Before being placed into service, all class 3B and class 4 lasers must be registered with EH&S. This includes laser systems operated by contractors at university locations, whether indoors or outdoors.

Lasers are to be registered before being placed in service so the LSO can verify that the system is operating within University and State requirements for safe use. Before new lasers are placed into service, or when old lasers are taken out of service or relocated, EH&S must be notified promptly. Even when lasers are on loan and/or borrowed, EH&S must be notified immediately.

§4. LASER CLASSIFICATION

Lasers are divided into several 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 to the beam or from reflections from reflective surfaces.

Commercially produced lasers are classified and identified by labels affixed to the laser. In cases where the laser has been fabricated on campus or is otherwise not labeled, the LSO should be consulted on the appropriate laser classification and labeling. Lasers are classified using the physical parameters of power, wavelength, and exposure duration. A narrative description of laser classes follows.

Class 1 Laser Systems. Class 1 lasers are considered to be incapable of producing damaging radiation levels, and are therefore exempt from most control measures or other forms of surveillance.

Class 1M Laser Systems. Class 1M lasers are considered to be incapable of producing hazardous exposure conditions during normal operation unless the beam is viewed with collecting optics. They are exempt from any control measures other than to prevent potentially hazardous optically aided viewing.

Class 2 Laser Systems. Class 2 lasers emit radiation in the visible portion of the spectrum, and eye protection is normally afforded by the human aversion response (blink reflex). They may be hazardous if viewed directly for extended periods of time.

Class 2M Laser Systems. Class 2M lasers emit radiation in the visible portion of the spectrum, and protection is normally afforded by the human aversion response (blink reflex).They may be hazardous if viewed directly for extended periods of time. Class 2M lasers are potentially hazardous if viewed with collecting optics.

Class 3R Laser Systems. Class 3R laser systems have reduced control requirements and are potentially hazardous under some direct and specular reflection viewing conditions if the eye is appropriately focused and stable but the probability of an actual injury is small. These lasers will not pose a fire hazard or a diffuse reflection hazard.

Class 3B Laser Systems. Class 3B laser systems may be hazardous under direct and specular reflection viewing conditions, but are normally not fire hazards, diffuse reflection hazards, nor *laser-generated air contaminant* (LGAC) production hazard.

Class 4 Laser Systems. Class 4 laser systems are hazards to the eye or skin from the direct beam, may pose a fire hazard or diffuse reflection hazard, and may also produce LGAC and hazardous plasma radiation.

An investigator is only required to register Class 3B and 4 laser systems with EH&S. Laser systems containing embedded Class 3B or 4 lasers are exempt when the system's lower classification is established by the manufacturer according to the requirements of the Center for Devices and Radiological Health of the U.S. Department of Health and Human Services (CDRH).

§5. OPERATOR TRAINING AND REGISTRATION

Before operating a Class 3B or 4 laser system, a laser operator must meet the training and registration requirements outlined below and operational qualifications established by the PI. New laser operator must have documented EH&S training and on the job training from the Principal Investigator (PI) or the Responsible Individual (RI).

The EH&S training for new operators is only one part of the training requirement. In addition, operators must be provided with site-specific safety training regarding the procedures and equipment used in the laser laboratory. The site-specific training, by nature, is part of the standard operating procedure for a particular lab. The PI is responsible for ensuring that all individuals who work in areas where Class 3B or 4 lasers are used are provided with training that is sufficient for understanding of the risks from laser radiation.

Workers who operate lasers must also receive written safety instructions (standard operating procedures, see Appendix A), so that they can properly utilize equipment and follow all safety procedures. The PI or laboratory supervisor must retain records of lab- or equipment-specific operator training for review by the LSO during laser safety inspections.

Recurrent safety training must be provided every three years. The individual providing the lab-specific training must be designated by the PI and have knowledge adequate and appropriate to the subject matter being presented. This would include, but not be limited to: knowledge of lasers, laser safety concepts, laser safety standards, and each laser system used in the lab.

On-the-job training for Class 3B and Class 4 laser operators must include a thorough review of hazards associated with each laser that a person may operate. The training must also include the protective methods employed by the laboratory. At a minimum, the training must include basic instruction on the following topics:

1. The biological effects of laser radiation (see Appendix B).
2. The physical properties of lasers, including specular and diffuse reflection.
3. Access control.
4. Use of protective eyewear.
5. Control of related non-beam hazards, including electrical safety, fire safety, and chemical safety related to handling and storage.
6. Emergency response procedures.

