UNIVERSITY OF ARKANSAS

LASER SAFETY PLAN

OFFICE OF ENVIRONMENTAL HEALTH AND SAFETY,
FACILITIES MANAGEMENT DEPARTMENT

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UNIVERSITY OF ARKANSAS
LASER SAFETY MANUAL

1.0 Introduction

LASER is an acronym for "Light Amplification by Stimulated Emission of Radiation". The energy generated by the laser is in or near the optical portion of the electromagnetic spectrum. Energy is amplified to extremely high intensity by an atomic process called stimulated emission. The term "radiation" is often misinterpreted because the term is also used to describe radioactive materials or ionizing radiation. The use of the word in this context, however, refers to an energy transfer. Energy moves from one location to another by conduction, convection, and radiation. The color of laser light is normally expressed in terms of the laser's wavelength. The most common unit used in expressing a laser wavelength is a nanometer (nm). There are one billion nanometers in one meter (1nm = 1x 10(-9) m). Laser light is nonionizing and includes ultra-violet (100-400nm), visible (400-700nm), and infrared (700nm-1mm).

Most lasers are capable of causing eye injury to anyone who looks directly into the beam or specular reflections. In addition, diffuse reflection of a high-power laser beam can produce permanent eye damage. High-power laser beams can burn exposed skin, ignite flammable materials, and activate toxic chemicals that release hazardous fumes, gases, and debris. The equipment and optical apparatus required to produce lasing action and control and direct the laser beam also introduce additional hazards associated with high voltage, noise, optic radiation and toxic gases.

2.0 Policy

The University of Arkansas policy on laser safety requires that all lasers and laser systems be operated in a manner comparable to the American National Standards Institute, (ANSI) Z136.5-2000, *Standard for the Safe Use of Lasers in Educational Institutions*, and ANSI Z136.1-2007, *Safe Use of Lasers.*

The primary objective of the University of Arkansas 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 the use of dyes, and solvents, and chemical exposures from use of chemicals and vaporization of targets. Although Laser Pointers are normally classified as Class 3a lasers, they are specifically exempted from this program.

In order to implement the policy properly while giving the greatest possible latitude to the researcher, all laser operations at the University of Arkansas must be reviewed and approved by the Environmental Health and Safety Department.

3.0 Scope

The requirements and recommended details of this program are applicable to all lasers used in research and instructional laboratories, as well as, in construction and maintenance operations.

4.0 Responsibilities

4.1 Principal Investigators are responsible for:

a) The immediate supervision of lasers in the laboratory
b) Providing, implementing, and enforcing the safety recommendations and requirements prescribed in this program.
c) Classifying and labeling each of their lasers
d) Completing a Laser Registry form, for each laser, or each piece of laser producing equipment and sending it to EH&S
e) Training employees who work with the lasers in the safe use of the lasers. This training is to be documented and maintained.
f) Notifying EH&S immediately in the event of an exposure to a Class 3b or Class 4 laser.

4.2 Laser Operators are responsible for:

a) Following laboratory, administrative, alignment and standard operating procedures while operating lasers and reading the safety instructions in the laser equipment operator's operating manuals
b) Keeping the Principal Investigator fully informed of any departure from established safety procedures. This includes notification of an exposure incident.

4.3 EH&S or its representative will:

a) Conduct lab inspections to ensure that safety requirements are followed
b) Provide assistance in evaluating and controlling hazards
c) Update the University of Arkansas Laser Safety Program when necessary
d) Maintain a record of lasers and laser operators.
e) Ensure the provision of laser training for personnel who are assigned to an area where lasers are operated.
f) Participate in accident investigations involving lasers

5.0 Personnel Training and Qualification

5.1 All staff and students operating lasers are required to read the Laser Safety Policy.

5.2 Only qualified and authorized persons are permitted to operate lasers. The Principal Investigator determines the student or employee's operational qualification from departmental or technical training or other acceptable learning experience.

5.3 Before operating a Class 3b or Class 4 laser or Class 1 laser system that encloses a Class 3b or Class 4 laser, a person must complete appropriate Laser Safety Training. Guests of the University of Arkansas who request to use Class 3b or Class 4 lasers must contact EH&S regarding training and qualifications in using these lasers. New students, employees and guests must operate under the direct supervision of the Principal Investigator until proper training is completed. The Principal Investigator must notify EH&S of these new student, employee or guest laser users. All laser users are responsible for knowing the safety requirements that apply to their specific laser or laser system and for knowing the contents of the applicable Standard Operating Procedure, (SOP).

5.4 All new students, employees and guests who desire to use a Class 3b or a Class 4 laser must do the following before using the laser, or laser system:

a) Review the Laser Safety Program
b) Receive a thorough review of the laser equipment to be used and the administrative, alignment and SOP's, from the lab supervisor or Principle Investigator.

c) Review the operating and safety instructions furnished by the manufacturer.

6.0 Exposure Incidents.

6.1 If an exposure incident occurs, the Principal Investigator, or the laser operator must notify EH&S of that exposure.

6.2 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 make arrangements with the Health Center to have an eye exam performed.

6.3 EH&S will conduct an investigation, and an incident report will be written, for each exposure or suspected exposure incident.

7.0 Classification of Lasers

7.1 All lasers are divided into classes depending on the power of energy of the beam and the wavelength of the emitting radiation. Laser classification is based on the laser's potential for causing immediate injury to the eye or skin and/or potential causing fires from direct exposure to the beam or from reflection from diffused reflective surfaces.

Class 1: Class 1 lasers are considered to be incapable of causing immediate injuries and are therefore exempt from the most control measures or surveillance. Examples are laser printer, CD player.

