Laser

Safety

Manual

University of Hawaii

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1. INTRODUCTION

The purpose of this manual is to ensure the safe use of lasers in research by identifying hazards, providing recommendations for proper use, and for laser safety training for individuals using lasers. To achieve this goal, the University has adopted the American National Standard for the Safe Use of Lasers, ANSI Z136.1, and ANSI Z136.5, Safe Use of Lasers in Educational Institutions, recognized as minimum standards for laser safety, as well as other applicable regulations.

The primary objective of the laser safety program is to ensure that no laser radiation in excess of the maximum permissible exposure (MPE) limit reaches the human eye or skin. Additionally, the program is designed to ensure that adequate protection against collateral hazards is provided. These collateral hazards include the risk of electrical shock, fire hazard from a beam or from use of dyes and solvents, and chemical exposures from use of chemicals and vaporization of targets.

In order to implement the program properly while giving the greatest possible latitude to the researcher and instructional laboratories, all laser operations at the University must be reviewed and approved by the Laser Safety Officer (LSO) and the Laser Safety Committee (LSC).

2. RESPONSIBILITIES

2.1 Principal Investigators

The primary responsibility for ensuring the safe use of lasers belongs to Principal Investigators (PI). 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.
- Laser manufactured or modified at UH are properly classified and labeled.
- Proper laser warning signs are posted.
- All Class 3b and 4 lasers have been registered with the Radiation Safety Program (RSP).

2.2 Laser Operators

Persons operating lasers are responsible for:

- Following proper operating and safety procedures and only performing operations authorized by the PI.
- Restricting access to controlled areas during operations.

- Keeping the PI fully informed of any departure from established safety procedures, including notification of an exposure incident.
- Attending the University's Laser Safety Training program.
- Registering for the Medical Surveillance program.

2.3 Environmental Health and Safety Office – Radiation Safety Program

- Conduct lab inspections to ensure that safety requirements are followed.
- Provide assistance in evaluating and controlling hazards.
- Maintain all records of lasers and laser operators.
- Conduct or coordinate laser safety training for personnel who are assigned to an area where lasers are operated.
- Participate in accident investigations involving lasers.
- Coordinate the Medical Surveillance program.

3. PERSONNEL TRAINING AND QUALIFICATIONS

3.1 All personnel working with or frequenting areas where Class 2, 3, and 4 lasers are used shall be given training in the hazards associated with the devices. The Laser Safety training course is presented by the RSP. On-the-job training is to be provided by knowledgeable project personnel.

3.2 Only qualified and authorized persons are permitted to operate a laser. The PI determines the person's operational qualification from departmental or technical training or other acceptable learning experience.

3.3 Before operating a Class 3 or Class 4 laser, or a Class 1 laser system that encloses a Class 3 or Class 4 laser, a person must:

- Review the Laser Safety Manual
- Receive from the lab supervisor or PI a thorough review of the laser equipment to be used and the administrative, alignment and standard operating procedures (SOPs).
- Review the operating and safety instructions furnished by the manufacturer.

3.4 Laser users must participate in retraining at least once every three years.

4. MEDICAL SURVEILLANCE

4.1 Individuals operating Class 1, 2, and 3a lasers are exempt from eye exams.

4.2 Eye exams are to be provided upon the request of personnel who work in areas where they may be exposed to Class 3b and 4 laser beams. All users are to be informed that they may have such exams, or that they have the right to waive a pre-placement eye examination in areas where such exams are customarily required. Costs of pre-placement eye examination are charged to projects or departments. Also, users are to be informed by the PI that they have the right to consult a physician, if they believe they may have been injured by a laser beam.

4.3 An eye exam is required in the event of exposure or suspected exposure incident. Contact the Radiation Safety Program at 956-6475.

4.4 An examination is recommended when an individual terminates his or her work in a laser laboratory or when it has been a year since any previous laser use. The examination includes:

- Medical history
- Visual acuity
- External ocular examination
- Examination by slit lamp
- Ophthalmoscopy
- Manifest reaction, when indicated
- Fundus photographs with dilation

5. EXPOSURE INCIDENTS

5.1 If an exposure incident occurs, the LSO must be notified by the PI or the person operating the laser.

5.2 If the incident causes an injury or could potentially have caused an injury, the person or persons who have received an exposure should inform their supervisor and have an eye examination.

5.3 RSP will conduct an investigation and an incident report will be written.

6. CLASSES OF LASERS

All lasers and laser systems and/or devices in the United States are classified into one of several classes. Corresponding labels are affixed to the laser or laser system.

These laser classes are contained in ANSI Z136.1 American National Standard for the Safe Use of Lasers, ANSI Z136.5 Safe Use of Lasers in Educational Institutions, and Laser Products Performance Standard, 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.

<u>Class 1 Lasers</u>

Class 1 lasers do not emit harmful levels of radiation and are, therefore, exempt from control measures. As a matter of good practice, unnecessary exposure to Class 1 laser light should be avoided.

Class 2 Lasers

Class 2 lasers emit accessible laser light in the visible region and are capable of creating eye damage through chronic exposure. In general, the human eye will blink within 0.25 second when exposed to Class 2 laser light. This blink reflex provides adequate protection. It is possible, however, to overcome the blink reflex and to stare into a Class 2 laser long enough to cause damage to the eye. Class 2 lasers have power levels less than 1 mW. Class 2 lasers are commonly found in alignment applications.

Class 2a Lasers

Class 2a lasers are special-purpose lasers not intended for viewing. Their power output is less than 1 mW. This class of lasers causes injury only when viewed directly for more than 1,000 seconds. The 1,000 seconds is spread over an 8-hour day, not continuous exposure. Many bar-code readers fall into this category.

Class 3a Lasers

Class 3a lasers and laser systems are normally not hazardous when viewed momentarily with the naked eye, but they pose severe eye hazards when viewed through optical instruments (e.g., microscopes and binoculars). Class 3a lasers have power levels of 1-5 mW.

Class 3b Lasers

Class 3b laser light will cause injury upon direct viewing of the beam and specular reflections. The power output of Class 3b lasers is 5-500 mW cw or less than 10 J/cm2 for a ¼-s pulsed system. Specific control measures covered in this chapter must be implemented.

Class 4 Lasers

Class 4 lasers include all lasers with power levels greater than 500 mW cw or greater than 10 J/cm2 for a ¼-s pulsed system. They pose eye hazards, skin hazards, and fire hazards. Viewing of the beam and of specular reflections or exposure to diffuse reflections can cause eye and skin injuries. All of the control measures explained in this document must be implemented.

7. OTHER LASERS

Embedded Lasers

Lasers are embedded in laser products or systems with a lower hazard rating. For example, laser printer, CD players, and laser scanning confocal microscopes are Class 1 laser products, but they contain Class 3 or Class 4 lasers.

When the laser system is used as intended, the controls for the system's class apply. When the system is opened (e.g., for service or alignment) and the embedded laser beam is accessible, a temporary control area must be established. The controls for the temporary control area must be based on the classification of the embedded laser. Adequate controls are determined by the user and LSO. Confirmation of a system classification is the responsibility of the LSO. An abbreviated SOP may be required, as in the case of such commercially available enclosed laser systems as a Laser Scanning Confocal Microscope.

Invisible lasers

Since IR and UV lasers produce no visible light, this can contribute to their hazard potential and the use of laser eyewear that will protect against worst case exposures is recommended at all times.

- Infrared Lasers

Infrared laser beam (>0.7 um) must be terminated by a highly absorbent, non-specular backstop. Note that many surfaces that appear dull are excellent IR reflectors and would not be suitable for this purpose. Beam terminators for Class 4 IR laser beams must be made of fireproof materials.

- Ultraviolet Lasers

UV radiation causes photochemical reactions in the eyes and skin, as well as in materials that are found in laboratories. The latter may cause hazardous by-products such as ozone and skin-sensitizing agents. The direct beam and scattered radiation should be shielded to the maximum extents practicable to avoid such problems. The use of long-sleeved coats, gloves, and face protectors is recommended. Some medications can increase one's risk to UV. Contact the LSO for a detailed analysis and measurement of scattered UV radiation.

