# Environmental Health & Safety
# Laser Safety Guidelines

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## I. Purpose

To protect Wright State University (WSU) employees, students, visitors, and contractors from hazards associated with high powered lasers and to align university procedures with those established by American National Standards Institute American National Standard for Safe Use of Lasers (ANSI Z136.1-2007).

## II. Scope

This policy establishes reasonable and necessary steps that apply to any and all facilities, departments, and employees who are associated in any manner with the use and/or handling of lasers including anyone working under the supervision of WSU employees who use and/or handle lasers.

## III. Definitions

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

**High-powered laser**: lasers emitting very high optical powers (for example class 3b and class 4 lasers)

**Laser:** A device that produces radiant energy predominantly by stimulated emission. Laser radiation may be highly coherent temporally, or spatially, or both. 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 Hazard Classes**: Lasers are divided into hazard classes and identified by labels affixed to the laser. Laser classes are based on the:

1. Physical characteristics of the laser including power, wavelength emission, and duration of the exposure (pulse time)

2. Potential for causing injury or accident such as immediate injury to the eye or skin and/or the likelihood for starting fires either directly or from reflections from diffuse reflective surfaces).

    a) **Class 1 lasers:** Are considered to be incapable of producing damaging radiation levels, and are therefore exempt from most control measures or other forms of surveillance. *Example: laser printers.*

b) **Class 1M Lasers:** Are considered to be incapable of producing hazardous exposure conditions during normal operation and are therefore exempt from most control measures or other forms of surveillance.

c) **Class 2 lasers:** Emit radiation in the visible portion of the spectrum, and protection is normally afforded by the normal human aversion response (blink reflex) to bright light. These lasers may be hazardous if viewed directly for extended periods of time. *Example: laser pointers.*

d) **Class 2M Lasers:** Emit visible portion of the spectrum, and Class 2M is potentially hazardous if viewed with certain optical aids.

e) **Class 3 lasers:** May be hazardous under certain conditions such as specular reflection viewing. Class 3 is divided in two subclasses:

i) **Class 3R lasers** do not produce injury under normal conditions when viewed for a very brief period with the unprotected eye. These lasers may present a hazard if viewed using collecting optics, e.g., telescopes, microscopes, or binoculars. *Example: HeNe lasers above 1 milliwatt but not exceeding 5 milliwatts radiant power.*

NOTE: Lasers formerly labeled as ANSI Class 3A are renamed Class 3R

ii) **Class 3B lasers** can cause severe eye injuries when viewed directly or from specular reflection. A Class 3B laser is not normally a fire hazard, though in some circumstances flammable liquids could be ignited. *Example: visible HeNe lasers above 5 milliwatts but not exceeding 500 milliwatts radiant power.*

f) **Class 4 lasers:** Lasers that present an eye hazard from direct and diffuse reflections. In addition, such lasers can cause combustion of flammable materials and produce serious skin burns and injury from direct exposure.

**F. Maximum Permissible Exposure (MPE):** The maximum level of laser radiation to which a human can be exposed without adverse biological effects to the eye or skin.

1. $\alpha_{max}$ (alpha max**)**: The angular limit beyond which extended source MPE's for a given exposure duration are expressed as a constant radiance or integrated radiance.

2. **$\alpha_{min}$ (alpha min): The apparent visual angle which divides small-source viewing from extended-source viewing.**

3. Point Source Ocular: A source with an angular subtense at the cornea equal to or less than $\alpha_{min}$.

4. Extended Source Ocular Exposure: A source of laser radiation with an angular subtense at the cornea larger than $\alpha_{min}$.

**G. Nominal Hazard Zone (NHZ):** Space where the level of direct, reflected, or scattered radiation exceeds the MPE

**H. Person in Charge (PIC)**: The faculty or other identified staff member in charge of a lab or other area where lasers are in use.

## IV. Responsibilities

### A. Person in Charge

1. Ensuring the safe use of lasers in their area as established within this policy.

2. Registration of all Class 3B and 4 lasers with the Laser Safety Officer.

3. Identify laser users and ensure laser safety training as required by the LSO is obtained by all users.

4. Posting required signs and informing personnel of potential hazards.

5. Ensure the medical surveillance (see Section V.G.) costs required for all laser users within their area of responsibility are paid. Funding may come from the person in charge, their department, or their college.

