Laser Safety Manual

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PREFACE:

This document presents guidelines to help protect Kansas State University employees from the hazards associated with lasers and laser system operations. The intent of this manual is to ensure the safe use of lasers through engineering and administrative controls. This objective shall be accomplished by identifying potential hazards, providing recommendations for hazard control, and training laser operators and incidental personnel. The requirements and recommendations detailed in this program are applicable to all lasers used in research and instructional laboratories which are operated by Kansas State University. All laser users must register with the Office of Environmental Health and Safety.

This document provides guidance for compliance with applicable State and Federal regulations along with the **American National Standard for the Safe Use of Lasers, ANSI Z136.1-2007** and is recognized as a minimum standard for laser safety.

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Kansas State University
Department of Environmental Health and Safety

LASER SAFETY PROGRAM

I. INTRODUCTION

LASER is an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation. Laser is another form of radiation. The light energy generated by a laser is in or near the optical spectrum of light and amplified to extremely high intensity. This light energy is expressed as a laser's wavelength in nanometers (nm). The laser is an intense, highly directional beam of light that can be directed, reflected, or focused on an object. The object will partially absorb the light, raising the temperature of the surface and/or interior of the object, and causing changes in the object. The primary mechanism of beam damage for most lasers therefore, is thermal. When the wavelength of the laser is in the ultraviolet (UV) region, then photochemical effects can occur in the object. The intensity of the radiation that may be emitted and the associated potential hazards depend upon the type and classification of laser, the wavelength of the energized beam, and the proposed uses of the laser system.

The safe use of laser systems depends upon the basic principles of recognition, evaluation, and control of potential hazards. This program will review laser operations, the associated potential hazards, responsibilities of the laser user community, and the services provided by the Department of Environmental Health and Safety to help in the safe use of laser radiation.

II. CLASSIFICATIONS

Lasers are divided into a number of classes depending upon the power or energy of the beam and the wavelength of the emitted radiation. Laser classification is based on the laser's potential for causing immediate injury to the eye or skin and/or potential for causing fires from direct exposure or reflection off diffuse and reflective surfaces. Commercially produced lasers have been classified and identified by labels affixed to the laser since August 1, 1976. In cases where the laser has been fabricated on campus or is otherwise not labeled, the LSO will assist with labeling the laser including power, wavelength, and exposure duration.

A. **Class 1 laser or laser system-** cannot emit levels of optical radiation above the exposure limits for the eye under any exposure conditions inherent in the design of the laser product. For visible laser with wavelengths longer than 500 nm, the limit is 0.4 mW. For lasers of wavelengths shorter than 500 nm, the limit is 0.04 mW. There may be a more hazardous laser embedded in the enclosure of a Class 1 product, but no harmful radiation can escape from the enclosure. Class 1 lasers or laser systems are relatively safe, as long as the system is not modified.

B. **Class 1M laser system-** a class 1 laser using magnifying optics. Incapable of causing injury during normal operation unless collecting optics are used.

C. **Class 2 laser or laser system**- emits a visible laser beam which by its very bright nature will be too dazzling to stare into for extended periods. Momentary viewing is not considered hazardous. The upper radiant power limit on this type of device is 1 mW which corresponds to the total beam power entering the eye for a momentary exposure of 0.25 seconds. Class 2 lasers or laser system requires no special safety measures other than not staring into the beam.

D. **Class 2M laser system-** a class 2 laser using magnifying optics. Visible lasers incapable of causing injury in 0.25 seconds unless collecting optics are used.

E. **Class 3 laser**- can emit any wavelength, but cannot produce a diffuse or scattered reflection hazard unless focused or viewed for extended periods at close range. Safety training must be completed by the laboratory personnel before using these lasers. In addition, the laser should be operated within a well marked and controlled area. Class 3 is divided into two sub-classes 3R (formally 3A) and 3B.

1. Class 3R lasers are "Marginally Unsafe." This means that the aversion response is not adequate protection for a direct exposure of the eye to the laser beam, but the actual hazard level is low, and minimum precautions will result in safe use. This sub-class only allows visible lasers with a maximum continuous wave (CW) power of 5mW and an invisible laser with a CW power of up to 5 times the Class 1 limit. It is also not considered a fire or serious skin hazard. Since the output beam of such a laser is definitely hazardous for intrabeam viewing, control measures must eliminate this possibility.

2. Class 3B lasers are hazardous for direct eye exposure to the laser beam, but diffuse reflections are not usually hazardous (unless the laser is near the class limit and the diffuse reflection is viewed from a close distance). This sub-class includes continuous wave (CW) or repetitive pulse lasers with a maximum average power of 0.5 W. The maximum pulse energy for a single pulse class 3B laser in the visible and near IR varies with the wavelength. For visible lasers the maximum pulse energy is 30mJ. It increases to 150 mJ per pulse in the wavelength range of 1050-1400 nm. For UV and the far Infrared (IR) the limit is 125 mJ. Class 3B lasers operating near the upper power or energy limit of the class may produce minor skin hazards. Most Class 3B lasers do not produce diffuse reflection hazards. However, single pulse visible or near IR class 3B lasers with ultra-short pulses can produce diffuse reflection hazards at more than a meter from the surface. Eye protection may be needed while the laser is operating. The Laser Safety Officer (LSO) must perform a hazard analysis on the lab before operation of the laser.