Class 2: Class 2 lasers emit radiation in the visible portion of the spectrum, and protection normally occurs by human aversion response (blinking reflex) to bright radiant light. This reflex provides adequate protection. However, Class 2 lasers emit light in the visible range and are capable of causing an eye damage through chronic exposure. Examples are laser pointers and surveying lasers.

Class 3 (a)(b): Class 3a lasers are those that normally would not cause injuries if viewed only momentarily with the unprotected eye. They will present a hazard if viewed using collecting optics, e.g. telescopes, microscopes or binoculars. Examples are HeNe laser above 1 milliwatt but not exceeding 5 milliwatts radiant power or some pocket laser pointers.

Class 3b laser light will cause injury from direct viewing of the beam and specular reflections. Example is a visible HeNe laser above 5 milliwatts but not exceeding 500 milliwatts radiant power.

Class 4: Class 4 lasers include all lasers with power levels greater that 500mW radiant power. 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 suitable control measures explained in this Manual must be implemented.

8.0 Laser Hazard Analysis

Before appropriate controls can be selected and implemented, laser radiation hazards must be identified and evaluated.

8.1 Types of hazards include:

a) Eye: acute exposure of the eye to lasers of certain wavelengths and power can cause corneal and/or retinal burns. Chronic exposure to excessive levels may cause corneal or lenticular opacities (cataracts) or retinal injury.
b) Skin: acute exposure to high levels of optical radiation may cause skin burns, while carcinogenesis may occur for ultraviolet and near ultraviolet wavelengths.
c) Chemical: some lasers require hazardous or toxic substances to operate (i.e., chemical dye, excimer lasers). Some are carcinogenic.
d) Electric shock: Most lasers produce high voltages that can be lethal.
e) Fire hazards: the solvents used in dye lasers are flammable. High voltage pulse or flash lamps may cause ignition. Direct beams from high power lasers may ignite flammable materials.

8.2 Lasers and laser systems are grouped according to their capacity to produce injury, and specific controls are then described for each group. Lasers manufactured after August 1, 1967 are classified and labeled by the manufacturer. Information on the label must include class, the maximum output power, the pulsed duration (if pulsed), and the laser medium or emitted wavelengths.

8.3 Maximum Permissible Exposure (MPE): the level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin. The criteria for MPE for the eye and skin are detailed in Section 8 of ANSI Z136.1-2007.

8.4 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.

9.0 General laser Safety Recommendations and Requirements.

9.1 Eye Protection: Eye Protection is required for the use of all high-powered pulsed lasers, as well as, all UV and IR lasers. The Principal Investigator, Supervisor, and EH&S determine the need for eye protection in the use of other lasers.

9.2 The minimum laser radiant energy or laser power level required for the application should always be used.

9.3 Beam Control: to minimize direct eye exposure, observe these precautions.

a) Do not intentionally look directly into the laser beam or at a specular reflection, regardless of its power.
b) Terminate the beam path at the end of its useful path.
c) Locate the beam path at a point other that eye level when standing or when sitting at a desk.
d) Orient the laser so that the beam is not directed toward entry doors or aisles.
e) Minimize specular reflections.
f) Securely mount the laser system on a stable platform to maintain the beam in a fixed position during operation and limit beam traverse during adjustments.
g) Confine primary beams and dangerous reflections to the optical table.
h) Clearly identify beam paths and ensure that they do not cross populated areas or traffic paths.
i) When the beam path is not totally enclosed, locate the laser system so that the beam will be outside the normal eye-level range, which is between 1.2 to 2 meters from the floor. A beam path that exits from a controlled area must be enclosed where the beam irradiance exceeds the MPE.

10.0 Additional Controls for Class 1 and Class 2 Lasers

10.1 Warning signs: "CAUTION LOW POWER LASER" signs are to be posted at each entrance to the operating area using Class 1 and Class 2 lasers.

10.2 If the manufacturer has not labeled the laser, attach a label on the laser with its classification and relevant warning information.

11.0 Additional Controls for Class 3 and Class 4 Lasers

11.1 All principal Investigators are required to write SOPs for all laser operations involving Class 3 and Class 4 lasers detailing alignment, operation and maintenance procedures. The SOP should be posted or attached to the inside surface of the lab door.

11.2 Standard Operating Procedure (SOP**):** The Principal Investigator for all Class 3b and Class 4 laser systems must provide an approved written SOP. This SOP should cover laser operations (i.e. description of activities, hazard identification and mitigation, routine alignment procedures, schematics of laser set-up) and other relevant hazards in the laser environment. A general laser SOP template is attached to this Manual. The use of the template is recommended. The template provides a guide for the laser user in identifying the characteristics of the laser operation and collateral hazards and in formulating set-up and alignment procedures.

All SOPs need to be reviewed annually by laboratory personnel working with lasers to ensure the accuracy of the procedures. If no new hazards have been added to the system, the users can perform the review without notifying EH&S. If new procedures, use of sub-nanosecond laser system, for example have been added to the experiment, a review by EH&S may be necessary to assure that all applicable safeguards have been satisfied.

11.3 For assistance in completing an SOP, contact EH&S.

11.4 A log must be maintained showing periods of use, and incidents involving Class 3 or Class 4 lasers. The log must be available, for review, at all times.

11.5 Labels: A laser classification label must be conspicuously affixed to the laser housing.

11.6 Warning Signs: Each entrance must be posted with a DANGER sign in accordance with ANSI Z136.1-2007.

11.7 Warning Devices: Entrance to laboratories with a Class 3b or Class 4 laser shall have a lighted warning sign that is fail-safe interlocked with the laser to activate when the laser is energized. The sign must be tested monthly. A written record of each test must be maintained, and must be accessible for review at all times.

11.8 Safety interlocks:

a) All protective enclosures that surround laser devices and high-voltage electrical sources must also be equipped with interlocks to prevent operation of the equipment when the enclosures are not in place.
b) Interlocks must be tested monthly, to ensure that they are operational. A written record must be maintained of each test. Documentation of the tests, must be accessible for review.
c) Interlocks must be designed so that after they are actuated, the capacitor, banks, shutters, or power supplies cannot be re-energized except by manually resetting the system.