### B. Laser Safety Officer

1. Monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards.

2. Maintain registration inventory of all Class 3B and 4 lasers.

3. Perform and document periodic inspections, or Laser System Evaluations, regarding laser safety practices and inform responsible persons of situations where recommended safety practices are not being followed.

4. Provide and document introductory laser safety training and maintain training resources to assist laser users.

5) Take out of operation lasers that are a Non-Operational Laser System.

## V. Procedures

### A. Written Procedures

The PIC shall prepare written standard operating procedures (SOP) and service and maintenance procedures for each Class 3b and Class 4. At a minimum, the most salient features of laser safety are to be posted in a clearly visible manner at each laser installation. General exposure guidelines, special precautions, or unusual conditions may be outlined. The "owner's manual" and SOP's shall be available to operators.

### B. Design Standards

**1.** Appropriate design standards for all laser systems are as follows:

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

**i)** Access restriction
**ii)** Eye protection
**iii)** Area controls
**iv)** Barriers, shrouds, beam stops, etc.
**v)** Administrative and/or procedural controls
**vi)** Education and training

**b)** Protective housings shall be interlocked for Class 3a, 3b and 4 lasers. Commercially manufactured lasers come equipped with such interlocks.

**c)** A keyed master switch shall be provided for Class 3b or 4 lasers. Lasers shall be stored or disabled by removing the key when the laser is not in use for prolonged periods.

**d)** Viewing ports and collecting optics shall provide adequate protection to reduce exposure at viewing position to, at, or below the MPE level. (Classes 2, 3a, 3b, or 4).

**e)** If the beam path is not enclosed, then the Nominal Hazard Zone (NHZ) (areas where the exposure levels exceed maximum permissible exposure level), need to be assessed and a controlled area established. See Section on "Control of Laser Areas" below for more information.

**f)** If the beam is totally enclosed, the laser will meet the standard of a Class 1 laser (all areas below MPE), and no further restrictions are required.

**g)** Commercially manufactured Class 3b and Class 4 lasers must come equipped with a jack for external interlocks.

**h)** Lasers shall be stopped in a suitable "beam stopper." Most laser heads come equipped with a permanently attached stopper or attenuator, which will lower the beam power to MPE at the aperture from the housing. Additional beam stoppers may be needed in the beam path to keep the useful beam confined to the experimental area.

**2.** Lasers shall not be modified to defeat the engineering safeguards without notifying the LSO. If this is a research laser that is under construction and engineering safeguards and/or interlocks are not utilized, this information needs to be noted in the comments field of the Laser Registration Form.

## C. Control of Laser Areas

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

**2.** The requirements for control include the doors being locked, or interlocked, and a proper warning indication provided at the entrance to the area when the laser is operating. Also proper protective eyewear must be available at or immediately outside of the entrance.

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

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

**a)** Keep the exposure at the entryway below MPE by use of a barrier inside of the door. Don't direct the laser beam toward the entry.
**b)** Use shields and barriers around the laser work area so that the beam, reflections, and scatter are contained on the optical table. Try to keep the unenclosed beam path out of the normal eye-level zone. (The normal eye-level range is from 4 - 6 feet from the floor).
**c)** Ensure that only diffuse reflective materials are in or near the beam path to minimize the chance of specular reflections.
**d)** Ensure that locks or interlocks do not obstruct rapid egress from the door or the admittance to the room in the event of an emergency situation.

**e)** Have lighted, warning signs (preferably flashing) and/or audible signals to indicate when a Class 4 laser is energized and operating. Signage must clearly explain the meaning of the lights.

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

**6.** Many laser systems have a connection for room interlocks which can serve as a mechanism to link warnings and door locks to laser operation. The connections can also be used for door interlocks (to shut off the laser) or to operate solenoid switches to ditch the beam into a stopper if the door is opened. Momentary bypasses and timers can be used to permit controlled entry. The lines between the laser and warnings and locks system shall be low voltages. Also, users shall inspect the warning and access control systems periodically as a part of the overall safety program.