F. **Class 4 laser**- any that exceeds the Annual Exposure Limit (AEL) of a Class 3 device. Class 4 lasers have an average power level greater than 0.5 W. The lower power limit for single pulse Class 4 lasers varies from 0.03 J for visible wavelengths to 0.15 J for some near IR wavelengths. These lasers are powerful enough to be a fire, skin, and diffuse reflection eye hazard. Class 4 lasers require the use of eye protection, facility interlocks, and special safeguards. The LSO must perform a hazard analysis on the lab before operation of the laser.

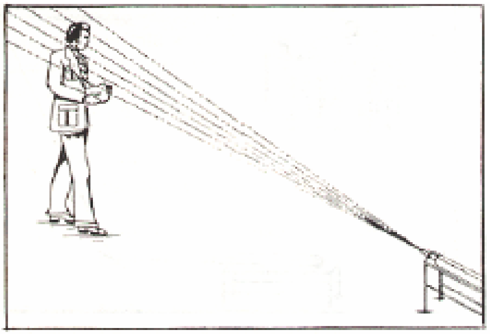
III. LASER REGISTRATION

The Principle Investigator is responsible for all safety precautions described in this manual that pertain to his/her laser systems. A Laser Registration Form (Appendix C) must be completed and returned to the LSO for each Class 2, 3R (formally 3A), 3B, and 4 laser systems used within research and instructional laboratories. Any changes in the use of the laser, laser location, and/or transfer of a laser require LSO notification. The Laser Relocation Form (Appendix D) must be filled out and faxed (532-1981) to the LSO prior to moving a laser or laser system. If you have any questions about completing the laser registration form or relocation form, please contact the LSO at **532-5856** or by email at **safety@ksu.edu**.

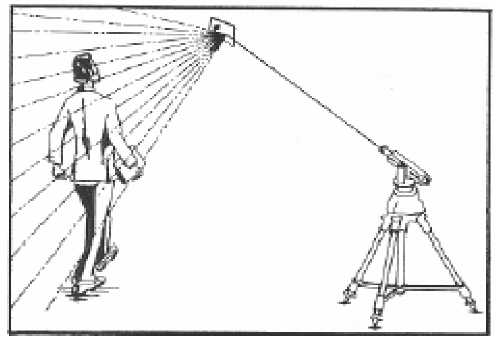
IV. LASER HAZARDS

A. **Beam Hazards**- Destruction of tissue can occur to the eye and skin. In the far-UV and far-IR regions of the optical spectrum, the cornea will absorb the laser energy and be damaged. In the near-UV region and near-IR at certain wavelengths the lens may be damaged. The greatest hazards are 400 - 1400 nm wavelengths which can damage the retina. Lasers below the visible spectrum (>1400 nm) are especially dangerous because the eye does not have a natural aversion at these wavelengths. Keep in mind that the light entering the eye from a collimated beam in the retinal hazard region is concentrated by a factor of 100,000 times when it strikes the retina. If the eye is not focused at a distance or if the laser light has been reflected off diffuse surfaces, this hazard is greatly diminished but can still be very dangerous.

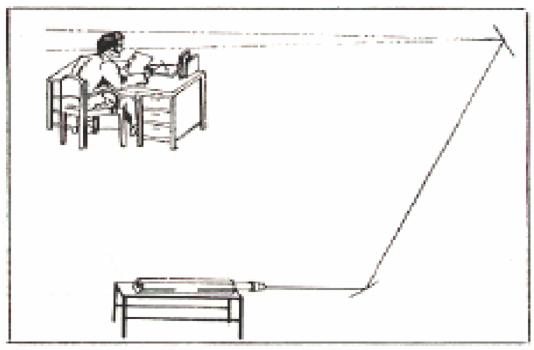
   There are a variety of types of beam exposures that are not limited to intrabeam viewing. For high powered laser, the specular or diffuse reflection may be equally as damaging.



Direct Intrabeam exposure.



Diffuse Reflection.



Specular Reflections.

Intrabeam exposure: The skin or eye is exposed directly to all or part of the laser beam resulting in a full exposure to the irradiance of the beam.

Specular reflection: The reflection from a smooth or mirrored surface. Items such as jewelry or cover glass of wrist watches produce specular reflections. These items should be removed prior to operating a laser. Exposure to specular reflections can be as dangerous as an intrabeam viewing.

Diffuse reflections: Reflection off a non-uniform or rough surface. Diffuse reflection scatter the beam and does not carry the full power of an intrabeam exposure like in specular reflections. However, diffuse reflections from Class IV lasers can contain enough power to initiate a fire.