"Homemade lasers"

It is the responsibility of the Principal Investigator who operates or supervises the operation of a "homemade" laser to classify and label the laser he/she controls. Refer to either ANSI Z136.1-2000 or contact RSP.

8. LASER HAZARDS

EYE

Different structures of the eye can be damaged from laser light, depending on the wavelength, beam divergence, and exposure duration. For pulsed lasers, the parameter include pulse length, pulse repetition frequency, and pulse train characteristics.

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 the far-infrared (>1400 nm) regions are primarily absorbed by and cause damage to the cornea. In the near-infrared 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 the 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 electrocution hazard. Proper lockout procedures should be followed when working on high-voltage components. (See HIOSH Lockout Program in Appendix ____).

FIRE

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

9. ANCILLARY HAZARDS

HAZARDOUS MATERIALS

Laser laboratories contain many of the same hazards found in many chemical laboratories and therefore, the same precautions should be taken. (See UH Chemical Hygiene Plan).

Many dyes and solvents used for dye lasers are toxic and some may be carcinogenic. Some recommended controls for laser dyes from a report entitled, Laser Dyes, Hazards and Controls, from Lawrence Livermore National Laboratory (LLNL) are included below.

Handling Laser Dye—See Appendix C

Potential exposures to dyes and solvents are most likely to occur during solution preparation. Failure of the dye laser's pressure system can also expose personnel, and can cause fires.

Recommended controls for handling dyes, preparing solutions, and operating dye lasers are as follows:

- During solution preparation, dye and solvent mixing should be done inside a fume hood. Mutagenic dyes should be weighed out in a glove box.
- Dampers can be used to adjust airflow turbulence to a minimum during delicate weighing out of fine dye powders. If, because of airflow, dyes cannot be weighed out accurately, scales should be located inside suitable enclosures to limit the potential airborne hazards. Avoid creating dust.
- Gloves, lab coats, and eye protection should be worn. Avoid skin contact.
- During dye laser disassembly, use proper personal protective equipment and be alert to contaminated parts, e.g., dye filters. Be sure to cap off dye solution lines.
- Don't smoke, eat, or drink in dye mixing areas.
- Dye pumps and tubing/piping connections should be designed to minimize leakage. Pumps and reservoirs (notorious for leaking) should be set inside spill pans. Tubing/pipe systems should be pressure-tested prior to using dye solutions and periodically thereafter. Dye solutions can be corrosive. Stainless steel heat exchangers are recommended.
- For waste disposal and spill, emphasis should be placed upon solvent characteristics since dye concentrations are low.
- Keep dye handling areas clean and segregate from other operations. Fortunately, the brilliant colors of dyes enable users to see spills.

Keep all containers of solvents, solutions, and dyes tightly closed, clearly labeled, and stored in a cool, dry place. Keep oxidizers away. Appropriate dye container should be labeled.

HAZARDOUS GASES AND CRYOGENIC MATERIALS

Laser interaction with certain materials may produce toxic fumes which must be properly vented. Hazardous gases may also be used in laser applications, i.e., excimer lasers (fluorine, hydrogen chloride).

Air contaminants may be generated when certain Class 3b and Class 4 laser beams interact with matter. When target irradiance reaches a given threshold of approximately 10 to the 7th W/cm2 target materials, including plastics, composites, metals, and tissues, may liberate toxic and noxious airborne contaminants. When laser beams are sufficiently energized to heat up a target, the target may vaporize, creating hazardous fumes or vapors that may need to be captured or exhausted.

When targets are heated to very high temperatures, as in laser welding and cutting, an intense bright light is emitted. This light often contains large amounts of short wavelength or blue light, which may cause conjunctivitis, photochemical damage to the retina, and/or erythema (sunburn-like reactions) to the skin.

Cryogenic fluids are used in cooling systems of certain lasers, and can create hazardous situations. As these materials evaporate, they can create oxygen deficient atmospheres and an asphyxiation hazard by replacing oxygen in the air. Adequate ventilation must be provided. Cryogenic fluids are potentially explosive when ice collects in valves or connectors that are not specifically designed for use with cryogenic fluids. Condensation of oxygen in liquid nitrogen presents a serious explosion hazard if the liquid oxygen comes in contact with any organic material. While the quantities of liquid nitrogen that may be used are usually small, protective clothing and face shields must be used to prevent freeze burns to the skin and eyes.

RADIOFREQUENCIES (RF)

Some lasers contain RF excited components as plasma tubes and Q switches. Unshielded and loosely tightened components may allow RF fields to leak from the device and expose staff.

ERGONOMICS

Ergonomic problems can arise from a laser operation by causing awkward unique arm and wrist positions. If such repetitive deviations occur for prolonged periods of time, medical problems such as repetitive strain injuries may arise. The EHSO can help the user develop appropriate control measures.

SEISMIC SAFETY

PLAMA EMISSIONS

Interactions between very high power laser beams and target materials may in some cases produce plasmas. The plasma generated may contain hazardous “blue light” and UV emissions, which can be an eye and skin hazard.

EXPLOSION HAZARD

High-pressure arc lamps, filament lamps, and capacitors may explode if they fail during operation. These components are to be enclosed in a housing which will withstand the maximum explosive forces that may be produced. Laser targets and some optical components also may shatter if heat cannot dissipate quickly enough. Consequently, care must be used to provide adequate mechanical shielding when exposing brittle materials to high intensity lasers.

IONIZING RADIATION (X-RAYS)

X-rays could be produced from two main sources, high voltage vacuum tubes of laser power supplies such as rectifiers, thyratrons and electric discharge lasers. Any power supplies that require more than 15 kilovolts may produce enough x-rays to be a health concern.

10. GENERAL LASER SAFETY RECOMMENDATIONS AND REQUIREMENTS

EYE PROTECTION

Principal Investigators or staff who operate or supervise the operation of a laser are responsible for determining the need for laser eye protection for a particular laser. If required, eye protection will be provided by the supervisor for staff and visitors to the area.

The following guidelines are suggested for maximum eye protection:

- Whenever possible, confine (enclose) the beam (e.g., use beam pipes), provide non-reflective beam stops, etc., to minimize the risk of accidental exposure or fire. Use fluorescent screens or similar "targets" to align the beam; avoid direct intrabeam exposure to the eyes. Laser optical systems should not be aligned by direct viewing
- Use the lowest laser power possible for beam alignment procedures. Use Class 2 lasers for preliminary alignment procedures, whenever possible. Keep optical benches free of unnecessary reflective items.
- Confine the beam to the optical bench unless necessary for an experiment, e.g., use barriers at the sides of benches or other enclosures. Do not use room walls to align Class 3b or Class 4 laser beams.
- 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.
- Do not wear reflective jewelry when working with lasers. Metallic jewelry also increases shock hazards.

Wear protective glasses whenever working with Class 4 lasers with open beams or when reflections can occur. In general laser glasses may be selected on the basis of protecting against reflections – especially diffuse reflections, and providing protection to a level where the natural aversion reflex will prevent eye injuries, unless intrabeam viewing is required.

Generally, protective eyewear may be selected to be adequate to protect against stray reflections. Wearing such glasses allows some visibility of the beam, preventing skin burns, making more likely that persons will wear the eye protection. Also, the increased visibility afforded by this level of protection decreases potential for other accidents in the lab, i.e., tripping, etc. Glasses designed for limited protection, are not appropriate for intrabeam viewing or for highly specular reflections. Glasses with side shields are recommended to prevent injuries from stray reflections from striking reflective objects.

For double wavelength systems, glasses (goggles) can be obtained with flip-down lenses to protect against the two different wavelengths. Where invisible beams and visible beams are produced by a laser, the inner lens can be designed to protect against the invisible radiation and the flip-down lens to protect against the visible laser radiation.