During the laser safety audits, the LSO will assess the effectiveness of training provided by the investigator. Each operator must demonstrate competence with operating, safety and emergency procedures.

§6. EYE PROTECTION

Each PI must ensure that appropriate eye protection is provided to individuals working with lasers and must ensure that protective eyewear is worn. Laser protective eyewear is specific to the types of laser radiation in the lab. Windows where Class 3B or 4 beams could be transmitted, causing hazards in uncontrolled areas, are to be covered or otherwise protected during laser operation. The following guidelines are suggested for maximum eye protection.

1. Whenever possible, confine (enclose) the beam (e.g., use beam pipes) and provide non-reflective beam stops to minimize the risk of accidental exposure or fire.

2. Use fluorescent screens or similar "targets" to align the beam.
3. Avoid direct intra-beam exposure to the eyes. Direct viewing must not be used to align laser optical systems.
4. Use the lowest laser power possible for beam alignment procedures.
5. Whenever possible, use Class 2 lasers for preliminary alignment procedures.
6. Keep optical benches free of unnecessary reflective items.
7. Confine the beam to the optical bench unless necessary for an experiment.
8. Whenever possible, keep the beam in a single plane on the bench.
9. Use barriers at the sides of benches or other enclosures.
10. Do not use room walls to align Class 3B or 4 laser beams.
11. Use non-reflective tools. Remember that some tools that seem to be non-reflective for visible light may be very reflective for the non-visible spectrum.
12. Do not wear reflective jewelry when working with lasers. Metallic jewelry also increases shock hazards.

Protective glasses must be worn whenever working with Class 3B or 4 lasers with open beams or when reflections can occur. In general, laser glasses may be selected on the basis of protection against reflections, especially diffuse reflections. Protective eyewear is designed to provide protection to a level where the natural aversion reflex will prevent eye injuries. Eye protection may also be selected to protect against stray reflections.

Factors to consider in selection of Laser protective eyewear include the following:

1. Wavelength or spectral region of the laser radiation.
2. Optical density at the particular wavelength(s).
3. Maximum irradiance (W/cm^2) or beam power (W) against which the eyewear provides protection for at least 5 seconds.
4. Type of laser system.
5. Power mode, single pulse, multiple pulse or CW, and the strength of the pulse, i.e., both peak and average power.
6. Possibilities of reflections, specular and diffuse.
7. Field of view provided by the design.
8. Availability of prescription lenses or sufficient size of goggle frames to permit wearing of prescription glasses inside of goggles.
9. Comfort.
10. Ventilation ports to prevent fogging.
11. Effect upon color vision.
12. Absence of irreversible bleaching if filter is exposed to high peak irradiances.
13. Impact resistance.
14. The ability to perform required tasks while wearing eyewear.

§7. OPERATIONAL REQUIREMENTS

The PI must provide written operating and safety procedures to personnel who operate lasers. These procedures are to include all restrictions required for the safe operation of each laser. They may incorporate sections of the manufacturer's technical manuals if those documents are available to the operator. For class 4 laser systems, written alignment procedures must be available and used by anyone who aligns the optics.

In each laser use location, a hazard evaluation must be performed when a new system is commissioned to determine where an individual may exceed the maximum permissible exposure (MPE). This hazard evaluation, along with the guidance in the current ANSI standard, will determine where and what warning signs are to be posted. For systems already in use without a hazard evaluation having been performed, the evaluation shall be completed as soon as practicable. The Laser Safety Officer will normally perform the hazard evaluation, based upon laser parameters provided by the PI. The PI is responsible for proper posting of caution signs.

For laser systems with unenclosed beam paths, the hazard evaluation will include the potential hazards that may be encountered from reflective surfaces. Reflective surfaces shall be excluded from the beam path at all points where the laser radiation exceeds the MPE. No individual may be exposed to levels of laser radiation higher than the MPE. Measurements and calculations performed to determine MPE limits will be made in a manner consistent with the criteria contained in the current ANSI standard, a copy of which is available for review at EH&S.