B. Electrical Hazards- The most common hazard encountered in laser use is electric shock. Potentially lethal electrical hazards may be present especially in high-powered laser systems. To reduce electrical hazards, high voltage sources and terminals must be enclosed unless the work area is restricted to qualified persons only. Whenever feasible, power must be turned off and all high-voltage points grounded before working on power supplies. Capacitors must be equipped with bleeder resistors, discharge devices, or automatic shorting devices.

Other general guidelines to follow include:

- **Never wear jewelry when operating a laser. Metal jewelry can be conductive. Jewelry in general can create a specular reflection hazard. This includes wrist watches.**
- **Use the one hand rule when working on circuits (make sure not to ground yourself).**
- **Avoid standing in water and assume that all floors are conductive when working with high voltage.**
- **Use rubber gloves and insulating floor mats when available.**
- **Do not work alone.**
- **Maintain access to main power shutoff.**

C. **Chemical Hazards**- Some material used in laser systems (excimer, dye, chemical lasers) may be hazardous or toxic substances. Also, laser-induced reactions may produce hazardous particles or gases around the laser system.

D. **Fire Hazards-** Solvents used in dye lasers may be extremely flammable. Ignition may occur via high voltage pulses or flash lamps. Direct beams and unforeseen specular reflections of high-powered CW infrared lasers are capable of igniting flammable materials during laser operation. Other potential fire hazards are electrical components and the flammability of Class IV laser beam enclosures.

E. **Compressed Gases-** Many hazardous gases are used in lasers including chlorine, fluorine, hydrogen chloride and hydrogen fluoride. Standard operating procedure must be developed for the safe handling of compressed gases which include:

- **Cylinders can not be free standing. They must be attached to a cart or secured by a chain or strap.**
- **Gases of different categories (toxics, corrosives, flammables, oxidizers) must be stored separately.**

F. **UV Radiation-** Laser discharge tubes and pumping tubes may emit hazardous levels of ultraviolet radiation called "collateral UV" and should be suitably shielded. UV radiation can cause photodermatitis as a result of exposure to some industrial chemicals or medications.

G. **Laser Dyes and Solutions-** Laser dyes are complex fluorescent organic compounds which, when in solution with certain solvents, form a lasing medium for dye lasers. Certain dyes are highly toxic or carcinogenic. These dyes are frequently changed and special care must be taken when handling, preparing solutions, and operating dye lasers. A Material Safety Data Sheet (MSDS) for dye compounds shall be made available to all appropriate workers.

H. **Laser Generated Air Contaminants (LGAC) -** Air contaminants may be generated when certain Class IIIB and Class IV laser beams interact with matter. The quantity, composition, and chemical complexity of the LGAC depend greatly upon the target material, cover gas, and beam irradiance. The LSO will ensure that the industrial hygiene aspects of exposure to LGAC are addressed and that the appropriate control measures are used.

V. HAZARD CONTROLS

A. The hazard controls necessary for the safe use of laser radiation depends upon:

1. The laser classification

2. The environment where the laser is used

3. The laser operating characteristics

4. The persons operating the laser

5. The general population within the vicinity of the laser

Laser safety procedures can best be evaluated by grouping them according to the class of laser in use. Appendix B of this program provides a list of appropriate control measures for each laser classification.

B. Review of repeated incidents have demonstrated that accidental eye and/or skin exposures to laser radiation, and accidents related to the ancillary hazards of a laser or laser system, are most often associated with personnel involved with the use of these systems under the following conditions:

1. Unanticipated eye exposure during alignment

2. Misaligned optics

3. Available eye protection not used

4. Equipment malfunction

5. Improper method of handling high voltage

6. Intentional exposure of unprotected personnel

7. Operator unfamiliar with laser equipment

8. Lack of protection for ancillary hazards

9. Improper restoration of equipment following service

10. Inadvertent beam discharge

11. Insertion of flammable materials into beam path

C. **Engineering Controls-** Engineering controls are the priority means of minimizing the possibility of accidental exposures to laser hazards. If engineering controls are impractical or inadequate, then safety should be supported through the use of administrative procedures and personnel protective equipment. Engineering controls that may prove useful and effective in improving the safety of a laser or laser system are provided in the following list:

1. **Protective Housing and Interlocks-** A protective housing is a physical barrier sufficient to contain the beam and laser radiation from exiting the laser system so that the maximum permissible exposure (MPE) is not exceeded on the outside surface. Protective housings must be interlocked so that the laser cannot operate when the housing is opened or removed. When the requirement of a protective housing are fulfilled, the laser system is considered a Class I laser and no further control measures are required. If the interlock is overridden or removed, usually for maintenance by a qualified individual, then the laser is no longer a Class I system and proper control measures must be used.