11.9 The responsible individual in a laser area controlled by a warning light is permitted to momentarily override (bypass) any door interlocks to allow access of authorized persons if all of the following conditions are met:

a) There is no radiation hazard at the point of entry.
b) The personnel entering the area wear the necessary protective devices.
c) An interlock bypass circuit is designed into the interlock control system. This bypass circuit must only be operated from inside the interlocked area. It must delay no more than 15 seconds before shutting down the system.

11.10 If interlocks are not feasible, the Principal Investigator may consider the use of alarms, voice warnings, danger lights, door lock, key cards, or extensive security. EH&S must be consulted in choosing alternative to interlocks.

11.11 Laser laboratories and controlled areas must be designed so that personnel can enter and leave under emergency conditions.

11.12 Lasers must have a master switch with a key or coded access that prevents use once the key has been removed, or a code has been entered. The key must not be left in the control panel when the laser is not in use.

11.13 Laser controlled areas shall be established which have limited access, covered windows, and doors, and only diffuse reflective material. The facility must be a fully enclosed room or laboratory with floor-to-ceiling walls. Access to the area during laser operation requires the permission of the responsible operator.

11.14 Class 3b and Class 4 infrared laser beams with a wavelength greater than or equal to 710 nm must be terminated with fire resistant material.

11.15 Securely fasten all mirrors, prisms, beam stops, etc. in the beam path. Ensure that the laser is also securely fastened.

11.16 Circuit breakers must be identified for each laser.

11.17 Beam Enclosure: The entire beam path of Class 3b and Class 4 lasers, including the target area, should be surrounded by an enclosure equipped with interlocks that prevent operation of the laser system unless the enclosure is properly secured. When total enclosure of the laser beam path is not practical, both the non-enclosed laser beam and any strong reflections must be terminated at the end of their useful path using such devices as backstops, shields, or beam traps.

11.18 Reflection Control:

a) Materials that diffusely reflect laser radiation must be used in place of specularly reflective surfaces whenever possible.
b) To minimize personnel exposure, specurlarly-reflecting surfaces that are needed for beam-path control should be enclosed or shielded.

11.19 Invisible Beams:
Ultraviolet (UV) and infrared (IR) lasers that emit invisible beams require several additional controls:

a) Visual or audible beam-warning devices must be installed in areas where personnel may be exposed to radiation in excess of the MPE. These warning devices must be clearly identified and visible from all areas of potential exposure.

b) Shielding must be installed that will attenuate UV radiation to levels below the MPE for the wavelength being used.
c) Hazardous concentrations of by-products formed by the reaction of intense UV radiation with materials in the area must be controlled.
d) IR beam enclosures and backstops must be fabricated of IR-absorbent material and must also be fire-resistant.

11.20 Beam Mapping: Controlled laser areas must be surveyed with appropriate measuring devices to locate and identify direct and reflected beams that exceed the MPE; shielding may be required to limit unwanted radiation.

11.21 Direct Viewing:

a) Personnel must never look directly into any laser beam, without the required special precautions.
b) The primary beam and specular reflections of Class 3 or Class 4 lasers are particularly hazardous. In those cases where it is necessary to directly view a beam from a Class 3 or Class 4 laser, special provisions such as filters are mandatory.
c) An SOP must be prepared for operations where the beam of a Class 3 or Class 4 laser must be viewed directly or where it is necessary to work with optical viewers in close proximity to the laser beam.
d) Alternatives to direct viewing must be considered, for example, video cameras.

11.22 Alignment:

a) High power laser optical systems must never be aligned by direct beam viewing if the radiant exposure or irradiance exceeds the MPE.
b) Use low-power lasers; diffuse reflectors, image-retaining screens, exposed Polaroid film, and other devices that will minimize eye exposure.

11.23 Optical Viewing Aids: Using optical systems such as cameras, telescopes, etc., to view laser beams may increase the eye hazard. Therefore, all collecting optics must incorporate suitable means (such as interlocks, filters, or attenuators) to prevent eye exposures above the MPE.

11.24 Protective Equipment:

a) Laser protective eyewear shall be worn whenever MPE levels may be exceeded. However, it is a good practice to always wear eye protection when lasers are in use.
b) In general, eyewear provides protection over a narrow range of the laser spectrum. Eyewear designed for protection at one wavelength may afford little or no protection at another wavelength.
c) Consult eyewear manufacturers for proper selection of protective eyewear.
d) Laser protective eyewear must be approved by the American National Standards Institute (ANSI) and clearly labeled with optical densities and wavelengths for which protection is afforded. Eyewear must be inspected periodically by the user for pitting and cracking of the attenuating material, and for mechanical integrity and light leaks in the frame.
e) Protection for the skin may be afforded through the use of clothing to cover normally exposed skin areas.
f) Protective equipment is no substitute for common sense and the uses of good safety practice.

11.25 Unattended Equipment:

a) When lasers are to be left unattended, de-energize the power supplies or capacitor banks and remove the keys from power switches or master interlocks to prevent unauthorized activation of the equipment.

b) The operation of unattended lasers is only allowed when a specific SOP has been written and approved by the Principal Investigator.

11.26 Temporary Installations:

a) Occasionally, it may be necessary to remove protective enclosures or override equipment interlocks or other safety devices for service adjustments, maintenance, special training exercises, etc.
b) In these instances, a temporary controlled laser area must be set up. Specific methods for handling situations of this type must be described in the SOP.
c) Because the area will not have all the standard safety features, the SOP must describe provisions for protecting personnel who potentially be exposed.
d) When the entire beam path is not fully enclosed, restrict access into the area to persons wearing proper protective equipment. Make sure that all optical paths from the restricted-access area are adequately covered to prevent escape of laser radiation greater than the MPE for the eye.