Protective eyewear can become damaged or deterioration. You should include a periodic inspection of eyewear.

11. LASER ACCIDENTS

The laser user can prevent laser accidents. Sixty percent of laser accidents in research settings occur during the alignment process. If individuals suspect they have received a laser hit, they should contact the laser safety officer. Unfortunately, experience has demonstrated that most laser injuries go unreported for 24-48 hours by the injured person. This is a critical time for treatment of the injury.

Some common practices that are causes of preventable laser accidents are:

- Not wearing protective eyewear during alignment procedures
- Not wearing protective eyewear in the laser control area
- Misaligned optics and upwardly directed beams
- Equipment malfunctions
- Improper methods of handling high voltage
- Available eye protection not used
- Intentional exposure of unprotected personnel
- Lack of protection from non-beam hazards
- Failure to follow SOP
- Bypassing of interlocks, door and laser housing
- Insertion of reflective materials into beam path
- Lack of pre-planning
- Turning on power supply accidentally
- Operating unfamiliar equipment
- Wearing the wrong eyewear

Laser alignment guidelines to help prevent accidents:

- No unauthorized personnel will be in the room or area
- Laser protective eyewear will be worn.
- All laser users must attend the UH laser safety class
- The individual who 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.
- To reduce accidental reflections, watches and reflective jewelry should be taken off before any alignment activities begin.
- Beam blocks must be secured
- A solid stray beam shield must be securely mounted above the area to prevent accidental exposure to the laser beam
- All laser users must receive an orientation to the laser use area by an authorized laser user of that area.

- Laser users must have had their baseline eye examination prior to performing any alignments.
- The lowest possible/practical power must be used during alignments.
- When possible, a coarse alignment should be performed with a HeNe alignment laser.
- Have beam paths at a safe height, below eye level when standing or sitting, not at a level that tempts one to bend down and look at the beam. If necessary, place a step platform around the optical table.

12. ENGINEERING CONTROLS FOR LASER SYSTEMS

It is University policy that lasers shall not be modified to defeat the engineering safeguards without review and approval of the Laser Safety Committee to ensure that appropriate controls are instituted. Appropriate design standards for laser systems are as follows:

- Lasers should be equipped with a protective housing, an aperture that is clearly identified and a clearly marked switch to deactivate the laser or reduce its output to less than maximum permissible exposure (MPE). If this is not possible, Laser Safety should be consulted to assess the hazards and to ensure that appropriate controls are in place. Such controls may include, but not be limited to the following:

    - Access restriction
    - Eye protection
    - Area controls
    - Barriers, shrouds, beam stops, etc.
    - Administrative and/or procedural controls
    - Education and training

- Protective housings should be interlocked for Class 3a, 3b and 4 lasers. Commercially manufactured lasers come equipped with such interlocks.
- A keyed master switch should be provided for Class 3b or 4 lasers. Lasers should be stored or disabled by removing the key when the laser is not in use for prolonged periods.
- Viewing ports and collecting optics shall provide adequate protection to reduce exposure at viewing position to, at, or below the MPE level.
- If the beam path is not enclosed, then the Nominal Hazard Zone (NHZ), the areas where the exposure levels exceed maximum permissible exposure level, need to be assessed and a controlled area established. LSP will assist in this process. See Section on “Control of Laser Areas” below for more information.
- If the beam is totally enclosed, the laser will meet the standard of a Class 1 laser (all areas below MPE), and no further restrictions are required.

- Commercially manufactured Class 3b and Class 4 lasers must come equipped with a jack for external interlocks.
- Laser should be stopped in a suitable “beam stopper.” Most laser heads come equipped with a permanently attached stopper or attenuator, which will lower the beam power to MPE at the aperture from the housing. Additional beam stoppers may be needed in the beam path to keep the useful beam confined to the experimental area.

It may not always be possible to equip laboratory-fabricated lasers with single master switches or key switches or other safety devices required for lasers which are marketed. Fabricators of these devices are expected to incorporate the functional equivalent of such safety features when they build a device.

13. CONTROL OF LASER AREAS

In many campus research areas, the requirement for controlled laser areas have been interpreted to mean that the doors must be locked, or interlocked, and a proper warning indication provided at the entrance to the area when the laser is operating, unless the area just inside the door is protected by a barrier as described below. Also, proper protective eyewear must be available must be available at or immediately outside of the entrance.

For Class 4 lasers that have unenclosed beam lines, the ANSI Standards call for interlocked doors (or sensors or pressure sensitive doormats, etc), or devices that turn off or attenuate the laser beam in the event of an unexpected entry into an area. An alternative method of protection is to provide a suitable barrier (screen or curtain) just inside the door or wherever most appropriate to intercept a beam or scatter so that a person entering the room cannot be exposed above the MPE limits.

Procedural methods may be used to control entry as an alternative to engineered interlocks, provided the above mentioned conditions are met and all personnel have been trained in laser safety, and protective equipment is provided upon entry. In general, access from public corridors cannot be controlled by procedures, as the public normally would not be trained in the necessary safety procedures.

Other conditions related to control of laser areas include the following:

- Keep the exposure at the entryway below MPE by use of a barrier inside the door. Don’t direct the laser beam toward the entry.
- Use shields and barriers around the laser work area so that the beam, reflections and scatter are contained on the optical table. Try to keep the unenclosed beam path out the normal eye-level zone. (The normal eye-level range is from 4-6 feet from the floor)
- Ensure that only diffuse reflective materials are in or near the beam path to minimize the chance of specular reflections.

- Ensure that locks or interlocks do not obstruct rapid egress from the door or the admittance to the room in the event of an emergency situation.
- Have lighted warning signs (preferably flashing) and/or audible signals to indicate when a Class 4 laser is energized and operating. Signage must clearly explain the meaning of the lights.

Unauthorized persons are to be prevented from entering an area, if the beam is not contained, i.e., areas at the room entrance may exceed MPE. Locks or electric door locks can be used to secure the room (access to the room should still be available by key or an override switch, egress should not be impeded). Locks and warning lights should activate when the laser is “ON”. It is always essential that the locks not impede exit from the room, and provide for entry in case of fire or emergency; hence slide bolts and dead bolts are not acceptable locks.

Many laser systems have a connection for room interlocks, which can serve as a mechanism to link warnings and door locks to laser operation. The connections can also be used for door interlocks (to shut off the laser) or to operate solenoid switches to ditch the beam into a stopper if door is opened.

Laser areas shall be designed so beams cannot exit from the area at levels exceeding MPE. Provide suitable barriers or cover windows with materials that will attenuate the beam. Check for leakage of stray beams around doors or barriers.

14. POSTING AND WARNING SYSTEMS FOR LASER CONTROLLED AREAS

Entrances to laser areas are to be posted in accord with ANSI Standards. Areas where Class 3b and 4 lasers are used must be secured against persons accidentally being exposed to beams, and be provided with a proper warning indication. All windows, doorways and portals should be covered or restricted to reduce transmitted laser levels below MPE.

The term “proper warning indication” generally means that an illuminated warning sign is outside the area. Preferably the light should be flashing and lit only when the laser is on. Lights alone do not suffice as adequate warning, unless the light is clearly posted as to its meaning. A well-designed warning light should have redundancy.

Personnel who do not read English language, and who may need to enter areas where lasers are used are to be given appropriate instruction as to the meaning of warning signs and labels. EHSO will assist in obtaining translations of warning signs, which may be needed.

15. STANDARD OPERATING PROCEDURES (SOPs)

All Principal Investigators are required to write standard operating procedures (SOP) for all laser operations involving Class 3 and Class 4 lasers detailing alignment, operation and maintenance procedures. The SOP should be posted or attached in a clearly visible location or to the inside surface of the lab door.