2. **Laser Use Without Protective Housing-** In the research environment, lasers are often used without protective housing in place. The use of optical tables and optical devices are typically employed in order to manipulate the laser beam. In this environment, the LSO will evaluate the hazards and recommend control measures to ensure safe operation. These control measures may include but are not limited to the following:

- **Access restriction (see below)**
- **Area controls (see below)**
- **Barriers, curtains, and beam stops (see below)**
- **Procedural controls**
- **Eye protection**
- **Training**

3. **Access Restriction-** For Class 3B and 4 laser laboratories, access controls are required to prevent unauthorized personnel from entering the area when the laser is in use. Doors must be kept closed when the laser is in operation. Secondary doors that can allow access to a laser in operation must be either locked or interlocked and must have signage similar to the primary entrance. Special cases will be reviewed by the LSO.

4. **Area Control-** Class 3B and 4 laser area control measures are used to minimize laser radiation hazards. The area must be posted with the appropriate signage and include a lighted sign or indicator light at the doorway indicating the "ON" status of a laser system. Only authorized personnel who have been appropriately trained will be allowed to operate the laser. Control of the laser beam path shall be accomplished in the following manner:

    - **<u>Totally Enclosed Beam Path</u>- where the entire beam path is unenclosed, a laser hazard analysis shall be performed by the LSO to establish the nominal hazard zone (NHZ) if not furnished by the manufacturer or available as part of the classification.**
    - **<u>Limited Open Beam Path</u>- Where the beam path is confined to significantly limit the degree of accessibility of the open beam, a hazard analysis shall be performed by the LSO to establish the NHZ.**
    - **<u>Enclosed Beam Path</u>- When the protective housing requirements are temporarily relaxed such as during service, the LSO shall establish the appropriate controls. These may include a temporary area control and administrative and procedural controls.**

5. **Barriers, Enclosures, and Beam Stops-** Beam barriers, enclosures, and stops are used to prevent beam propagation outside of the controlled access area in excess of the MPE. It is always desirable to enclose as much of the beam path as possible. As with a protective housing, the proper enclosure of the entire beam path may change the laser system to a Class 1 laser. When the beam needs to be directed to another area such as between optical tables, enclosure of the beam is recommended. Physical barriers are used to prevent laser radiation from exiting the systems. Rail curtains can be used to completely enclose an optical table or part of the laser system. Due to the power density of Class 3B and 4 lasers, the combustible properties of the barrier material must be evaluated and certified. Beam stops are used to prevent the beam from leaving the optical table and to terminate the beam path. Beam stops are to be used behind optical devices in the event that the beam becomes misaligned.

D. **Administrative Controls-** If administrative controls are impractical or inadequate, then safety should be supported through the use of administrative procedures and personnel protective equipment.

1. **Standard Operating Procedures (SOP's) -** A written SOP must be established for normal use, maintenance, and alignment operations. The SOP's will be maintained with the laser equipment for reference by operators or service personnel and can be used for instructional material to train new laser users in the laboratory. All SOP's will be updated to reflect any changes in laboratory protocol and equipment usage and sent in to the LSO for record purposes.

2. **Warning Signs and Labels-** All signs and labels must comply with ANSI Z136.1 (2007) and the Food and Drug Administration Center for Devices and Radiological Health (FDA/CDRH) standards. Entry ways into laboratories containing Class 2 and 3R (formally 3A) lasers shall be posted with a "Caution" sign if the beam is an expanded beam. If a Class 3R beam is a narrow or "small" beam a sign with "Danger" shall be posted. Entry ways into laboratories containing Class 3B and 4 lasers shall be posted with a "Danger" sign. The signs shall include the type of laser (i.e. Nd:YAG, Helium Neon), the emitted wavelength, maximum output, and class (see Appendix F). All lasers classes except Class I shall have appropriate equipment warning labels affixed to a conspicuous place on the laser housing or control panel. Free signage can be found; i.e. Lawrence Berkeley Laser Safety Webpage (**http://www.lbl.gov/ehs/ih/lasers/laserSigns.shtml**).

E. **Personal Protective Equipment**

1. **Eye Protection-** Eye protection is required for Class 3B and 4 lasers when engineering and administrative controls are inadequate to eliminate potential exposure in excess of the applicable MPE. The use

of laser protective eyewear is especially important during alignment procedures since most laser accidents occur during this process. Protective eyewear must be labeled with the absorption wavelengths and optical density (OD) rating at those wavelengths. The LSO will determine the proper OD for protective eyewear.

In addition to selecting the appropriate OD for safe viewing, one should consider the percentage of visible light transmitted to the eye while wearing eye protection so that the beam can be adequately viewed without the need to remove the eyewear. Comfort and fit are also important factors when selecting protective eyewear. Protective eyewear must also be replaced if they start to be scratched up and become difficult to see through.

A. Eye Injuries- Laser irradiation of the eye may cause damage to the cornea, the lens, or the retina, depending on the wavelength of the light and the energy absorption characteristics of the ocular media. Lasers cause biological damage by depositing heat energy in a small area, or by photochemical processes. Infrared, Ultraviolet, and Visible U.V. radiation are capable of causing damage to the eye.