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

**8.** Procedural methods may be used to control entry as an alternative to engineered interlocks provided there are measures in place to indicate potential laser use within, entry requires laser safety training and measures are in place to assure laser protective eyewear is worn before anyone is allowed to enter the area. In general, access from public corridors cannot be controlled by procedures, as the public normally would not be trained in the necessary safety procedures.

## D. Purchases and Acquisitions

**1.** Note that laser systems that are purchased, acquired through transfers, or built by researchers, must meet federal certification requirements. This can be a problem for imported lasers and it is the responsible faculty member's responsibility to fulfill the certification requirements. It is recommended that a clause be included in purchase orders for special imports that the "laser must meet applicable certification requirements of the United States as stipulated in Title 21, Code of Federal Regulations, Part 1040."

**2.** Transfer of a Class 3b or 4 laser to a person who does not have appropriate training, does not understand the hazards of the laser, and does not have proper protective equipment could result in injuries. The transferor shall

obtain assurance from the recipient that the recipient is qualified to own and safely operate the laser. The parties shall consult EHS for information on laser hazards and safeguards and the necessary qualifications of the recipient.

## E. Registration

**1.** Responsible faculty members must register all Class 3b and 4 lasers under their control. The registration form is available from the LSO. The registration information that is requested includes:

**a)** Manufacture
**b)** Beam diameter
**c)** Model (laser head)
**d)** Beam Divergence
**e)** Serial No.
**f)** Type: (Argon-ion, Nd:YAG, etc.)
**g)** Location: (Building, room)
**h)** Classification
**i)** Wavelength
**j)** Responsible faculty member and laser operators

## F. Posting and Warning Systems for Laser Controlled Areas

**1.** Entrances to laser areas are to be posted in accord with ANSI standards. In particular, areas where Class 3b or 4 lasers are used must be secured against persons accidentally being exposed to beams, and be provided with a proper warning indication. All windows, doorways, and portals shall be covered or restricted to reduce transmitted laser levels below MPE. EHS provides assistance to laser users in obtaining appropriate signs for posting and advice on controlling laser areas.

**2.** The term "proper warning indication" generally means that an illuminated warning sign is outside of the area. Preferably the light shall be flashing and lit only when the laser is on. (When a Class 3b or 4 laser is left on and the personnel leave the room, the door shall always be locked).

**3.** Lights alone do not suffice as adequate warning, unless the light is clearly posted as to its meaning. A well-designed warning light shall have redundancy, e.g., two lights, a "safe" light when the laser is off, or two lamps wired in parallel in the "laser on" signal.

**4.** The PIC is responsible for posting signs and informing personnel of potential hazards.

### G. Medical Surveillance

1. Medical evaluation is required for all Class 3b and 4 laser users in the university. This evaluation may be scheduled by the Department Of Environmental Health and Safety (EHS) and must be completed prior to laser use, and upon termination of employment or transfer to non-laser related duty.

2. The initial medical evaluation establishes the faculty/staff member's baseline, so that changes in the eye resulting from an acute laser exposure may be accurately and efficiently diagnosed and treated. The exam also documents pre-existing eye conditions which could become worse with exposure to lasers. The exam is also an opportunity for the faculty/staff member to discuss laser related health issues with the medical provider.

3. Any faculty, staff member or student who has an acute laser exposure or injury shall report it to their supervisor, and seek medical attention immediately. The supervisor shall immediately notify EHS of any laser exposure incidents, and complete the Occupational Injury/Illness Report form.

### H. Disposal

1. Sale or disposal of lasers requires certain precautionary measures be taken involving the notification of the potential hazards of the equipment. Before the laser is released, contact the LSO for direction on this matter.

2. Please contact the LSO if you have additional questions regarding laser safety or related safety concerns.

## VI. Regulatory Limits

**A.** MPE for Point Source Ocular Exposure and Extended Source Ocular Exposure (Table 5a and Table 5B of ANSI Z136.1).B. MPE for Skin Exposure to a Laser Beam (Table 7 of ANSI Z136.1)

## VII. Training and Recordkeeping

### A. Training

1. Only qualified and trained faculty, staff or students may operate Class 3b and 4 lasers. To be qualified, a laser operator must meet both the training requirements outlined below, and operational qualifications established by the responsible faculty member and/or the LSO. The LSO provides introductory laser safety training and can help provide additional training materials to assist with facility-specific training that covers procedures specific to each laser. (Note that documentation must be maintained to verify that the site-specific training is provided.)