The SOPs must include procedures to address when:

- Use of eyewear, shields, and access control are necessary.
- Two or more Class 3 or Class 4 lasers will be used in the same area by different operators without permanent, intervening barriers.
- An interlock bypass is installed that does not conform to the conditions of the Laser Safety Manual.
- A Class 3 or Class 4 laser will be used by non-University personnel; (e.g., contract personnel or visiting colleagues).
- A laser installation does not include all the required controls specified in this manual (e.g., temporary operations.)
- A University of Hawaii Class 3 or Class 4 laser or laser system is operated off campus.
- Other hazards may be involved that require an SOP (e.g., acutely toxic gases, unattended laser operation.)

For assistance in completing a SOP, contact the Radiation Safety Program.

16. INVENTORY, ACQUISITION, AND TRANSER (DISPOSAL)

ACQUISITION

Send a copy of purchase orders for Class 3 or 4 lasers to RSP. LSO has the responsibility to periodically visit laser labs to ensure that standards are being observed. RSP needs to know where such lasers are located. If a Class 3 or Class 4 laser is fabricated in the lab, send a note describing the laser.

Note that laser systems that are purchased (or those that are built in an R & D lab and transferred to other users), must meet federal certification requirements. This can be a problem for imported lasers. It is the PI’s responsibility to fulfill the certification requirements. It is recommended that a clause be included in purchase orders for special imports that the “laser must meet applicable certification requirements of the United States as stipulated in Title 21, Code of Federal Regulations, Part 1040”.

INVENTORY

Principal Investigators are responsible for keeping a list of Class 3 and Class 4 lasers under their control. The RSP makes a census of these classifications by contacting all departments that are likely to have Class 3 and Class 4 lasers. The census asks that PIs provide the following information:

- Manufacturer

- Model (laser head)
- Serial number
- Type (Argon, CO_2, HF, Dye, etc.)
- Power: (Energy emitted)
- Beam diameter
- CW: Pulsed: (pulse rate)
- Location: (Building, room)
- Person Responsible:
- Active: Inactive:

DISPOSAL

Sales or disposal of lasers off-campus requires that certain safety steps be taken. Bills of sale should warn persons that the device may emit hazardous laser light, which could cause injuries, and that the University neither offers nor implies any warranty as to safety of its use. The bill of sale shall bear the buyer's signature acknowledgement and include a "hold-harmless" clause.

Uncertified lasers (those not meeting federal standards) and lab-built lasers shall be rendered inoperative before disposal.

TRANSFER ON-CAMPUS

Transfer of a Class 3 or 4 laser to a person who does not have appropriate training, who does not understand the hazards of the laser and who does not have proper protective equipment, could result in injuries. The transferor should obtain assurance from the recipient that the recipient is qualified to own and safety operate the laser. The parties should consult RSP for information on laser hazards and safeguards and the necessary qualifications of the recipient.

TEMPORARY LASER CONTROL AREAS

Temporary laser control areas can be created for the servicing and alignment of embedded lasers, enclosed beams/lasers, and in special cases where permanent laser control areas cannot be provided

APPENDIX A

GLOSSARY

Accessible Emission Level (AEL)
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
The maximum accessible emission level permitted within a particular class.

American National Standards Institute (ANSI)
The technical body which releases the Z136.1 Standard for the Safe Use of Lasers. The secretariat for the Z136.X standard series is the Laser Institute of America (LIA).

Aperture
An opening through which laser radiation can pass. This term usually refers to te opening on the laser (or a protective housing) where the beam is emitted.

Average Power
The average power of a pulsed laser is the product of the energy per pulse (J/pulse) and the pulse repetition frequency (Hz or pulses/sec). The average power is expressed in Watts (J/sec).

Aversion Response/Blink 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.

Coherent radiation
Radiation whose waves are in-phase. Laser radiation is coherent and therefore, very intense.

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 classificiation 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 pass light through thousands of glancing (total internal) reflections.

Fluorescense

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 0.7 to 1000 micrometers.

Intrabeam exposure

Exposure involving direct on-axis viewing of the laser beam. Looking into the laser beam would constitute intrabeam exposure. Note: Intrabeam viewing of lasers is not permitted on campus.

Irradiance

The optical power per unit area reaching a surface (W/cm^2).

Joule (J)

A unit of energy (1 joule = 1 watt/second).

Laser

A device which produces an intense, coherent, directional beam of light. Also an acronym for Light Amplification by Stimulated Emission of Radiation.

Laser System

An assembly of electrical, mechanical, and optical components which includes a laser.

Laser Use Registration (LUR)

The mechanism used by the Laser Safety Program to track lasers on campus. The LUR details the safety requirements for each Class 3a, 3b, and 4 laser.

Laser Safety Committee (LSC)
The campus academic committee which makes laser safety policy and oversees the Laser Safety Program

Laser Safety Officer (LSO)
A member of the EHSO staff, the LSO is responsible for implementation of the Laser Safety Program.

Maximum Permissible Exposure (MPE)
The maximum level of radiation which human tissue may be exposed to without harmful effect. MPE values may be found in the ANSI Z136.1 Standard.

Material Safety Data Sheet (MSDS)
A document, required by law, that is supplied by the manufacturer of a chemical. The MSDS details the hazards and protective practices required for protection from those hazards, as well as other information.

Nominal hazard zone (NHZ)
The area surrounding an operating laser where access to direct, scattered or reflected radiation exceeds the MPE.

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 Ii is the incident irradiance and It is the transmitted irradiance.

Peak power
The highest instantaneous power level in a pulse. The peak power is a function of the pulse duration. The shorter the pulse, the greater the peak power.

Principal Investigator (PI)
The person directly responsible for the laser beam and its use. The PI has direct responsibility for all aspects of safety associated with his/her research and/or teaching.

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 second.

Q-switched laser
A laser that emits short (~30 nanoseconds) high-power pulses by means of a Q-switch.

Radiant exposure (H)

The energy being delivered over the area of the laser beam. Also called energy density, radiant exposure applies to pulsed lasers and is expressed in J/cm^2.

Radiant Flux (F)

Power emitted, transformed, or received in the form of radiation (Joules).

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 small than the wavelength of the incident light.

Standard Operating Procedures (SOP)

A procedure which explains a standard procedure or practice. For lasers, SOPs usually deal with alignment.

Transmittance

The ratio of total transmitted radiant power to the total incident radiant power.

Tunable Laser

A laser system that can be “tuned” to emit laser light over a continuous range of wavelengths or frequencies.

Ultraviolet Radiation (UV)

Electromagnetic radation 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 400-700 nm.

Wavelength

The length of the light wave, usually measured from crest to crest, which determines its color. Common units of measurements are the micrometer (micron) and the nanometer (nm).

APPENDIX B

STANDARDS

American National Standards Institute (ANSI) Z136.1-2000, American National Standard for the Safe Use of Lasers (or later revision).

American National Standards Institute (ANSI) Z136.5, American National Standard for the Safe Use of Lasers in Educational Institutions.

REFERENCES

21 CFR 1040.1 AND 1040.11,Federal Laser Products Performance Standard.

Laser Safety Guide, Laser Institute of America, Tenth Edition

Lawrence Berkeley National Laboratory Laser Safety Manual
Stanford University Laser Safety Manual
Iowa State University Laser Safety Manual
Caltech Laser Safety Manual
Oklahoma State University Laser Safety Manual
University of California at Berkeley Laser Safety Manual

APPENDIX C

Safety with Laser Dyes

Overview

Due to their usefulness, many laser laboratories use various laser dyes. Most of these dyes come in a solid powder form which must be dissolved in solvents prior to use in the laser system. Improper use of dyes or solvents may present a range of hazards for the laser researcher.

Dye Hazards

Although little is known about them, many organic laser dyes are believed to be toxic and/or mutagenic. Because they are solid powders, they can easily become airborne and possibly inhaled and/or ingested. When mixed with certain solvents (DMSO), they can be absorbed through unprotected skin. Direct contact with dyes and with dye/solvent solutions should always be avoided. Contact the LSO at 956-6475 if you want additional information on laser dye toxicity.