1. **Retinal Damage--Visible and Near Infrared (Spectral Region 400-1400nm) -** Visible wavelengths penetrate through the cornea to be focused on a small area of the retina, the fovea centralis, and could damage your ability to focus your eye permanently. This process greatly amplifies the energy density and increases the potential for damage to the retina. Lesions may form on the retina as a result of local heating of the retina subsequent to absorption of the light.

2. **Corneal Damage--Infrared (Spectral Region 1.4 to 1000nm) -** The Cornea of the eye is opaque to infrared radiation. The energy in the beam is absorbed on the surface of the eye and damage results from heating of the cornea. Excessive infrared exposure causes a loss of transparency or produces a surface irregularity on the cornea.

3. **Corneal Damage--Ultraviolet (Spectral Region 200-400nm) -** The cornea of the eye is also opaque to ultraviolet radiation. As with infrared radiation, the energy of the beam is absorbed on the surface of the eye and corneal damage results. Excessive ultraviolet exposure results in photokeratitis (Welder’s Flash), photophobia, redness, tearing, conjunctival discharge, and stromal haze. There is a 6-12 hour latency period before symptoms of photochemical damage appear.

4. **Other Ocular Damage-** There are two transition zones between corneal hazard and retinal hazard spectral regions. These are located at the bands separating UV and visible, and near infrared and infrared regions. In these regions, there may be both corneal and retinal damage. An example of this hazard would be the Nd: YAG near-infrared region laser. This wavelength can be focused by the eye but not perceived by it. Damage can thus be done to the retina in the same manner as visible light even though the beam itself remains invisible.

B. Maximum Permissible Exposure (MPE) - On the basis of retinal damage thresholds and concentrations of light by the lens, maximum permissible exposure limits have been recommended by the American National Standards Institute (ANSI Z136.1-2007). The MPE values for visible light are based on a pupil diameter of 7mm, which is considered to the maximum opening of the iris of the eye. For other wavelengths, the incident laser energy is averaged over a 1mm diameter circle. The MPE values are below known hazardous levels. However, the MPE values that appear in the table may be uncomfortable to view. Thus, it is good practice to maintain exposure levels as far below the MPE values as practically possible. MPE's for intrabeam viewing and diffuse reflections are located in Appendix G.

2. **Skin Protection-** Skin effects can be of significant importance with the use of lasers emitting in the ultraviolet spectral region. The potential for skin injury from the use of high power lasers can present a potential hazard. For laser systems using an open beam, skin protection may be necessary. Covering exposed skin by using lab coats, gloves and an UV face shield will protect against UV scattered radiation. Adequate skin protection may be required for certain applications using high power laser systems.

VI. RESPONSIBILITIES

A. Department of Environmental Health and Safety and Laser Safety Officer

1. Conduct periodic laboratory/facility inspections to ensure that safety requirements are being met.

2. Provide assistance in evaluating and controlling beam and non-beam hazards.

3. Recommend laser safety controls including administrative, engineering, and personal protective equipment.

4. Maintain records of laser locations, responsible faculty, and training.

5. Conduct and/or coordinate laser safety training for laser operators and other incidental personnel.

6. Investigate accidents involving lasers.

7. Has authority to terminate operations if controls are inadequate

8. Update the Laser Safety Program as needed.

B. Principal Investigator

1. Register all lasers with LSO by completing a Laser Registration Form (Appendix C) for each laser within the laboratory.

2. Provide immediate supervision of laser use.

3. Maintain an up-to-date list of all laser workers in the laboratory.

4. Provide, implement, and enforce the safety recommendations and requirements described in this program.

5. Maintain a written standard operating procedure (SOP) for laser use.

6. Provide training in the administrative, alignment, and standard operating procedures for laser users and keep this on record.

7. Attend laser safety training provided or coordinated by the LSO.

8. Notify LSO immediately in the event of an exposure to a Class 3B or 4 laser.

C. Laser Operator Responsibilities

1. Follow laboratory administrative, alignment, and SOP.

2. Keep the Principal Investigator fully informed of any departure from established safety procedures including all exposure incidents.

3. Attend the laser safety training program provided or coordinated through the LSO.

D. Employee Responsibilities

1. Recognize and adhere to the laboratory signage and written safety protocols.

2. Attend laser safety awareness training for incidental personnel.

3. Do not enter areas that contain unfamiliar equipment.

E. Laser Safety Sub-Committee Responsibilities

1. Report to the Radiation Safety Committee.

2. Make changes to Laser Safety Manual as needed.

3. Responsible for the University's compliance with the most up-to-date standards for the safe use of lasers (ANSI Z136.1).

APPENDIX A

Glossary of Terms

Absorption: Transformation of radiant energy to a different form of energy by interaction with matter.

Aperture: An opening through which radiation can pass.

Attenuation: The decrease in the radiant flux as it passes through an absorbing or scattering medium.

Average Power: The total energy imparted during exposure divided by the exposure duration.

Aversion Response: Closure of the eyelid, or movement of the head to avoid an exposure to a noxious stimulant or bright light. In this standard, the aversion response to an exposure from a bright laser source is assumed to occur within 0.25 s, including the blink reflex time.