No laser may be operated or made ready for operation until all individuals have vacated the area along all points of the beam path where the laser radiation will exceed the MPE, unless the individuals are wearing appropriate protective devices. In crowded laboratories this may require the use of curtains designed to block laser radiation. Alignment of laser optical systems shall be performed in a manner that assures that no one is exposed to laser radiation above the MPE. A controlled area must be established when exposure to laser radiation in excess of the MPE limit is possible. Access to the controlled area shall be only by permission of an experienced trained operator.

The laser system shall be operated at all times under the direct supervision or control of an experienced, trained operator who maintains visual surveillance of conditions for safe use and can terminate laser emission in the event of any unsafe condition of use. Unattended use of the laser system can be permitted only when the PI has implemented control measures that provide adequate protection and has provided laser safety training to those who may enter the laser controlled area during times of unattended use. Engineered control measures are always preferred over procedural controls.

§8. WARNING SIGNS AND LABELS

A controlled area, in which access is restricted for the purpose of protection from laser radiation, must be conspicuously posted with caution signs as prescribed for the class of the laser. Because the warning sign must have certain prescribed wording at specific locations depending on the class and type of laser, these signs should be obtained from EH&S. Additionally, the aperture through which the laser radiation is emitted must be labeled with a prescribed warning that laser radiation is emitted from the aperture.

For enclosures that are designed to be removed during normal operations, maintenance or servicing and that would permit human access to the beam, an additional warning sign must include a prescribed warning that there is laser radiation when opened. The specific requirements for the warning signs and labels may be found in the current ANSI standard.

§9. NOTIFICATIONS AND REPORTS

Each laser investigator must **immediately** notify EH&S by telephone at **9-2553** of any incident involving exposure to laser radiation that has caused injury to an individual in the course of use, handling, operation, manufacture or discharge of a laser system. If the incident took place after regular business hours, call dispatch at **9-4861** and ask the operator to page the EH&S person on duty.

After the initial notification, the PI must prepare a written report of the incident and submit it to the LSO within two weeks after the incident. The report must include:

1. The full name of each exposed individual.
2. An estimate of each individual's exposure (in multiples of MPE), if possible.
3. The levels of laser radiation involved.
4. The cause of the exposure.
5. A description of any injuries.
6. Corrective actions to prevent a recurrence.

§10. ENFORCEMENT POLICY

The policies set forth in this Handbook are intended to ensure that UC Santa Cruz is in compliance with all regulatory requirements regarding the safe use of lasers. Failure to comply with these policies could jeopardize all UCSC research involving laser radiation.

Any non-compliance identified by the LSO must be corrected promptly. Failure to correct a violation in a timely manner is considered a willful disregard for safety.

APPENDIX A

Sample Procedure #1

Laser Safety

Purpose: To define the area in which control measures shall be applied and to describe the control measures necessary in order to maintain a safe environment for use of the laser system.

Policy: Class 3B and Class 4 lasers shall be operated in areas where traffic flow and compliance with all safety procedures can be monitored. No individual's exposure may exceed the Maximum Permissible Exposure (MPE) for the wavelength and power of the beam.

Procedure:

1. Appropriate warning signs shall be posted at eye level on all doors that access a room where a laser is to be operated. These signs shall state all required information, along with an additional sign, such as a lighted sign, to show when a laser is being operated.
2. Safety goggles labeled with the appropriate wavelength and optical density shall be available at the entry where each door sign is posted.
3. Glass windows shall be covered with shades or filters of appropriate optical density whenever a laser system is operational.
4. All safety procedures shall be followed during service, maintenance and demonstrations.
5. No one shall be allowed into a laser room unless properly authorized and protected.
6. Laser keys shall be kept in a secured area and signed out only by those authorized to do so.
7. During an emergency, STOP and ask for help if you are not sure how to proceed. Above all, do no harm.

Sample Procedure #2

Ocular Safety

Purpose: To prevent ocular injuries to personnel working with Class 3B and Class 4 lasers.

Policy: Within the controlled area, all personnel shall adhere to appropriate eye protection procedures during all laser applications. Under some conditions, the controlled area may include the entire room in which the laser procedure is performed. Under those conditions, the ocular safety procedures listed below apply to the entire room. In health care facilities, ocular safety procedures shall also apply to the patient receiving laser treatment. All personnel involved in maintenance and demonstrations of laser systems shall follow all ocular safety procedures whenever a laser is in operation in the facility.