Solvent Hazard

A wide variety of solvents are used to dissolve laser dyes. Some of these (alcohols) are highly flammable and must be kept away from ignition sources. Fires and explosions resulting from improper grounding or overheated bearings in dye pumps are not uncommon in laser laboratories. Dye pumps should be inspected, maintained, and tested on a regular basis to avoid these problems. Additionally, dye lasers should never be left running unattended. Some of the solvents used with laser dyes may also be skin irritants, narcotics, or toxics. You should refer to the Material Safety Data Sheet (MSDS) which is supplied by the solvent manufacturer for additional information on health effects.

Dye/Solvent Handling

Powdered laser dyes should never be handled where the airborne dust could be breathed. Dyes must be mixed only in a properly functioning fume hood. The proper protective equipment (PPE = safety glasses, chemical gloves, and lab coat) should always be used by the person handling the dye. The gloves being used should be resistant to the solvent being handled. Mixing of dyes and solvents should be done carefully, so as to avoid spilling. Any spills or leaks should be cleaned up immediately using appropriate PPE. Avoid breathing vapors from the solvent being used. Clearly identify and mark containers used for mixed dye/solvent solutions. Practice good hygiene and wash your hands well after handling dyes.

Storage/Use of Mixed Dye/Solvent

Limit the amount of mixed dye/solvent being stored in the laboratory. Once mixed, the dye/solvent should be stored in sealed Nalgene or other unbreakable plastic containers (beware of solvent incompatibility) until ready to use. Be sure to check transfer lines and pump connections for continuity prior to each use with the dye/solvent. All pumps and dye reservoirs must be placed in trays with sufficient capacity to contain all of the dye/solvent should it leak. This “double containment” method should prevent dye stains on floors and other surfaces.

Dye Waste Disposal

Dyes and dye/solvent solutions are considered hazardous wastes and must be disposed of properly. Contact the Hazardous Materials Management Program at 956-3198 for guidance on proper disposal of hazardous wastes.

APPENDIX D

Electrical Safety Guidelines for Laser Users

Electrical Hazards and Laser Users

Laser systems and power supplies normally require thousands of volts and tens of amperes to operate. The electrical needs associated with laser use present inherent electrical safety hazards.

These hazards are normally mitigated by the engineering controls (enclosures, interlocks, grounding, etc.) built into the laser systems. However, if these engineering controls are defeated during tuning or maintenance, live contacts can be directly accessed. Contact with these may cause any number of adverse bioeffects, up to and including death by electrocution.

It is essential that laser users be aware and protect themselves from the electrical hazards found in laser facilities.

Electrical Terminology

Alternating Current (AC) – A current which reverses polarity with a given frequency expressed in cycles/second or Hertz (Hz). U.S. wall current is 60 Hz AC.

Amperage (I) – the current (number of electrons) flowing in a circuit (measured in Amperes or Amps).

Conductor – a material which has a normally low resistance.

Direct Current (DC) – A current with a fixed polarity normally associated with batteries or rectified AC current.

Electrical Ground – AC circuits usually contain a third conductor which provides a pathway to ground should a short circuit occur. NOTE: the electrical ground is intended to protect equipment and prevent fires; it is not intended to protect persons from shock hazards.

Insulator (dielectric) – a material which has a normally high resistance.

Ohms Law – Amperage is equal to voltage divided by the resistance and expressed in the formula $I = V / R$.

Resistance (R) – the ability of a material to allow the flow of electrons (measured in Ohms or W).

Short Circuit – when current is allowed to take an unintended path back to its source. If that path runs through a person, serious injury or death can result.

Voltage (V) – the potential (energy of the electrons) flowing in a circuit (measured in volts).

Wattage (W) – the unit of power, devices are often rated as to the power in Watts required for their operation (W = V x I).

Materials that are Good Conductors

Materials that are good conductors include: precious metals, copper, aluminum, other elemental metals and alloys, and ionic solutions (especially water containing dissolved salts). Both tap water and human bodily fluids are considered ionic liquids.

Materials that are Good Insulators

Materials that are good insulators include: rubber and most plastics, dry wood, ceramics, fiberglass, organic materials, and non-ionic liquids (like distilled water).

Sources of Electrical Hazards in Laser Facilities

Common AC wall current at 120 volts.

Specialty AC wall current of 240 or 480 volts.

High voltage (>600 volts) AC supplies.

DC power supplies (including batteries and capacitors).

Static electricity (NOTE: Spark temperatures exceed 1000 degrees F and can ignite solvents used for cleaning or for laser dyes).

Examples of Electrical Hazards in Laser Facilities

1. Electrical supply boxes. These boxes may be left open and/or unlatched. Combustible materials must have a 3 foot separation distance from the boxes as required by OSHA.
2. Wall sockets, power plugs, power cables and couplings. Wall sockets may not be properly wired. Power plugs may have exposed conductors if they are damaged. Power cables and couplings are not only a tripping hazard but may have exposed conductors if they are damaged by foot and cart traffic.
3. Laser, power supplies, and other lab equipment. Laser housings contain high voltae/amperage which can be directly accessed if the covers are removed. Power supplies often contain large capacitors which can retain a lethal charge even after the laser is turned off or unplugged.

4. Ungrounded laser systems and optical tables. Failure to maintain proper grounding of lasers and optical tables can allow short circuit conditions to endanger persons who contact the laser or optical table.
5. Home or shop made electrical components. Often built without a knowledge of electrical safety codes, home built equipment can be improperly grounded, not have sufficient safety enclosures, etc. Research equipment must be constructed with components that have been tested by a recognized testing organization (e.g., Underwriter's Laboratory). For assistance in evaluating equipment, contact the EHSO.
6. Jewelry. Do not to wear metal jewelry (gold, silver) around laser systems or power supplies. In addition to their highly conductive electrical properties, metal jewelry can also present a specular beam reflection hazard.
7. Special situations which could create short circuits to ground. Should there be a cooling water leak which contacts a hot conductor, the current will flow through the liquid to ground. Persons in contact with the spilled water could become part of the circuit.

Types of Electrical Hazards

1. Shock – if the human body becomes part of the circuit, current will flow through various organs (depending on the pathway). If current flows through the human heart, it may cause fibrilation (abnormal muscle contractions) which can result in death.

2. Arc – The flash ionization of air resulting from direct flow of high current from one conductor to another. The resulting vaporization of materials (like conductors) creates a plasma with an extremely high temperature (as high as 50,000 degrees C.) which can ignite combustible materials at several meters and cause severe burns to tissue.

3. Blast – The pressure transient resulting form plasma arc vaporizatioln of materials (mainly metal conductors). This blast has been known to cause severe injury through the transfer of kinetic energy to objects and persons.

4. Fire – Combustion of materials from electrical sources can cause injuries and destroy property.

Electrical Exposure Bioeffects

1. Cardiac fibrillation – disruption of the heart rhythm, either immediate or delayed (the major cause of death from electrical shock).

2. Internal (organs) burns – often resulting in amputations or death.

3. External (skin) burns – usually caused by metals melted/vaporized by an arc.

4. “Blow out” injuries – from vaporized body fluids caused by current flow in tissues.

5. Neurological damage – either immediate or delayed (can be very severe).

6. Physical shock – usually related to trauma (complicates other injuries).

7. Psychological trauma – common with severe injury.

8. Blast related physical trauma injuries – broken bones, internal bleeding, etc.

9. Electrical shock associated injuries – falls, etc.

10. Death – by electrocution (about 500 deaths per year in the U. S. from all electrical sources).

11. Other deaths related to electricity – fatal fires, contact with moving parts, etc. (accounts for about 1000 deaths per year).

Components of a Good Electrical Safety Program

1. Qualification of Workers – Work on electrical equipment can only be performed by “qualified” personnel. These personnel must be properly trained in electrical safety practices and procedures and must be approved by their department to work on electrical equipment. It is essential that you do not work on electrical equipment if you are unfamiliar with electrical devices or if you are untrained in electrical safety.