Authorized Laser Operator: An individual who has been trained in laser safety and laser operating procedures.

Beam: A collection of rays which may be parallel, divergent, or convergent.

Beam Diameter: The diameter of that portion of the beam which contains 86% of the output power.

Blink Reflex: (See Aversion Response)

Carcinogen: An agent potentially capable of causing cancer.

Coherent: Radiation composed of wave trains vibrating in phase with each other, which can simply be expressed as parallel rays of light.

Continuous Wave (CW): The output of a laser, which is operated in a continuous rather than pulsed mode. In this standard, a laser operating with a continuous output for a period >0.25 s is regarded as a CW laser.

Controlled Area: An area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from radiation hazards.

Cornea: The transparent outer coat of the human eye that covers the iris and the crystalline lens. The cornea is the main refracting element of the eye.

Diffraction: Deviation of part of a beam, determined by the wave nature of radiation and occurring when the radiation passes the edge of an opaque obstacle.

Diffuse Reflection: Change of the spatial distribution of a beam of radiation when it is reflected in many directions by a surface or by a medium.

Divergence: The angle at which the laser beam spreads in the far field; the bending of rays away from each other, as by a concave lens or convex mirror. Sometimes this is also referred to as beam spread.

Electromagnetic Radiation: Includes radio waves; X-rays; gamma rays; and infrared, ultraviolet, and visible light. The flow of energy consisting of electric and magnetic fields lying transverse to the direction of propagation, X-ray, ultraviolet, visible, infrared, and radio waves occupy various portions of the electromagnetic spectrum and differ only in frequency, wavelength, or photon energy.

Enclosed Laser: A laser that is contained within a protective housing of itself or of the laser or laser system in which it is incorporated. Opening or removal of the protective housing provides additional access to laser radiation above the applicable MPE than possible with the protective housing in place. An embedded laser is an example of one type of enclosed laser.

Energy: The capacity for doing work. Energy content is commonly used to characterize the output from pulsed lasers, and is generally expressed in joules (J).

Erythema: Redness of the skin due to congestion of the capillaries.

Extended Source: An extended source of radiation that can be resolved into a geometrical image in contrast with a point source of radiation, which cannot be resolved into a geometrical image. A light source whose diameter subtends a relatively large angle from an observer.

Failsafe Interlock: An interlock where the failure of a single mechanical or electrical component of the interlock will case the system to go into, or remain in, a safe mode.

Hertz (Hz): The unit that expresses the frequency of a periodic oscillation in cycles per second.

Infrared Radiation: Electromagnetic radiation with wavelengths that lie within the range 0.7 µm to 1 mm.

Intrabeam Viewing: The viewing condition whereby the eye is exposed to all or part of the laser beam.

Ionizing Radiation: Electromagnetic radiation having sufficiently large amount of photon energy to directly ionize atomic or molecular systems with a single quantum event.

Irradiance (E): The power emitted per unit area upon a surface; expressed in watts per square centimeter (W/cm^2).

Joule: A unit of energy (J). 1 Joule=1 watt x second.

Laser: A laser is a cavity, with mirrors at the ends, filled with material such as crystal, glass, liquid, gas, or dye. A device which produces an intense beam of light with the unique properties of coherency, collimation, and monochromaticity. An acronym for Light Amplification by stimulated Emission of Radiation.

Laser Safety Officer (LSO): One who has authority to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards.

Laser System: An assembly of electrical, mechanical, and optical components that includes a laser.

Maximum Permissible Exposure (MPE): The level of laser and radiation to which a person may be exposed without hazardous effect or adverse biological changes to eye or skin. MPE is expressed in terms of either radiant exposure (Joules/cm^2) or irradiance (Watts/cm^2). The criteria for MPE's are detailed in Section 8 of ANSI Z136.1.

Maintenance: Performance of those adjustments or procedures specified in user information provided by the manufacturer with the laser or laser system, which are to be performed by the user to ensure the intended performance of the product. It does not include operation or service as defined in this section.

Nominal Hazard Zone (NHZ): A zone that describes the space within which the level of the direct, reflected or scattered radiation during normal operation exceeds the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE level.

Operation: The performance of the laser or laser system over the full range of its intended functions (normal operation). It does not include maintenance or service as defined in this section.

Optical Density (OD): A logarithmic expression for the attenuation of the irradiation produced by an attenuating medium, such as an eye protection filter.

Photosensitizes: Substances that increase the sensitivity of a material to irradiation by electromagnetic energy.

Point Source: Ideally, a source with infinitesimal dimensions. Practically, a source of radiation whose dimensions are small compared with the viewing distance. For the purpose of this standard, a point source leads to intrabeam viewing condition.

Power: The rate at which energy is emitted, transferred, or received. Unit: Watts (Joules/second).

PRF: Abbreviation for Pulse Repetition Frequency.