12.0 Converting to a Class 1 Enclosed Laser

Any laser or laser system can be converted to a Class 1 enclosed laser by including all of the following controls in the laser system design. These controls must effectively enclose the laser, thus preventing personnel contact with emitted radiation while permitting unrestricted access into the area.

12.1 Protective Housing:

a) House the laser system within a protective enclosure to prevent escape of laser radiation above the MPE.
b) The protective housing must prevent personnel access to the laser system during normal operations.
c) Personnel entering the enclosure to perform maintenance or adjustment tasks must be made aware of the higher risk laser class.

12.2 Safety Interlocks:

a) Install safety interlocks wherever the protective enclosure can be opened, removed or displaced.
b) When activated, these interlocks must prevent a beam with radiant energy above the MPE from leaving the laser or laser system.
c) Service adjustments or maintenance work performed on the laser system must not render the interlocks inoperative or cause exposure levels outside the enclosure to exceed the MPE, unless the work is performed in a laser area with limited access and appropriate safeguards, supervision and control.

12.3 Fail-Safe Design: The protective enclosure and the laser system must be designed and fabricated so that if a failure occurs, the system will continue to meet the requirements for an enclosed laser operation.

12.4 The Primary Investigator must evaluate modifications to commercial laser systems, EH&S may be contacted for assistance and input. If the modifications decrease the safety controls, an SOP will be required.

12.5 Attenuated Viewing Windows: Use viewing windows containing a suitable filter material that will attenuate the transmitted laser radiation, to levels below the MPE under all conditions of operation

12.6 Warning Signs and Labels:

a) Label the enclosure with **"CAUTION-ENCLOSED LASER"** signs.

b) Attach a label directly to the laser, which gives the laser classification in the absence of the enclosure. Make sure that the label can immediately be seen when the enclosure is opened.

13.0 Controlling Associated Hazards

Many chemical and physical hazards other than laser radiation can be found in the laser area, and these must also be adequately controlled.

13.1 Electrical Equipment and Systems:
Most lasers contain high-voltage power supplies and often large capacitors or capacitor banks that store lethal amounts of electrical energy. In general, systems that permit access to components at such lethal levels must be interlocked. However, during maintenance and alignment procedures, such components often become exposed or accessible. This has caused numerous serious and some fatal shocks at other facilities.

a) Always be aware of the high risk of injury and fire in laser operations because of the presence of electrical power sources.
b) The installation, operation, and maintenance of electrical equipment and systems must conform to the standards stated in the National Electric Code (NFPA 70). Contact Physical Plant, Electrical Division for assistance.
c) No one should work on lasers or power supplies unless qualified to perform the specific tasks
d) Before working with electrical equipment, de-energize the power source. Lock and tag out the disconnect switch in accordance with the University Lockout/Tagout policy. If in question on proper procedures contact EH&S.

13.2 Lighting:

a) Adequate lighting is necessary in controlled areas.
b) If lights are extinguished during laser operation, provide control switches in convenient locations or in stall a radio-controlled switch.
c) Luminescent strips should be used to identify table and equipment corners, switch locations, aisles, etc.
d) When ambient light is not sufficient for safe egress from a laser area during an electrical power failure, install emergency lighting.

13.3 Ionizing and Non-Ionizing Radiation:

a) A laser operation may involve ionizing radiation that originates from the presence of radioactive materials or the use of electrical power in excess of 15kV. If radioactive material is present in the laser system, a "CAUTION-RADIOACTIVE MATERIAL" sign must be prominently displayed. If X-rays are generated a "CAUTION-X-RAYS" sign must be prominently displayed.
b) Microwave and radio frequency (RF) fields may be generated by laser systems or support equipment.

13.4 Hazardous Materials:

a) Bring only those hazardous materials that are needed for the operation, into the laser area.
b) All hazardous materials must be properly used, stored, and controlled. Consult Material Safety Data Sheets, and EH&S for information.
c) Do not allow laser beams and strong reflections to impinge on combustible materials, explosives, highly flammable liquids or gases or substances that decompose into highly toxic products under elevated temperatures, without providing adequate controls.

13.5 Dyes and Solutions: Laser dyes are often toxic and/or carcinogenic chemicals dissolved in flammable solvents. This creates the potential for fires, chemical spills, and personnel exposures above the permissible limits. Frequently, the most hazardous aspect of a laser operation is the mixing of chemicals that make up the laser dye. All of the chemical storage and mixing must be in accordance with the university's Chemical Hygiene Plan

a) Dye lasers normally use a lasing medium composed of a complex fluorescent organic dye dissolved in an organic solvent. These dyes vary greatly in toxicity, mutagenicity, and potential carcinogenitity.
b) All dyes must be treated as hazardous chemicals. Most solvents suitable for dye solutions are flammable and toxic by inhalation and/or skin absorption.
c) Obtain Material Safety Data Sheets for all dyes and solvents used in the operation.
d) Use and store all dyes and solvents in accordance with the instructions of the Material Safety Data Sheets.
e) All used dyes and solvents are to be disposed of as hazardous waste, using the protocol established in the Chemical Hygiene Plan, and on the EH&S web site.

f) Prepare and handle dye-solutions inside a chemical fume hood.
g) Wear a lab coat, eye protection and gloves.
h) Pressure-test all dye laser components before using dye solutions. Pay particular attention to tubing connections.
i) Install spill pans under pumps and reservoirs.
j) Be alert to contaminated parts.
k) Keep dye-mixing areas clean.