2. All persons who work in areas where Class 3b or 4 lasers are used must be provided with appropriate training and written safety instructions (Standard Operating Procedures), so that the user will be able to safely use the equipment and will know how to follow procedures that will protect themselves and others. It is the faculty member's responsibility to make sure this training is provided for Class 3b and 4 lasers.

3. Safety training must be provided before persons are permitted to operate lasers without supervision.

4. Site-specific training for Class 3b and Class 4 laser users shall include a thorough review by a senior, knowledgeable individual who recognizes all hazards associated with each laser that a person may operate and the protection methods that are required for each laser. For personnel who work with Class 3b or 4 lasers, the training shall include basic instruction on the following topics:

   **a)** The biological effects of laser radiation
   **b)** The physical principles of lasers
   **c)** Classification of lasers
   **d)** Control of areas
   **e)** Medical examination options
   **f)** Basic safety rules
   **g)** Use of protective equipment (includes direction on how to select proper eyewear
   **h)** Control of related hazards including electrical safety, fire safety, and chemical safety (handling and storage)
   **i)** Emergency response procedures.

5. All persons who work in areas where Class 2, 3a, or 3R lasers are used shall be provided with appropriate training and written safety instructions (Standard Operating Procedures), so that the user will be able to safely use the equipment and will know how to follow procedures that will protect themselves and others. It is the PIC or responsible faculty member's responsibility to determine whether this training is necessary for Class 2, 3a, and 3R lasers.

## B. Record Keeping

1. Records will be maintained by the LSO for all aspects of the University laser safety program. This shall include an inventory of lasers at Wright State, records of users allowed to work with lasers and their training history, records of inspections performed at laser facilities, medical surveillance documentation if performed, and any hazard evaluations performed by the LSO.

## VIII. Information

**A.** The following information includes ancillary hazards associates with the use of lasers and includes guidance on proper management of these hazards.

### 1. X rays

**a)** Some of the high voltage systems with potentials greater than 30 kV may generate X-rays at significant dose rates. Plasma systems and ion sources operated at high voltages shall also be checked for X-rays. High power (kilojoule) electron pumped Excimer lasers can generate significant X-ray levels (300 mrad per pulse at 15 feet). These devices need to be checked by EHS upon installation to ensure adequate shielding is included.

**b)** Free electron lasers are driven by powerful radiation producing devices, which are Controlled Radiation devices regulated by ODH. All users are required to be oriented concerning the ionizing radiation hazards and the protection systems and procedures associated with these devices.

### 2. Plasma Radiation

**a)** Materials can be made incandescent when exposed to laser radiations. These incandescent spots are very bright and can cause serious photochemical injuries to the eyes. The laser protective eyewear may not protect against such exposures. Whenever possible, view such spots through suitable filters such as TV cameras, etc.

### 3. Fires

**a)** Keep flammable materials out of the beam line and maintain segregation between reactive reagents in the lab. For combustible and electrical fires, a fire extinguisher of the proper class (i.e. ABC or general purpose) shall be readily accessible in the area. Contact EHS for assistance.

### 4. Laser Generated Air Contaminants

**a)** Air contaminates, produced by the interaction of the laser beam with the target material, can result in the production of hazardous materials.

**b)** Fumes produced when laser radiation vaporizes or burns a target material whether metallic, organic or biological may be hazardous. Adequate local exhaust ventilation may need to be provided in the laser target zone. Contact EHS for assistance.

## 5. Chemicals

**a)** Many gases and all laser dyes and solvents used in some laser systems are highly toxic. Several laser dyes are carcinogenic. When dimethyl sulfoxide (DMSO) is the solvent, the dyes may be particularly hazardous if spilled on the skin because DMSO promotes absorption through the skin. If toxic chemicals are used in a laser system, users must consult the Material Safety Data Sheets (MSDS) for recommended protective measures. MSDS's are available from manufacturers and online through the EHS web site (http://www.wright.edu/admin/ehs/). If the MSDS cannot be located, call EHS at 2215.