Protective Housing: An enclosure that surrounds the laser or laser system that prevents access to laser radiation above the applicable MPE level. The aperture through which the useful beam is emitted is not part of the protective housing. The protective housing may enclose associated optics and a workstation and shall limit access to other associated radiant energy emissions and to electrical hazards associated with components and terminals.

Pulse Duration: The duration of a laser pulse; usually measured as the time interval between the half-power points on the leading and trailing edges of the pulse.

Q-Switched Laser: A laser that emits short (<30 ns), high-power pulses by means of a Q-switch.

Repetitive Pulsed Laser: A laser with multiple pulses of radiant energy occurring in sequence with a pulse repetition frequency greater than or equal to 1 Hz.

Service: Repair to laser or laser system beyond regular maintenance. This must be performed by a professional trained on repairs on your particular laser or laser system.

Source: A laser or a laser-illuminated reflecting surface.

Specular Reflection: A mirror-like reflection.

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

Ultraviolet Radiation (light): Electromagnetic radiation with wavelengths smaller than those of visible radiation; for the purpose of laser safety, 200-400 nm.

Visible Radiation (light): Electromagnetic radiation that can be detected by the human eye. This term is commonly used to describe wavelengths that lie in the range of 400-700 nm.

Watt: The unit of power or radiant flux. 1Watt = 1 Joule/second.

Wavelength: The distance between two successive points on a periodic wave which are in phase.

APPENDIX B

Control Measures	Classification				
Engineering Controls	**1**	**2**	**3R (3a)**	**3B**	**4**
Protective Housing	X	X	X	X	X
Without Protective Housing	LSO shall establish Alternative Controls				
Interlocks on Protective Housing	Δ	Δ	Δ	X	X
Service Access Panel	Δ	Δ	Δ	X	X
Key Control	--	--	--	•	X
Viewing Portals		MPE	MPE	MPE	MPE
Collecting Optics	MPE	MPE	MPE	MPE	MPE
Totally Open Beam Path	--	--	--	X NHZ	X NHZ
Limited Open Beam Path	--	--	--	X NHZ	X NHZ
Enclosed Beam Path	LSO Determination				
Remote Interlock Connector	--	--	--	•	X
Beam Stop or Attenuator	--	--	--	•	X
Activation Warning Systems	--	--	--	•	X
Emission Delay	--	--	--	--	X
Indoor Laser Controlled Area	--	--	--	X NHZ	X NHZ
Class 3B Indoor Laser Controlled Area	--	--	--	X	--
Class 4 Indoor Laser Controlled Area	--	--	--	--	X
Laser Outdoor Controls	--	--	--	X NHZ	X NHZ
Laser in Navigable Airspace	--	--	•	•	•
Temporary Laser Controlled	Δ MPE	Δ MPE	Δ MPE	--	--
Remote Firing and Monitoring	--	--	--	--	
Labels	X	X	X	X	X
Area Posting	--	--	•	X NHZ	X NHZ

Legend
- X -Shall
- • -Should
- -- -No Requirements
- Δ -Shall if enclosed Class 3B or Class 4
- MPE -Shall if MPE is exceeded
- NHZ -Nominal Hazard Zone analysis required

Administrative and Procedural Controls	**1**	**2**	**3R (3a)**	**3B**	**4**
Standard Operating Procedures	--	--	--	•	X
Output Emission Limitations	--	--	LSO Determination		
Education and Training	--	•	•	X	X
Authorized Personnel	--	--	--	X	X
Alignment Procedures	--	X	X	X	X
Protective Equipment	--	--	--	•	X
Spectator	--	--	--	•	X
Service Personnel	Δ MPE	Δ MPE	Δ MPE	X	X
Demonstration with General Public	MPE	X	X	X	X
Laser Optical Fiber Systems	MPE	MPE	MPE	X	X
Laser Robotic Installations	--	--	--	X NHZ	X NHZ
Eye Protection	--	--	--	• MPE	X MPE
Protective Windows	--	--	--	X NHZ	X NHZ
Protective Barriers and Curtains	--	--	--	•	•
Skin Protection	--	--	--	X MPE	X MPE
Other Protective Equipment	Use may be required				
Warning Signs and Labels (Design Requirements)	--	--	--	X MPE	X MPE
Service and Repairs	LSO Determination				
Modifications and Laser Systems	LSO Determination				

Legend		
	X	-Shall
	•	-Should
	--	-No Requirements
	Δ	-Shall if enclosed Class 3B or Class 4
	MPE	-Shall if MPE is exceeded
	NHZ	-Nominal Hazard Zone analysis required

APPENDIX C

Kansas State University
Department of Environmental Health and Safety

Laser Registration Form

Please complete (1) form for each laser and fax (532-1981) or mail (108 Edwards Hall) to the Laser Safety Officer

Contact Information

Principal Investigator: ____________________________ Phone: ______________

Email: ______________________________

Title: _______________________________ Department: ___________________

Building where laser is located: _________________ Room #: _________________

Please list all laser users/operators:

___________________________________ ______________________________

___________________________________ ______________________________

___________________________________ ______________________________

___________________________________ ______________________________

Laser Identification Information

Laser Manufacturer: ____

Model Number: _________________________ Serial Number: _________________

Laser Type (Nd:YAG, Argon, etc.): ____

Laser’s "subname" or “nickname” (Laser 1, “Big Boy”, etc.): ______________________

Classification Class 3R (or IIIa) ___ Class 3B ___ Class 4 ___

Optical Characteristics

Wavelength (nm): ______________ Type (CW, Pulsed, or Both) __________________

CW lasers- Average Power (W)= ________ Pulsed Lasers- Peak Power (W) = ________

General Information

Have all operators/users received training? Yes ____ No ____

Has the training been documented? Yes ____ No ____

Have laboratory Standard Operating Procedures and Safety Guidelines been established for the use of the laser? Yes ____ No ____

Laser Safety Checklist

A. Does the door have the proper sign? Yes ____ No ____

B. Is equipment labeled with laser parameters? Yes ____ No ____

C. Is access to the room controlled? Yes ____ No ____

D. Are warning devices used when laser is energized? Yes ____ No ____

E. Are system interlocks used? Yes ____ No ____

F. Is proper eye protection provided? Yes ____ No ____

G. Is there adequate room illumination? Yes ____ No ____

H. Are reflective surfaces in the room controlled? Yes ____ No ____

I. Are elements in the beam path secured? Yes ____ No ____

J. Date of Last Inspection: ____

K. Other Comments:

Principal Investigator Signature: ______________________________

Date: ________________________

APPENDIX D

Kansas State University
Department of Environmental Health and Safety

<u>Laser Reassign/Relocation Form</u>

Please complete (1) form for each laser and fax (532-1981) or mail (108 Edwards Hall) to Laser Safety Officer

<u>Contact Information</u>

Principal Investigator: ______________________________ Phone: _______________

Email: ________________________________

Title: _________________________________ Department: _____________________

Building where laser is located: ___________________ Room #: __________________

<u>Laser Identification Information</u>

Laser Manufacturer: ____

Model Number: ___________________________ Serial Number: __________________

Laser Type (Nd:YAG, Argon, etc.): ____

Laser's "subname" or "nickname" (Laser 1, "Big Boy", etc.): ________________________

Classification Class 3R (or IIIa) ___ Class 3B ___ Class 4 ___

<u>Laser Location</u> – Please check one below

_____ The laser/laser system identified above will remain in its current location.

<u>OR</u>

_____ The laser/laser system identified above is being relocated to:

Building: _______________________ Room #: ________________

NOTE: If laser is moving to another department or leaving K-State completely, please explain:

____

____

____

Principle Investigator Signature: ___________________________

Date: _____________________

APPENDIX E

Kansas State University
Department of Environmental Health and Safety

Laser Exposure Incident Report

Name of exposed individual: ____

Status (student, staff, faculty, visitor, etc.): _____________________________________

Date of incident: _______________________   Time of incident: _______________

Location of facility where exposure occurred- Building: __________________________

Room #: ___________________________

Type of laser producing exposure (HeNe, Nd:YAG, etc.): _________________________

Class: 3R   3B   4

Name of person whom registered laser: ____

Supervising or witnessing individuals: _______________________________________

____

Nature of exposure: ____

Eye Exposed: Left only ____   Right only ____   Both ____

Skin Location: ____

Duration: Minutes: ____________   Seconds: ____________

Describe the exposure circumstances (work being performed): _____________________

____

____

How was the incident caused? ____

____

____

Personal protective equipment being used at the time of exposure: __________________

____

____

Did you seek medical attention?   Yes ____   No ____

Accident Report (PER-17) filed?   Yes ____   No ____

APPENDIX F

Laser Warning

This label must be affixed to laser, along with an indication of the class and type of laser.

Laser Aperture

The label must be affixed to laser on the aperture where laser is emitted.

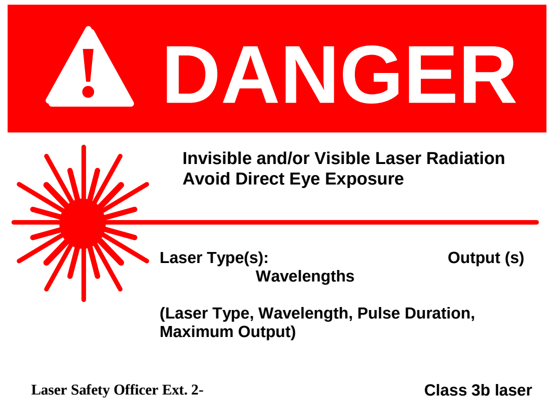
Laser: Class 3

This alerting sign must be posted at the entrance of an area containing a Class 3a and 3R lasers.

Laser: Class 4

This alerting sign must be posted at the entrance of an area containing a Class 4 laser.

Laser: Class 3B



This alerting sign must be posted at the entrance

of an area containing a Class 3B laser.