14.0 Disposal or Transfer of Lasers

14.1 Disposal

a) Lasers cannot be sold, donated, or transferred off campus without prior authorization from Environmental Health and Safety
b) Lasers must be rendered inoperative and any hazardous materials must be removed before disposal
c) A note must be sent to the Environmental Health and Safety Department stating that the laser was disposed of with the date it was done.

14.2 Transfer On-campus, Off –campus

a) To transfer Class 3b or 4 lasers on or off campus the PI must consult with Environmental Health and Safety Department.
b) All lasers and laser containing equipment must be examined to determine whether or not Federal Export Controls on access by foreign persons apply.

HAZARD DATA SHEET
ARGON ION LASER

The Argon Ion laser consists of a gas plasma tube held in a resonator consisting of two mirrors. The pressure within the tube is below atmospheric, and the plasma is excited by electrical arc discharge. An axial solenoid magnet is wound around the laser tube and the whole lot is water-cooled. The laser power supply is usually remote from the laser head, being connected by a service umbilical. Most argon lasers are operated from three-phase electrical supplies.

OPTICAL HAZARDS

1. The argon laser may emit radiation at wavelengths ranging from the near infrared to the near ultra-violet; this is dependant upon model and configuration. Typically, we may see the following:

    a) Multiline visible output with lines at 459nm, 476nm, 488nm, 501nm, 514.5nm, and 527nm. This is the configuration, which gives the most optical power.
    b) Single line output. Many lasing transitions are available, although some require special optics. A prism wavelength selector is used to change wavelength. The most common lines used are to two strongest: 488nm (blue) and 514.5nm (green).
    c) Multiline UV. There are two transitions at 351nm and one on either side. Most of the power is in the 351nm lines; this can be over 3W if the correct optics are fitted.

2. Most argon lasers are high power cw devices with outputs ranging from a few hundred milliwatts to tens of watts. It should be remembered that argon lasers are widely used in surgery, and are therefore very good at burning and cutting flesh

3. High power argon lasers constitute a fire hazard. An unfocused 200mW 514.5 nm wavelength beam can cause a black card to catch fire.

4. If the laser is misaligned no laser output will be seen, although amplified spontaneous emission will be. This contains a deep UV component and is hazardous. Never stare into the plasma.

5. There is medical evidence to suggest that long-term exposure to even low levels of blue light may have a serious effect on the color discrimination ability of the eye. Argon ion lasers emit a lot of blue light. Use personal protection, especially laser safety eyewear, enclose the experiment and remember that the hazards include low power diffuse reflections.

6. When using dielectric mirrors to reflect multilane laser output, ensure that all the lines are adequately reflected. There may some light transmitted by the mirror which could constitute a hazard.

7. The plasma tube is terminated with windows at Brewster's angle; laser beams may emerge vertically during laser maintenance. Vertical or skew beams may emerge from the laser during maintenance of the prism wavelength selector or the reference photodiode.

ELECTRICAL HAZARDS

1. An argon ion laser giving 20W of multilane optical output will take around 60A per phase from the 415V three-phase supply. Such a laser has a plasma tube length of around 2m and the arc discharge is maintained by a DC potential of 520V with a current of 55A. This is clearly a severe electrical hazard.
2. This laser uses a mixture of electricity and water. Unless handled carefully this can be lethal.
3. An electrical shock or laser burn may not be fatal, but it will cause your body to flinch. You may jump back into the electrical supply or hit your head on a table. This is a very serious hazard.
4. Be aware that many of the tube components are 'live' and that many of the voltages within the laser are referenced to a floating level which may be up to 300V below ground potential.
5. Do not open the laser head or power supply unless you have received training approved by both the Primary Investigator, and EH&S.

HAZARD DATA SHEET
EXCIMER LASER

The excimer laser uses a mixture of halogen and rare gases as the lasing medium. The gases are contained in a chamber at a pressure of 3.7 Bar (i.e. 3.7 atmospheres.). The gas is circulated by an internal fan and cooled by a water-cooled heat exchanger. Lasing is initiated and sustained by high voltage electrical discharge. Output is in the ultra-violet range of the spectrum.

OPTICAL HAZARDS

1. The laser is set up for fluoride operation and will emit at 193 nm with argon fluoride, and 248 with krypton fluoride. These wavelengths pose long-term exposure risks as well as immediate burn possibilities. The long-term photochemical changes to the skin include the "sun-tan" effect (the equivalent to sunburn), and for extreme cases, the risk of skin cancer. The major ocular risk is that of cataract formation. It must be noted that the maximum permissible exposure, according to the HSE, is only 30 Jm-2 (measured with a 1nm aperture). The low MPE is important; taking the case 1 J pulses and 10 HZ operating frequency, the power output will be 10W. This means that for a 10S sec chance exposure 41 dB of attenuation would be required in order not the exceed the MPE. Only one exposure per day is allowed.
2. Absorption of the UV by air poses a problem because ozone is generated. Exposure to ozone may produce symptoms such as nausea, light-headedness and may lead to collapse. All beam paths should be adequately and safely vented of ozone.
3. In order not to exceed to low maximum permissible exposure, all experiments should be enclosed. The enclosures and beam tubes should be interlocked in order to minimize the chance of accidental exposure.

CHEMICAL HAZARDS

1. The excimer laser uses krypton (or argon), helium, neon and fluorine gases; the fluorine is present as 5% in helium. Fluorine gas is corrosive, toxic, and the most powerful oxidizing agent known. It must be stored in a vented gas cabinet, at all times, and must be handled in piping designed specifically for the use of fluorine. Only trained authorized personnel may handle fluorine.
2. The exhaust vents of the vacuum pump and the laser must be connected to an operational fume extraction system designed for this particular purpose.

3. Read the Material Safety Data Sheets (MSDS) for the gases and abide by the guidelines for the safe handling, and usage of the gases.
4. If you suspect a fluorine leak, evacuate the laboratory immediately, close the doors, and seek help.