2. Lock-Out/Tag-Out (LOTO) Procedures – As required by state and federal law, proper procedures must be followed for safe installation, service, maintenance, adjustment, or other handling of laser systems and other powered equipment.

   These LOTO procedures apply whenever the unexpected energizing of the equipment or release of stored energy (such as from charged capacitors) could cause injury. Equipment which has the potential to be energized must be properly locked and/or tagged out in accordance with the campus procedure if:

   - A person may contact energized components while performing the work.
   - A person is required to remove or bypass any guard, interlock, or other safety device (including covers) to perform the work.
   - A person is required to place any part of his or her body into an area on the equipment (or piece of machinery) where work is performed during the equipment’s operation.

3. “Energized Work” procedures – If the equipment can only be serviced or adjusted while energized, special “energized work” procedures, testing equipment, special tools, and personal protective equipment may be required. In these cases, speical controls may be necessary to ensure safety. These controls may include the use of ground fault circuit interrupter (GFCI), insulated tools, and/or trained stand-by personnel.

(**Note:** LOTO procedures should always be followed unless it is physically impossible to conduct the work without the equipment being energized. Only in such instances are “energized work” procedures allowed.)

4. Other Issues - All electrical hazards should be properly marked and/or labeled. Proper switching and grounding techniques must be learned and practiced.

APPENDIX E

Emergency Procedure for Laser Accidents
(Emergency Contact Listing)

In the event of a laser accident, do the following:

1. Shut down the laser.

2. Provide for the safety of personnel (first aid, evacuation, etc.) as needed.

NOTE: If laser eye injury is suspected, have the injured person keep their head upright and still to restrict any bleeding in the eye. Laser eye injuries should be evaluated by a physician as soon as possible.

3. Obtain medical assistance for anyone who may be injured.

5. If there is a fire, leave the area, pull the fire alarm, and contact the fire department by calling 9-911. Do not fight the fire unless it is very small and you have been trained in fire fighting techniques.

6. Inform the Radiation Safety Program (RSP) as soon as possible.

During normal working hours, call these numbers.

RSP phone number	956-8591
Laser Safety Officer	956-6475
Radiation Safety Officer	956-6475

After normal working hours, call 956-6911 to contact the UH Campus Security (they have an EHSO emergency call list).

7. Inform the Principal Investigator as soon as possible. If there is an injury, the PI must submit a report of injury to EHSO.

8. After an accident, do not resume the use of the laser system until the Laser Safety Committee has reviewed the incident.

APPENDIX F

Safety Requirements for Lasers Built/Modified in UH Laboratories

The UH Laser Safety Committee (LSC) has directed that all lasers and laser systems constructed/modified at UH must meet certain safety standards (see below). The Laser Safety Officer (LSO) shall be contacted prior to operation of such lasers so that they can be properly classified as per the ANSI Z136.1 (2000) standard. The LSO will inspect the laser system, make power output measurements (if needed), classify the laser, and will inform researchers of any deficiencies which need to be corrected prior to use. All lasers classed as 3a, 3b, or 4 will need to be operated under a Laser Use Registration (LUR).

NOTE: Lasers or laser systems built on campus shall not be moved off of the campus without the knowledge of the LSO. Depending on the specific circumstances, such lasers may be "in commerce" and as such would be required to meet the full FDA/CDRH performance standard under U.S. law. No money needs to change hands for these regulations to apply. The FDA/CDRH requirement are much more extensive than the normally required safety standards.

Safety Standards for Lasers Assembled on Campus

1. An appropriate fixed enclosure shall be provided so as to preclude casual contact with exposed electrical contacts, radiation from excitation sources, and hazardous materials (laser dyes, excimer gases, etc.). The enclosure shall be marked on the outside with appropriate warnings on enclosed hazards (see the LSO fro assistance). The enclosure should not be removable without the use of tools.

2. The laser system shall meet reasonable standards for electrical safety. These shall include: components rated for the appropriate amperages and voltages, proper grounding of housings, the use of properly wired 3 prong (grounded) plugs, enclosure of all live contacts/wires with appropriate insulators, and proper marking of electrical hazards.

3. Lasers shall be designed so as to preclude accidental activation/operation. At a minimum, a properly marked and lighted on/off switch shall be required. It is preferable to use a key interlock switch, so that the laser cannot be operated when the key is removed from the switch.

4. The physical components used in the laser shall be made of appropriate materials so as to assure safety both during normal operation and failure modes (implosion of flash lamps, etc.). Some examples are: cardboard is not an appropriate material for the laser enclosure (sheet aluminum is acceptable), and tubing used for piping halogen gases should be stainless steel or copper, rather than aluminum.

5. Although it is not required, the LSC recommends that researchers involve the LSO for assistance during the design process. The LSO can be reached by phone at 956-6475 or by email at isakimot@hawaii.edu.

APPENDIX G

Laser Applications Outside the Laboratory

<u>Introduction</u>

The use of laser outside of a controlled area can present special hazards to the campus community and to the general public. This appendix addresses the control of any laser (Class 3a, 3b, or 4) used outside the normal research laboratory environment. These applications may include: lasers used for telecommunications, laser research being performed outdoors, and lasers used for entertainment or public viewing.

<u>Applicability</u>

Any laser (Class 3a, 3b, or 4) used for entertainment, displays, demonstrations, or any related use intended for public viewing (indoors or outdoors) shall be operated in accordance with Federal, State and Local and campus regulations/requirement.

Any laser system (Class 3a, 3b, or 4) used outdoors for telecommunication applications or for research projects shall be registered with the Radiation Safety Program as per the requirements of the Laser Use Registration (LUR) program.

The operators of laser systems used for entertainment are required by law to file a "Report on Laser Light Show Display' (or a variance document), with the Food and Drug Administration's Center for Devices and Radiological Health (FDA/CDRH). If the venue is outdoors and the beam(s) may terminate in navigable airspace, then the operators are also required to file a report with the Federal Aviation Administration (FAA) office.

All Class 3a, 3b, or 4 laser systems being used on UH property must be used in accordance with the campus Laser Safety Program. Any variation from the Laser Safety Program must be approved by the Laser Safety Committee.

<u>Procedures</u>

Campus departments, and campus affiliated group (student or otherwise) shall notify the LSO of any laser light show (indoor or outdoor) to be performed on UH property. The LSO will request from the light show operators a copy of the CDRH required 'Report on Laser Light Show Display' (or variance document) prior to the show. Upon receipt, the LSO shall review the description of the show and the operators safety of the operators.

The Principal Investigator (PI) shall inform the LSO of any lasers used outdoors for research projects. Such laser uses will need to be covered under a SOP. The department will be responsible for informing the LSO of any indoor or outdoor telecommunication applications being pursued by that department. In both cases, the application and operation of the laser system(s) shall be evaluated by the LSO to ensure that appropriate safety measures are in place prior to operation.

<u>Laser Safety Requirements – Laser Light Shows</u>

NOTE: A LUR is not normally required for laser light shows.

- The CDRH and ANSI requirements specified by the LSO must be met.
- Any audience exposure to laser radiation must not exceed the ANSI Class 1 limit.
- Operators, performers, and employees must be able to perform their duties without having to directly view laser radiation exceeding the ANSI Class1 limit, and without being exposed to laser radiation exceeding the ANSI Class 2 limit.
- All laser scanners (including mirror balls) must incorporate proper scanning safeguards.
- If the laser is not under continuous operator control, any Class 3a, 3b, or 4 level of laser radiation cannot be closer than 6 m vertically or 2.5 m horizontally from any standing surface or standing position where the audience may be located.
- If the laser is under continuous operator control, any Class 3a, 3b, or 4 level of laser radiation cannot be closer than 3 m vertically or 2.5 m horizontally from any standing position where the audience may be located.
- An operator with an accessible control to terminate the beam must be available if conditions become unsafe.
- FAA notification is required (for Class 3a, 3b, and 4 lasers) if the display is being used in navigable airspace.
- Additional safety requirements may be needed as specified by the LSO.
- The CRDH “Report on Laser Light Show Display” forms are available from the LSO.