**b)** Potential exposures to dyes and solvents are most likely to occur during solution preparation. During solution preparation, dye and solvent mixing shall be done inside a chemical fume hood. Dye pumps and tubing/pipe connections shall be designed to minimize leakage. Pumps and reservoirs shall be set inside spill pans. Tubing/pipe systems shall be pressure-tested prior to using dye solutions and periodically thereafter. Dye solutions can be corrosive. Stainless steel heat exchangers are recommended. Keep dye handling areas clean and segregated from other operations.

**c)** Gas cylinders, dyes and solvents must be properly disposed of through the EHS chemical waste disposal program. Contact EHS for disposal instructions.

## 6. Hazardous Gases and Cryogenic Materials

**a)** Flammable gases, e.g., hydrogen, and oxygen tanks present significant hazards if proper handling, manifolding, and storage precautions are not followed. Other hazardous gases may also require special handling and ventilation. Gas cylinders must be properly anchored with metal linked chains, fastened at the top and near the base of the tank to prevent falling.

**b)** Such tanks can become high velocity projectiles and can cause significant property damage and injuries, contact EHS for assistance. A number of laser systems utilize toxic gases (e.g., HF). These gases must be contained in approved ventilation and manifold systems. EHS will provide information on approved systems.

**c)** Wear appropriate protective clothing and face shields when handling large quantities of liquid nitrogen (LN) or other cryogenic materials. The normal moisture and oils present on the skin will protect against a few drops of LN spilled on the skin, but large quantities can cause severe frostbite. LN and inert gases can displace air in a room or confined area and cause asphyxiation. Good ventilation is required in areas where these gases and cryogenic liquids are used.

**d)** Open dewars of LN can condense oxygen from the room air and cause fire or explosion hazards if the oxygen contacts a fuel.

**7. Electrical Safety**

**a)** Most laser systems involve high potential, high current power supplies. The most serious accidents with lasers have been electrocutions. There has been several electrocution fatalities related to lasers nationwide. **Make sure that high voltage systems are off and locked out, and especially that high-energy capacitors are fully discharged prior to working on a system**. Beware that capacitors may have their charges restored after initial discharge. Systems shall be shorted during repair or maintenance procedures. The discharge of large capacitors requires proper equipment and procedures because significant levels of stored energy can be released as heat or mechanical energy. Class 3b and 4 lasers shall have a separate circuit and local cut-off switch (breaker) for the circuit.

**b)** Label and post electrical high voltage hazards and switches. Clearly identify the main switches to cut-off power. Before working on a laser, de-energize the machine.

**c)** Keep cooling water connections away from main power and high voltage outlets and contacts. Use double hose clamps on cooling water hoses. Inspect cooling water hoses and connections and power cables and connectors periodically as part of a regular equipment inspection. General Lockout/Tagout training is available. Contact EHS for additional information on electrical safety.

**d)** Refer to the university Lockout/Tagout Policy for further information.

**8. UV Lasers**

**a)** Since UV radiation scatters easily from many surfaces, and exposure to UV radiation can cause cancer it is important to contain UV radiation as much as possible. Wear gloves, (when hands are near the beam) long sleeve lab coats, and face and eye protection against UV radiation exposure. Avoid putting hands into the invisible beam (use fluorescent screens to define the beam). When intense UV radiation is absorbed in air, ozone will be produced and proper ventilation may be needed. Contact EHS for assistance on ozone concerns and UV radiation hazards.

## IX. References

**A.** American National Standard for Safe Use of Lasers: ANSI Z136.1-2007
**B.** LASER HAZARDS: Chapter 6 of OSHA Technical Manual

**C.** Performance Standards For Laser Products : FDA 21 CFR 1040
**D**. Navy Laser Safety
**E.** Eye and face protection: OSHA 29 CFR 1910.133, and OSHA 29 CFR 1926.102
**F.** Nonionizing radiation: OSHA 29 CFR 1926.54
**G.** Laser Institute of America

## X. Forms

**A.** Laser Registration
**B.** Laser System Evaluation
**C.** Non-Operational Laser System Tracking

## XI. Approvals

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| Implementation Date:<br>07-01-08<br><br>Last Reviewed:<br><br>Last Revision Date: | Approval:<br><br>Stephen Farrell<br>Director, EHS | Signature:<br>  <br>Stephen Farrell |