ELECTRICAL HAZARDS

1. The laser is pulsed at a rate of up to 10Hz. The electrical discharge potential is adjustable between 10kV and 30kV. If the laser is opened up during operation, there is a very real risk of electrocution. Keep the covers on the laser and power supply at all times.
2. Even if the laser is switched off, the capacitor banks within the device may spontaneously charge up so there is still a risk of electrocution, unless the grounding rod is in place.
3. The laser uses a mixture of electricity and water. Unless handled carefully, this can be lethal.
4. An electrical shock or laser burn may not be fatal, but it will cause your body to flinch, and cause you to jump back into the electrical supply, or hit your head, and cause an injury.

HAZARD DATA SHEET
HARMONIC GENERATION

If an intense laser beam is passed through a crystal, which exhibits non-linear optical properties, the crystal may produce a harmonic of the fundamental lasing wavelength. The emergent beam may contain both the original wavelength and the harmonic (usually the second harmonic; i.e. half of the wavelength of the fundamental). Using combinations of fundamental and harmonic wavelengths as the crystal input can yield higher harmonics and sum and difference frequency generation.

The efficiency of harmonic generation depends primarily upon the peak power of the pump laser, but also upon the type of crystal, its cut and temperature and the angle of incidence of the pump beam. Typical efficiencies range from fractions a percent for a cw pump beams up to around 50% for Q-switched pumping.

Harmonic generation is most commonly used with Nd: YAG lasers to produce doubled (532nm), tripled (355nm) and quadrupled (266nm) output from the 1064 nm fundamental. Other lasers can be used depending on the circumstances.

OPTICAL HAZARDS

1. The pump laser is likely to be very powerful. See the relevant hazard data sheet.
2. Personal protection, particularly laser eyewear, should cover the fundamental laser wavelength and all harmonics.
3. It is usual to separate the fundamental from the harmonics using a diachronic mirror. Such a mirror is coated to reflect one wavelength and transmit the other. There is usually some residual fundamental in the reflected harmonic and vice-versa, and although the amount will be low, even 1% of a 10W pump is100mW in the harmonic beam. Multiple filtration is therefore needed to ensure that the reflection of the unwanted wavelength is kept to an acceptable level.
4. Only use absorbing wavelength filters when the pump power is low, because they may bleach, crack, or even explode.
5. Always be particularly careful of stray reflections. Prisms and gratings will disperse the different wavelengths at different angles, and lenses and mirrors will behave differently for the different wavelengths.

HAZARD DATA SHEET
HELIUM-NEON LASERS

The helium-neon laser consists of a gas plasma tube held in a resonator consisting of two mirrors. The gas is a low-pressure mixture of helium and neon in which plasma is excited by an electrical discharge. The HeNe laser is most commonly available in the red 632.8nm configuration, but there are variations emitting at a number of wavelengths from green to infrared.

OPTICAL HAZARDS

1. Helium-neon lasers are perceived as being "safe". This is not the case. Consider the following example: a low powered red HeNe beam accidentally entered a person's eye. Clinical examination showed no eye damage, but the person went into clinical shock (which may exhibit itself as disorientation, nausea, high temperature and even collapse). Do not underrate the hazardous effects of a HeNe beam strike.
2. The HeNe laser may emit light in the visible or infrared area of the spectrum. Some helium-neon lasers are tunable. Powers may extend from sub-milliwatt to several tens of milliwatts. In all cases the beam is tightly collimated. The tightly collimated beam presents an eye hazard over a considerable distance.
3. Higher power helium-neon lasers may well be able to cause black cardboard to smolder if the beam is focused.

ELECTRICAL HAZARDS

1. Helium-neon lasers are usually DC excited, although some RF devices do exist. The power is usually obtained from a standard single-phase wall socket, but battery operation is sometimes possible. In all cases, the power supply converts the incoming electrical voltage to a high voltage around the KV level. There is an obvious risk of electrical shock or electrocution if the laser is mishandled.
2. The voltage converter in the power supply often uses high capacity capacitors; these may hold their charge even when the laser is switched off. Beware of electrical shocks even id the laser is switched off and unplugged.
3. An electric shock may not be fatal, but it will cause your body to flinch. You may jump back into other hazards.
4. Keep the covers on the laser and power supply at all times.

HAZARD DATA SHEET
QUANTEL Q-SWITCHED YAG

This is a small "Giant-Pulse" laser, which is capable of producing very high peak powers at several discrete wavelengths from the near infrared through to the near ultra-violet. It is a pulsed system with a maximum pulse repetition frequency of 10 Hz. At this frequency it emits 10W average power, (i.e. 1 J per pulse) at 1064nm. The peak power per pulse is well over 10MW. This is clearly a very severe optical hazard.

OPTICAL HAZARDS

1. Secondary reflections may contain enough power to constitute a fire hazard.
2. The laser may be used at the fundamental wavelength of 1064nm, or frequency doubled (532nm) tripled (355nm) or quadrupled (266nm). A mixture of any of these wavelengths may be emitted under some circumstances. Although the power obtained decreased with decreasing wavelength, the power obtained from higher harmonics will still be sufficient to constitute a serious optical hazard.
3. Wherever possible, use a low powered helium-neon laser for optical alignment of the YAG beam, and when this is not possible, take extreme care over beam tracing, paying particular attention to stray beams and back-reflections.
4. Always use personal protection and ensure that laser safety eyewear covers all the wavelengths that you will use, and has adequate power handling ability. Remember that three of the wavelengths emitted from this laser lie outside the visible region of the spectrum. While 355nm and 266nm light tends to be blocked by the cornea, the physiological effects of intense light of these wavelengths include cataract formation and skin cancer. Radiation at 1064nm is transmitted by the cornea and focused by the lens onto the retina to form an image with a power density 500,000 times that of the laser itself. This is a very severe hazard, and it should be borne in mind that the majority of the laser output will be at this wavelength.
5. Never take the cover off the laser unless you have been trained to do so. There are optical and electrical hazards inside.