Procedure:

1. Appropriate eyewear shall be worn by everyone in the controlled area while the laser is in operation. Appropriate eyewear consists of glasses or goggles of sufficient optical density to prevent ocular damage at the respective laser wavelength. Exception to this is the operator looking through an attached microscope with a lens that has the appropriate optical density for the laser in use.
2. Prior to use, the operator and ancillary personnel shall be responsible for selecting and examining eyewear for comfort, proper fit, and presence of labels describing

both wavelength and proper optical density.

3. If eyewear is damaged, it shall not be worn and a report shall be made to the laser safety officer.
4. Contact lenses are not acceptable as protective eyewear. Prescription lens wearers shall use appropriate laser safety eyewear.
5. All goggles shall have side shields to protect from peripheral injury and impact.
6. Any articulated arm that is not shuttered shall be capped when not connected to the hand piece or the operating microscope.
7. The laser system shall be placed in standby mode when delivery optics are removed away from the target.
8. In health care facilities, patients shall be fitted with appropriately labeled eyewear, or have their eyes covered with wet cloth pads or towels. Metal or dry materials shall be placed on the patient's face or eyes only when indicated.

APPENDIX B

Biological Effects of Laser Radiation

Biological effects of laser radiation are generally caused by thermal and photochemical effects. Because of the high radiant power of many laser systems, a very short exposure can cause a lasting effect. Most accidental injuries are caused by unexpected reflections and the damage usually occurs before anyone knows it is happening.

Although class 4 lasers can cause damage to the skin through thermal effects, the primary hazard from laser radiation is to the eye. The type, location and severity of the ocular damage vary with the energy, power and angle of incidence of the beam on the eye tissue. The most significant variation is by wavelength.

The electromagnetic spectrum extends from gamma rays at very short wavelengths to radio waves at very long wavelengths. The visible spectrum is just a narrow slice of the whole spectrum, with blue light at the shortest wavelengths and red light at the longest wavelengths; below the region of the visible wavelengths is the ultraviolet region (UV); above the visible wavelengths is the infrared region (IR), which is divided into the near-infrared region (NIR) and far-infrared region (FIR). Lasers operate in the UV, visible, NIR and FIR regions, and each spectral region presents unique safety issues.

UV light ranges from 200 nm (and less) to 400 nm. It has the potential for photochemical damage to both eyes and skin. This means that it must be handled in a manner that avoids long term hazardous exposures at low levels (such as skin cancer and cataracts).

Visible light has a wavelength range from 400 nm to 700 nm and can be seen by the eye; the fact that you can see this light helps you avoid hazardous exposures. However, it must be emphasized that visible light can lead to permanent severe retinal effects.

The near-infrared region ranges from 700 nm to 1400 nm. It cannot be seen because the retinal receptors do not work at these wavelengths, but the optical elements of the eye transmit and focus the NIR wavelengths on the retina. This produces an invisible retinal hazard and the potential for serious eye injury; the most stringent laser safety precautions are required in this range of wavelengths. Several of the most useful lasers used in research are NIR lasers.

The far-infrared spectrum ranges from 1400 nm up to 10,600 nm and more. These wavelengths are completely absorbed by water in the cornea before any of the light reaches the retina; this protects the retina from damage. Wavelengths in the FIR can damage other parts of the eye, but the absorption is spread over a larger area resulting in a larger allowed exposure. Besides, since the cells involved are replaced rapidly, these effects are generally considered to be temporary.

The severity of the retinal damage depends on where the incident beam strikes the tissue at the rear of the eye; cones are used for color and detail, and if these are damaged, they recover slowly (if at all); rods are used for low-light vision, and recover better from severe damage. Lesions in the retina are often permanent, causing a spot to appear in every image. Large amounts of energy deposited by ultra-violet radiation to the lens can cause opacity and cataracts.

APPENDIX C. GLOSSARY

ANSI	American National Standards Institute
EH&S	Environmental Health and Safety Office, 9-2553
FIR	Far Infra-Red
FWHM	Full Width at Half Maximum
IR	Infra-Red
LSC	Laser Safety Committee
LSO	Laser Safety Officer
µm	Micrometer (micron), 10^{-6} m
MPE	Maximum Permissible Exposure
NIR	Near Infra-Red
nm	Nanometer (10^{-9} meter)
NHZ	Nominal Hazard Zone
NOHD	Nominal Ocular Hazard Distance
OSP	Operational Safety Procedures
UV	Ultra-Violet
SOP	Standard Operating Procedures