<u>Laser Safety Requirements – Other Outdoor Uses of Laser</u>

NOTE: A LUR is required for the use of a Class 3a, 3b or 4 laser.

- Meet the specified LUR safety requirements.
- The LSO will establish a Nominal Hazard Zone (any area where the maximum permissible exposure (MPE) is exceeded.)
- The NHZ must be posted and/or restricted as directed by the LSO.
- The PI must ensure that only trained personnel enter the NHZ, and that appropriate PPE (personal protective equipment) is issued and used.
- The PI must ensure that users are properly trained and meet the campus laser safety training requirements.
- The PI must ensure only authorized personnel are allowed to operate the laser.
- The PI must ensure the use of any required administrative/engineering controls.

- Laser beams shall not be directed toward structures, automobiles, aircraft, or other vehicles within the NHZ unless adequate training and protective equipment is provided and used by all personnel within these structures/vehicles.
- The laser beam path shall not be maintained at eye level without LSO approval.
- FAA notification is required (for Class 3a, 3b, or 4 lasers), if the laser is being used in navigable airspace.
- Additional safety requirements may be needed as specified by the LSO.

Policy Exceptions

Any exceptions to this policy must be approved by the Laser Safety Committee. Contact the LSO at 956-6475 if you need exemption from this policy.

Emergencies

The potential for injuries from a laser light show/display is minimal if the operators observe the CDRH requirements. In the event that an individual suspects an eye injury, the operators of the laser system shall be notified immediately so that the laser beam(s) can be terminated. The event staff shall be notified and medical attention shall be provided to the injured individual if needed. The LSO shall be informed as soon as possible should any laser injury be suspected. The LSO or his alternate can be contacted at any time by calling 956-6911 and asking for the Radiation Safety Program.

Regulatory References

- Food and Drug Administration's Center for Devices and Radiological Health (FDA/CDRH)
- Federal Aviation Administration (FAA)
- American national Standards Institute (ANSI) Z136.1 (200) – Safe Use of Laser
- UH Laser Safety Manual

APPENDIX H

Table of Typical Laser Classes (from ANSI)

APPENDIX J

Laser Warning Signs (from ANSI)

APPENDIX K

Laser Pointer Safety Guidelines

When used as intended these devices do not present a hazard to the user or members of the public. To ensure safety the following guidelines must be followed.

- No person shall intentionally stare into the laser beam
- No person shall intentionally aim the pointer beam at oneself or another person
- The beam should be turned off when not in use
- Mirror like surfaces should be avoided when directing the laser beam

The use of laser diode pointers that operate in the visible radiation (400-760 nanometers [nm]) has become widespread. Laser pointers are today, usually Class 3a (1-5 mW) devices as defined by the ANSI Z136.1 standards. Class 3a lasers are moderate power lasers which could be hazardous even if viewed for a very short time. Until about 1993, most pointers were Class 2 (<1 mV) lasers. Class 2 lasers are low power devices that are safe to view for time periods less than 0.25 second, commonly known as the blink or aversion effect. The time it takes to blink ones eyes from the glare of a bright light. If the viewer overrides the urge to turn away and stares into the laser beam, even a Class 2 laser pointer can be a hazard. The Class 3a pointers can be recognized by the DANGER labels. Class 2 lasers will have a CAUTION label. Most laser pointers operate on a continuous wave (CW) basis, however, there are some commercially available that can operate having a repetitive pulse mode.

Pointers at 670 nm emit a “dark red” and require 3-5 mW (Class 3A) in order to be “visible”. Pointers at 635 nm emit a “brighter orange” and require only about 1 mW (Class 2) to be “visible”. Some new pointers are diode pumped – frequency doubled Nd:YAG lasers that emit at 532 and emit in the power range of 5 mW AND HIGHER! Note the eye response is much higher at this wavelength. Another diode-pumped frequency-doubled Nd:YAG laser operating at 532 nm is imported from China and emits 5 mW in a CW beam. The pointer has no labeling and unscrewing the front end cap removes the 1064 nm blocking filter. In this case, the combined 1064 nm and 532 nm beams exceed 15 mW; clearly a Class 3B emission.

<u>Safety Concerns</u>

Other concerns with low power laser include ocular effects such as flash blindness, afterimage, and glare. Persons exposed to the beam from pointers can be subject to such effects which could lead to temporary vision dysfunction and cause possible physical damage if the exposed person is engaged in a vision-critical activity such as driving, flying or operating machinery.

Often laser pointers can be used in situations where effects such as temporary flash blindness, afterimages, or glare can occur that cause the person to be distracted from his immediate work task. For example, there have been recent reports of laser light exposures of pilots at airports in regions where there were no known outdoor laser light show activities. Suspicion of exposure to pilots were from persons using such laser pointers has been reported in both the U.S. and U.K. Similar concerns have been voiced for exposures to persons driving cars and buses. Bus drivers and Fire Engine driver exposures have been reported in the U.K.

There is also the concern for glare when the beam strikes a highly reflecting surface. Such distraction could lead to other primary or secondary effects of more serious nature. An example could be a lathe operator being “flashed” while concentrating on the work and losing concentration. This could cause the person to become temporarily distracted or startled and cause fingers or the whole hand to make contact with the lathe chuck and pose the potential for serious physical harm.

The visual impairment concepts are as follows:

Afterimage: The perception of light, dark, or colored spots after exposure to a bright light that may be distracting or disruptive. Afterimages may persist for several minutes.

Flash blindness: A temporary vision impairment that interferes with the ability to detect or resolve a visual target following exposure to a bright light. This is similar to the effect produced by flashbulbs, and can occur at exposure levels below those that cause eye damage. This impairment is transitory, lasting seconds to minutes depending upon the laser light exposure level and time, the visual task, the ambient lighting, and the brightness of the visual target.

Glare: A reduction or total loss of visibility, such as that produced by an intense light source, such as oncoming headlights, in the central field of vision. These visual effects last only as long as the light is actually present affecting the individual field of vision. Visible laser light can produce glare and can interfere with vision even at low energies well below those that produce eye damage.

In addition to the above light induced factors that could certainly affect perception during vision-critical activities, the authors also believe there to be yet another factor. This is the case of an individual exposed and having the perception for a significant potential harm. In some cases, this can lead to reactions based on factors other than retinal damage or flash blindness.

APPENDIX L

Laser Laboratory Visitor Policy

Definitions:

- A laboratory visitor is any person who is present in the laboratory as an invited guest of any UH employee or student researcher.
- Visitors who are to be in the laboratory for a period of more than one day but less than one month are considered short term researchers.
- Persons who will be in the laboratory for a period of more than one month are considered to be campus laser users.
- The UH Radiation Safety Program works with Principal Investigators and laser users to ensure that the visitor policy is properly enforced.

Visitor Policy and Requirements

It is the policy of the UH Laser Safety Committee to require the same level of laser laboratory safety for all visitors and short term researchers as is required for laser users. All visitors and short term researchers are to be escorted by a person whose name appears on the Laser Use Registration (LUR) as a laser user. If it is necessary for a short term researcher to work alone in the laser laboratory, the individual must be added to the LUR as a laser user.

It is the responsibility of the Principal Investigator to ensure that his/her laser users are informed of, understand, and follow this visitor policy.

It is the responsibility of the visitor's laser user escort to provide the visitor with an appropriate safety orientation covering the hazards in the laser laboratory. The escort shall also provide appropriate safety equipment and require the safety equipment be used by the visitor.

Short term researchers must meet the same laser safety training requirement as campus laser users (but do not need to be added to the LUR). Laser users must be immediately added to the LUR as specified in the Laser Safety Manual.

As a reminder, no unregistered use of any laser is allowed under any circumstances. The LUR indicates the registered use(s) of the laser system. All LUR and UH policy requirements must be followed at all times. No intrabeam viewing of any laser is allowed under any circumstances by any person.

It is the responsibility of the Principal Investigator to assure that persons who are not invited into the laser laboratory or who fail to follow direction regarding safety policy or the use of safety equipment are immediately escorted from the laser facility.

Visitor Recommendations:

Although it is primarily the responsibility of the escort to provide a safe environment for laboratory visitors, consideration should be given to the following:

- Unless it is absolutely necessary to have the laser energized during the visit, it is recommended that all lasers and laser power supplies be turned off and the activation keys removed during the visit.
- Research environments can prove very hazardous to children. It is recommended that all persons under the age of 18 not be allowed into any laboratory.
- It is recommended that any laser demonstration be conducted so that the laser beam be directed away from any visitor, regardless of the laser eye protection being used.

Appendix M

LASER USE REGISTRATION (LUR) FORM

Date: ______________________________ Page: ____________ of ________

Name of Principal Investigator: _____________________ Phone Number: __________

Name of Laboratory Contacts: ______________________ Phone Number: __________

Names of Laser Users:

____

Department of Principal Investigator:

____

Building and Room Location of Laser:

____

Make/Model of Laser:

____

Laser Serial Number:

____

Type of Lasing Medium:

____

LASER INFORMATION:
Laser Classification marked on Laser: (circle one) 3a 3b 4 none

CW		Pulsed	
Wavelength(s):	_________(nm)	Wavelength(s):	___________ (nm)
Max. Op. Power:	_________(W)	Pulse duration:	___________ (sec)
Avg. Op. Power:	_________(W)	Pulse frequency:	__________ (Hz)
		Max. Op. Energy:	_________ (J)
		Avg. Op. Power:	__________ (J)

Beam Diameter at aperture: _____________(nm)
Beam Divergence: ____________ (mrad)

Laser Use (describe briefly):

____

Please check all items that apply:

_____ Use of Cryogens
_____ Use of Compressed Gases
_____ High Voltage Power Supplies
_____ High Voltage >30 kVp
_____ Dye Laser
_____ Exposed Beam Paths
_____ High Noise Levels
_____ Laser Cutting/Welding
_____ Use of Pumping Laser
_____ Beam Focusing Optics
_____ UH Fabricated Laser
_____ UH Modified Laser
_____ Freq. Doubling Crystals
_____ Turnable Laser
_____ Invisible Beam

If you have questions regarding this form, please call the Laser Safety Officer at 956-6475. After completion, please return the form to: EHSO, Laser Safety Program, 2040 East-West Road, Honolulu, HI 96822.

Appendix N

Laser Eye Examination Policy and Procedure

Statement of Policy

Laser eye examinations are performed to identify those laser users which may have a predisposition for vision related injury and to meet the medical monitoring requirements for the ANSI Z136.1 Standard for the Safe Use of Lasers.

Requirement for Examinations

Those laser users who have a reasonable potential of eye exposure to Class 3b or Class 4 laser beams are required to have eye examinations within 60 days of joining the Laser Use Registration (LUR). Eye examinations will also be performed on UH staff whenever a laser eye injury is suspected.

Responsibilities

The Laser Safety Committee (LSC) is responsible for developing and periodically reviewing the laser eye examination policy.

The Laser Safety Officer (LSO) is responsible for implementing the laser eye examination policy. The LSO is responsible for identifying those laser users who are required to have examinations and providing a list of those users to the Principal Investigator (PI).

The Radiation Safety Program is responsible for maintaining a database of laser users and when they receive the examinations.

The PI is responsible for assuring that laser users identified by the LSO make appointments with their own doctors or with the ________________. If the laser user does not wish to use their vision care insurance to cover the cost of a __________________ examination, the PI is responsible for costs associated with examinations.

Laser users are responsible for making and attending appointments with either their own doctors or _________________.

Eye Examination Criteria

Eye examinations include the following:

Medical history of the eye and photosensitivity
Visual acuity (far and near) for both eyes
Macular function (Amsler grid)
Color vision assessment
Dilated retinal examination of both eyes
Retinal photographs of both eyes (while dilated)

Examinations will be performed by professionally qualified personnel. Patients whose results fall outside of acceptable criteria will be referred for a comprehensive examination.

Procedure

The LSO works with the PI to identify the laser users who need eye examinations and provides the PI with a written list of those users.

The PI informs the identified laser users and works with them to assure they schedule their eye examinations.

The laser users are seen by a private practitioner or _________________. The private practitioner or ______________ informs the user of the results and refers the patient for further examination if they fall outside the acceptable criteria.

Records

The LSO maintains a database of users identified and when they had their examinations.

APPENDIX O

STANDARD OPERATING PROCEDURES (SOP) FOR CLASS 3B AND CLASS 4 LASERS USERS

1. GENERAL INFORMATION

   A. Title: ______________________________________
   B. Location of Work : Bldg ________________ Room:
   C. Division:
   D. Laser Safety Contact:____________________________

2. DESCRIPTION OF ACTIVITY:

   A. Description of Activity including unique equipment (its application) or activity and principal parameters
   B. Duration: on going __________, limited period ______months

3. IDENTIFICATION OF HAZARDS

   Identification of potential hazards associated with the activity, lasers, and any additional hazards (i.e., toxic gases).

4. MITIGATION OF HAZARDS

   Controls to reduce the potential hazards. From a laser perspective, the following needs to addressed

   A. Identification of laser(s): Laser specifications

   Complete chart (as much as possible), list all lasers, including low power alignment lasers

	LASER 1	LASER 2	LASER 3
Type:			
Manufacturer:			
Model:			
Serial #:			
Max. Power:			
Wavelength:			

Wavelength used:

Power used:

Pulse Length:

Pulse Repetition Rate:

Beam Diameter:

Beam Divergence:

Property #:

Made in House:

Class:

B. Laser Users:

Only those personnel listed below are authorized to use the laser system unsupervised. They have attended the UH laser safety class. Users are responsible for assuring access control policies are followed. Signatures below indicate receipt of training on the specifics of this SOP.

Names	Date of laser safety Training	Date of eye examination	Signature

C. Attach a diagram of laser use area. (Simple block diagram will do, should also be posted on lab, door).

D. Describe access controls, including use of interlocks

It is the responsibility of the user to maintain and enforce access control.

E. Describe alignment procedures

All laser users need to keep in mind that the majority of laser accidents occur while aligning the laser. All possible steps will be taken to prevent any such accidents. Alignment procedures are performed in accordance to the manufacturer and at the lowest possible laser output, such that the primary beam or a specular reflection of the primary beam does not expose the eye to a level above the maximum permissible exposure for intrabeam exposure. Safety laser glasses are worn at all times during alignment procedures. The laser beam is never to viewed directly. As a precaution, reflective jewelry will be taken off by those handling the laser.

F. Where have the laser warning signs been posted?

Laser warning signs indicate the lasers in the control area, maximum power output, wavelength and hazard class in use in the area. (Warning signs can be obtained from LSO)

G. Laser protective eye wear:

Has eyewear been selected?
The number that will be/are on hand: __________

Manufacturer	Optical Density	Wavelength

H. Beam Path:

Is beam path open, enclosed, or partially enclosed? Please explain.

I. Nonbeam hazards, if any. List and describe how they have been addressed.

MAINTENANCE -- The equipment will be maintained by specially trained and/or certified laboratory personnel. All relief devices, safety interlocks, alarms, and other hazard prevention devices will be maintained, calibrated, and tested for functionality on a regular basis in accordance with standard practices and recommendations of the manufacturer.

EMERGENCY PROCEDURES -- Authorized laser users will be familiar with the building Emergency Plan, location of emergency equipment, and emergency procedures for fires, earthquakes and evacuations. Emergency shut off procedures for lasers consist of shutting off the electrical power to the laser system. The location of main electrical shut off switches to the laser must be posted on the exits.

ANNUAL REVIEW SCHEDULE -- Annual reviews will be one year from approval date. If new hazards have been introduced, a full RSP review will be required. Please send an update of the user's list to the LSO.