HAZARD DATA SHEET
SEMICONDUCTOR LASERS

There are many types of semiconductor lasers available, in general, the laser itself is a very small device (a few hundred microns in dimension) and does not possess any obvious sign of being hazardous. Some manufacturers supply purpose-built power supplies and device drivers and these may offer the standard electrical hazards of any mains-powered equipment, but in general the laser device itself is a low voltage, high current component. The semiconductor laser devices may be placed inside external cavities, which alter the optical attributes of the laser. In general, it is worth remembering that the power circulating inside the external cavity will be much greater than that emitted from the output coupler. Semiconductor lasers are available with a wide range of output powers, from sub-mW to Watts, though the majority of lasers in the department operate at the level of a few mW.

OPTICAL HAZARDS

1. The laser devices themselves usually emit a highly divergent beam; nonetheless, it only requires a lens to collimate the beam to the size of the eye's pupil. Do not rely on the divergence of the beam as a safety mechanism.
2. Lasers emitting visible light (400nm to 700nm) are relatively safe up to outputs of 1mW due to the protection afforded by the eye's blink response, however, this is not the case for those emitting between 700nm and 1400nm. At these wavelengths, the light is not visible (i.e. the blink response will not function) yet the eye's lens will focus the light to a small spot on the retina, increasing the irradiance by up to 500,000 times. Consequently, the maximum permissible exposure levels are very low in this region. Typically, taking an 850nm laser and assuming a 10 sec chance exposure time the MPE is around 750 microWatts (through a 7mm aperture). This is the maximum level which may safely reach the eye.
3. Light from semiconductor lasers emitting at wavelengths longer than 14nm is absorbed by the front of the eye and hence, does not reach the retina. However, due to the possibility of cataract formation, the irradiance of such lasers must be kept well down for safe usage. Typically, taking a 1500nm laser and assuming a 10 sec chance exposure time, the MPE is around 1mW (measured with a 1mm aperture).
4. In the light of the above, make it a point to always wear suitable and adequate eye protection whenever it is possible to access the beam from an IR-emitting semiconductor laser. Use a viewer or a viewing card and eye protection when locating the beam.

5. Powers above 30mW may constitute a fire hazard if the beam is focused.

HAZARD DATA SHEET
TI:SAPPAHIRE LASER

The Ti:sapphire laser consists of a folded optical cavity built around the active medium of a Ti: spphire crystal. Energy is supplied to the cavity by a pump laser: in this case, an argon-ion laser operating all lines. This pump power is sued by the Ti:sapphire laser to produce high power tunable cw output at wavelengths between 675nm and 1100nm. The majority of the wavelength range of the laser is thus not visible to the human eye, lying as is does in the near infrared region of the spectrum. The power produced by the Ti:sapphire laser is a function of wavelength a pump laser power: thus, for a 5Wpump, the Ti:sapphire will yield just over 1W of 800nm output: a 10W pump gives around 2.5W at the same wavelength. There are no electrical connections to the laser body, but the crystal is water-cooled, and the cavity may be nitrogen purged in order to improve the stability of the longer wavelength output.

OPTICAL HAZARDS

It should be borne in mind that this is a class r emitting a high power collimated beam of around 1nm diameter. Generally speaking, the beam will not be visible, so special care must be taken. Near infra-red radiation below 1400nm poses a particular risk, as these wavelengths are readily focused the by the eye's lens onto the retina creating a small spot with a power density 500,000 times greater than that of the original beam. This, coupled with the fact that the spot will in fact be invisible, lead to a very low maximum permissible exposure to such radiation: around 12 micro Watts at 800nm, or 3.2x10-4 times the output of a Ti:sapphire laser pumped with a 10W argon laser.

Although the primary optical hazard is that of the infrared output of the Ti:sapphire laser, the argon ion pump laser produces visible output at much higher powers. Under normal operating conditions, this will pose few problems, as it will be permanently aligned with the Ti:sapphire laser, and should not therefore require any form of beam steering. However, great care must be taken when aligning the two lasers (see the hazard data sheet for the argon ion laser for further details).

In the light of the above, make it a point to always wear suitable and adequate eye protection whenever it is possible to access the beam from an IR-emitting Ti:sapphire laser: Use a viewed or a viewing card and eye protection when locating the beam.

Both the Ti:sapphire laser and pump laser produce output powers sufficiently high to pose a fire hazard. An unfocused 200m

Wk 2mm diameter green beam can cause bleck card to catch fire, and a similar risk is present with infrared wavelengths.

University of Arkansas
Laser Registration

Principal Investigator's Name: ____

Department: ______________________

Campus Phone: ___________________ E-mail:______________________________

Laser Lab Location: Building:__________________ Room:____________________

Laser system Information:

Manufacturer:______________________Model#_____________________________

Serial #___________________________

Strength____________________ Laser Class: (1, 2, 3a, 3b, 4) _______________

Description of Laser Use / Research:

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Laser SOP's

Recommended Operating Procedures for Class 2 and Class 3a Visible Lasers:

Introduction: Class 2 and Class 3a lasers are not normally hazardous to the eye unless one stares into the direct or specularly reflected beam(the aversion response is usually sufficient to prevent eye damage). However, if the beam from a Class 3a laser is viewed with optics, a serious retinal injury may occur before one can react. The diffusely reflected beam from a Class 3a laser poses no hazard to the eye or skin. Although Laser Pointers are normally classified as Class 3a lasers, they are specifically exempted from this program.

Sample SOP for Class 2 and Class 3a Lasers:

1. Class 2 and Class 3a lasers should not be used outdoors or pointed toward windows without the written consent of the LSO.
2. The faculty member responsible for the laboratory or lecture session shall inform the students of the potential hazards associated with Class 2 and Class 3a lasers before their use in a laboratory or classroom setting, and instruct the students in the proper and safe use of the laser. Persons who have not received such instruction shall not be permitted to operate Class 2 or Class 3a lasers.
3. Faculty, staff, or students utilizing Class 2 and Class 3a lasers shall not stare into the direct or specularly reflected laser beam or encourage others to do so.
4. Appropriate **CAUTION** or **DANGER** signs, as approved by the LSO, shall be prominently posted for the area or areas in which these lasers are utilized, so as to warn possible passersby.
5. Faculty, staff, or students utilizing Class 3a lasers should execute reasonable cares such that the direct or specularly reflected beam from the laser is not directed toward the eyes of any person. They should try, in particular, to keep the beam either below, or above the eye level of persons sitting or standing nearby. In order to avoid exposing their own or the eyes of any other person, they should think about the beam path before attempting to use mirrors or other optical devices to change the direction of the beam.
6. These lasers may not be used in conjunction with optics that concentrate the beam; however, under these conditions one must exercise greater care to prevent the concentrated beam from entering the eye.

7. Class 2 and Class 3a lasers shall not be left unattended, and shall be turned off after use.
8. Power supplies shall only be serviced by a person or persons trained to do so.

Sample Standard Operation Procedure (SOP) for Class 3b or Class 4 Laser:

ONLY STUDENTS AUTHORIZED BY AN INSTRUCTOR SHALL OPERATE THIS LASER.

Follow these steps anytime the laser is used.

1. Obtain the interlock key from your instructor.
2. See that all unauthorized people leave the room.
3. Secure the laboratory door, then activate the laboratory interlock system. Be ready to turn the laser off if any unauthorized person or person without laser safety eyewear enters the laboratory.
4. Have emergency telephone numbers readily available.
5. Ensure all people remove wristwatches or other reflective jewelry from their bodies.
6. Set up the optical components necessary for the experiment.
7. Check that all beam stops are in place and that there are no unnecessary reflective surfaces in the optical path. One block should be placed behind the first optical component. A second beam should be placed behind the second optical component etc.
8. Turn on the cooling water to the laser (if appropriate).
9. Set the laser power control to the lowest power possible.
10. Ensure everyone in the laboratory wears that appropriate laser safety eyewear.
11. Insert the interlock key into the laser switch and unlock the laser.
12. Announce loudly, with a short countdown that you are turning the laser on.
13. Turn the laser on.
14. Align the optical components starting with the component nearest the laser. When it is properly aligned, move the first beam block behind the third optical component. Repeat this procedure until the entire optical system is aligned. It is important that the laser beam be limited to one new component at a time until the system is aligned. This will minimize uncontrolled reflection during the alignment procedure.

DO NOT REMOVE YOUR SAFETY EYEWEAR DURING THE ALIGNMENT PHASE. IF YOU CANNOT SEE A FAINT IMAGE OF THE BEAM YOU HAVE THE WRONG OPTICAL DENSITY EYEWEAR.

TURN OFF THE LASER AND OBTAIN EYEWEAR WITH THE CORRECT DENSITY.

1. Increase the beam power if necessary and complete the assigned task. Always use the lowest beam power necessary for the procedure.
2. Turn off the laser.
3. Remove your laser safety eyewear and place it in their proper storage area.
4. Allow the laser to cool down and then turn off the cooling water.
5. Remove the key from the laser interlock switch.
6. Turn off the laboratory interlock system.
7. Return the key to your instructor.

EMERGENCY INSTRUCTIONS

1. If possible, shut the laser off and remove the interlock key. If not possible, alert everyone to get out of the laboratory and leave the laboratory yourself.
2. If there is a fire, get everyone out of the laboratory immediately. At the same time shout "FIRE" loudly and frequently. Turn in a fire alarm. Do not try to "fight" the fire from inside the laboratory—do it from the doorway so that you have an escape route.
3. Contact your instructor or other responsible person immediately and describe the emergency.
4. If necessary, call security or the Fire Department. The emergency telephone numbers are: **911 or 575-2222. EH&S may be reached at 575-5448**

Sample Laser Standard Operating Procedure Template
University of Arkansas

Laser: ____ Date: ____________

Department/Division:____

Location:____

This procedure shall be read and signed annually by all persons Who use lasers listed in this SOP.

1. **LASER SAFETY CONTACTS:**

University of Arkansas: EH&S ______________________ Phone (479) 575-5448

Principal Investigator:______________________________
Phone:________________

Maintenance/Repair _____________________________
Phone:___________________

Medical
Emergencies:______________________________Phone:___________________

2. **LASER DESCRIPTION**
Attach latest laser system description. This includes the laser type, intended application, location, wavelength, output beam diameter, and beam divergence. For continuous wave (CW) lasers include the average power; for pulsed lasers include the energy per pulse, pulse duration, and repetition rate. Update as required.

3. **LASER SAFETY PROGRAM**
Clearly outline each category below:
   a) Hazards of this particular type of laser
   b) What actions are taken to mitigate those hazards
   c) Responsibilities of the laser operator(s)
   d) Laser Training received by all laser users
   e) Laser Registration Requirements
   f) Sign and Labeling Requirements
   g) Personnel Protective Equipment Requirements

h) Disposal Requirements and Procedures

4. OPERATING PROCEDURES

a) Initial preparation of Laboratory environment for normal operation (key location, outside status indicator on, interlock activated, warning sign posted, personnel protective available, other):
b) Target area preparation:
c) Special Procedures (alignment, safety tests, maintenance tests, other):
d) Operation procedures (power settings, Q-switch mode, pulse rate, other) are as follows:
e) Shutdown procedures are as follows: