

Vanderbilt University Laser Safety Program Guide

Responsibilities

The faculty member in charge of a lab is responsible for safety associated with laser use in his or her area. When a department or faculty member has a number of lasers under his or her control, it may be appropriate to appoint a Laser Safety Officer (LSO) or a safety committee to review and implement local safety procedures.

Duties of the Laser Safety Officer include:

- The Laser Safety Officer (LSO) is someone who has authority to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards.
- All Class 3b and 4 lasers must have a LSO.
- The LSO will usually be a faculty member who has primary authority for the laser in question.

VEHS will perform periodic inspections regarding laser safety practices and inform responsible persons of situations where recommended safety practices are not being followed. VEHS provides introductory laser safety training and maintains training resources to assist laser users. VEHS provides links to current laser safety regulatory requirements and maintains copies of the current ANSI Laser Safety Standard, Z136.1. The ANSI standard must remain in the VEHS administrative office so that it will be available for users to review. Because VEHS only has one copy of the standard, users will need to review the document within the VEHS main office. (VEHS recommends that all groups using Class 3b or 4 lasers purchase their own copy of the ANSI Laser Safety Standard Z136.1. <http://www.laserinstitute.org/bookstore/ansi/>)

Each department or research facility with lasers must provide training specific to the hazards associated with the lasers which they are using.

Laser Hazard Classes

Lasers are divided into hazard classes based on the

1. Physical characteristics of the laser:
 - Power
 - Wavelength emission
 - Duration of the exposure (pulse time)and
2. Potential for causing injury or accident such as
 - Immediate injury to the eye or skin and/or
 - Likelihood for starting fires either directly or from reflections from diffuse reflective surfaces).

Since August 1, 1976, commercially produced lasers have been classified and identified by labels affixed to the laser. Following is a qualitative description of laser hazard classes:

Class 1 lasers

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.*

Class 2 lasers

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.*

Class 3a lasers

Class 3a 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*).

Class 3b lasers

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.*

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.

NOTES: *Retinal injuries can occur instantaneously with Class 3b and Class 4 lasers and the damage may be irreparable. Corneal burns from far-Infrared (IR) and ultraviolet (UV) lasers may also be irreparable. Class 4 beams may be of sufficient power intensities to penetrate through the sclera (white) of the eye and damage the retina and other structures; turning one's head or not looking directly at the laser offers little or no protection to high power lasers. Lens damage may also be caused by the beam and by photochemical reactions from exposure to UV and blue frequencies.*

Table 1 and Table 2 show examples of lasers in various hazard classes, based on American National Standards Institute (ANSI) Z136.1.

Table 1

Laser	Wavelengths (nm)	Wavelengths Range (nm)	Class 1 (W)	Class 2 (W)	Class 3 (W)	Class 4 (W)
cw Neodymium: YAG (quadrupled)	266	UV: 100-280	$\leq 0.8 \times 10^{-9}$ for 8 hrs	----	>Class 1 but ≤ 0.5	> 0.5
He-Cd Argon Krypton	325 351.1, 363.8 350.7, 356.4	UV: 315-400	$\leq 0.8 \times 10^{-6}$	----	>Class 1 but ≤ 0.5	> 0.5
He-Cd Argon (visible) He-Ne	441.6 457.9, 476.5 488, 514.5 460, 4-700 (numerous)	Visible 400-700	$\leq 0.4 \times 10^{-6}$	>Class1 but $\leq 1 \times 10^{-3}$	>Class2 but ≤ 0.5	> 0.5
cw Neodymium: YAG (double) He-Ne Krypton	532 632.8 647.1, 530.9 676.4		$\leq 0.4 \times C^B \times 10^{-6}$ (See ANSI Z136.1 for values of C^B)			
cw Ga-Al-As cw Ga-As cw Neodymium: YAG He-Ne	850 (20° C) 905 (20° C) 1064 1080, 1152	Near IR: 700-1400	$\leq 80 \times 10^{-6}$ $\leq 0.1 \times 10^{-3}$ $\leq 0.28 \times 10^{-3}$	----	>Class 1 but ≤ 0.5	> 0.5
HF CO CO ₂ He-Ne	4000-6000 5000-5500 10,600 3390	Far IR: 1400-100,000	$\leq 0.8 \times 10^{-3}$	----	>Class 1 but ≤ 0.5	> 0.5
H ₂ O vapor HCN	118,000 337,000	Far IR: 100,000-1,000,000	≤ 0.1	----	>Class 1 but ≤ 0.5	> 0.5

Eight-hour exposure times predicated on no mechanical or electrical design incorporated in the laser to prevent exposures from lasting to 8 hours; otherwise the Class 1 limits could be larger than shown.

Table 2 - Typical Laser Classifications for Selected Single Pulsed Lasers

Laser	Wavelengths (nm)	Wavelength Region (nm)	Pulse Duration(s)	Class 1 (J)	Class 3 (J/cm ²)	Class 4 (J/cm ²)
Neodymium: YAG Q switch (Quad) Ruby (Doubled)	266.1 347.1	UV 100-400	10-30 x 10 ⁻⁹	----	≤ 10	> 10
Q sw Neodymium: YAG (Doubled) Q switch Ruby Ruby long pulse Rhodamine 6G	532 694.3 693.3 450-650	Visible 400-700	$\sim 20 \times 10^{-9}$ $\sim 1 \times 10^{-3}$ $\sim 1 \times 10^{-6}$	$\leq 0.2 \times 10^{-6}$ $\leq 4.0 \times 10^{-6}$ $\leq 0.2 \times 10^{-6}$	> Class 1 but < 74 x 10 ⁻³ > Class 1 but < 3.1 > Class 1 but < 0.31	>75 x 10 ⁻³ >3.1 >0.31
Neodymium- YAG Erbium-glass Carbon Dioxide	1064 1540 10,600	Infrared	$\sim 20 \times 10^{-9}$ (Q sw) $\sim 10-100 \times 10^{-9}$ (Q sw) $\sim 1-100 \times 10^{-9}$ (Q sw)	$\leq 2 \times 10^{-6}$ $\leq 8 \times 10^{-3}$ $\leq 80 \times 10^{-6}$	> Class 1 but < 0.16 > Class 1 but < 10 > Class 1 but < 10	> 0.16 >10 >10

In cases where the laser has been fabricated on campus or is otherwise not labeled, VEHS can provide assistance on the appropriate laser classification and labeling.

Training (per ANSI Z136.1)

Only qualified and trained faculty, staff or graduate 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 Laser Safety Officer (LSO). VEHS provides introductory laser safety training and can help provide additional training materials to assist LSO's 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.)

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 LSO, or responsible faculty member's responsibility to make sure this training is provided for Class 3b and 4 lasers.

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

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:

1. The biological effects of laser radiation
2. The physical principles of lasers
3. Classification of lasers
4. Control of areas
5. Medical examination options
6. Basic safety rules
7. Use of protective equipment (includes direction on how to select proper eyewear)
8. Control of related hazards including electrical safety, fire safety, and chemical safety (handling and storage)
9. Emergency response procedures.

All persons who work in areas where Class 2 or 3a lasers are used should 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 LSO, or responsible faculty member's responsibility to determine whether this training is necessary for Class 2 and 3a lasers.

Eye Protection

Laser protective eyewear is specific to the types of laser radiation in the lab. Each department or responsible faculty member shall provide appropriate eye protection for persons working with the laser. The following guidelines are suggested for maximum eye protection:

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

Protective eyewear must be worn whenever working with Class 3b or 4 lasers with open beams or when reflections can occur. In general, laser eyewear should be selected on the basis of protecting against reflections -- especially diffuse reflections, and provide protection to a level where the natural aversion reflex will prevent eye injuries.

Wearing protective eyewear should allow some visibility of the beam. This will help prevent skin burns, and decrease the potential for other accidents in the lab, i.e., tripping, etc. **Glasses designed for limited protection, such as those discussed above, are not appropriate for intrabeam viewing or for highly specular reflections.** For this reason, it is **strongly** recommended that side shields be a part of protective eyewear.

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

- Wavelength or spectral region of laser radiation.
- Optical density at the particular wavelength(s).
- Maximum irradiance (W/cm²) or beam power (W).
- For which the eyewear provides protection for at least 5 seconds.
- Type of laser system.
- Power mode, single pulse, multiple pulse or cw, and the strength, i.e., both peak and average power.
- Possibilities of reflections, specular and diffuse.
- Field of view provided by the design.
- Availability of prescription lenses or sufficient size of goggle frames to permit wearing of prescription glasses inside of goggles.
- Comfort.
- Ventilation ports to prevent fogging.
- Effect upon color vision.
- Absence of irreversible bleaching if filter is exposed to high peak irradiances.
- Impact resistance.
- Ability to perform required tasks while wearing eyewear.

For double wavelength systems, glasses (goggles) can be obtained with flip-down lenses to protect against the two different wavelengths. Where invisible beams and visible beams are produced by a laser, the inner lens can be designed to protect against the invisible radiation and the flip-down lens to protect against the visible laser radiation. The specimen eyewear may be borrowed for evaluation. Broad-spectrum glasses are also available for certain applications. VEHS has a number of catalogs and specifications for protective eyewear. As laser protective eyewear is subject to damage and deterioration, the lab safety program should include periodic inspection of these protective items. See Table 3 for more information on selecting appropriate eyewear.

Table 3

Simplified Method for Selecting Laser Eye Protection for Intrabeam Viewing for Wavelengths between 400 and 1400nm									
Q-Switched Lasers (1 ns to 0.1 ms)		Non-Q-Switched Lasers (0.4 ms to 10 ms)		Continuous Lasers Momentary (0.25 s to 10 s)		Continuous Lasers Long-Term Staring Greater than 3 hours		Attenuation	
Maximum Output Energy (J)	Maximum Beam Radiant Exposure (J·cm ⁻²)	Maximum Laser Output Energy (J)	Maximum Beam Radiant Exposure (J·cm ⁻²)	Maximum Power Output (W)	Maximum Beam Irradiance (W·cm ⁻²)	Maximum Power Output (W)	Maximum Beam Irradiance (W·cm ⁻²)	Attenuation Factor	OD
10	20	100	200	NR	NR	NR	NR	100,000,000	8
1.0	2	10	20	NR	NR	NR	NR	10,000,000	7
10 ⁻¹	2 x 10 ⁻¹	1.0	2	NR	NR	1.0	2	1,000,000	6
10 ⁻²	2 x 10 ⁻²	10 ⁻¹	2 x 10 ⁻¹	NR	NR	10 ⁻¹	2 x 10 ⁻¹	100,000	5
10 ⁻³	2 x 10 ⁻³	10 ⁻²	2 x 10 ⁻²	10	20	10 ⁻²	2 x 10 ⁻²	10,000	4
10 ⁻⁴	2 x 10 ⁻⁴	10 ⁻³	2 x 10 ⁻³	1.0	2	10 ⁻³	2 x 10 ⁻³	1,000	3
10 ⁻⁵	2 x 10 ⁻⁵	10 ⁻⁴	2 x 10 ⁻⁴	10 ⁻¹	2 x 10 ⁻¹	10 ⁻⁴	2 x 10 ⁻⁴	100	2
10 ⁻⁶	2 x 10 ⁻⁶	10 ⁻⁵	2 x 10 ⁻⁵	10 ⁻²	2 x 10 ⁻²	10 ⁻⁵	2 x 10 ⁻⁵	10	1

NR = Not Recommended

As one other precaution, any window through which Class 2, 3, or 4 beams could be transmitted and cause hazards in uncontrolled areas shall be covered or otherwise protected during laser operation.

Medical Surveillance

Medical evaluation is required for all Class 3b and 4 laser users in the university and medical center. This evaluation may be scheduled in the Vanderbilt Occupational Health Clinic and must be completed prior to laser use, and upon termination of employment or transfer to non-laser related duty.

The initial medical evaluation establishes the faculty/staff member's baseline, so that changes in the eye or skin resulting from an acute laser exposure may be accurately and efficiently diagnosed and treated. The exam also documents pre-existing eye or skin 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.

Any faculty, staff member or graduate student who has an acute laser exposure or injury should report it to their supervisor, and seek medical attention immediately at the Occupational Health Clinic, or at the Emergency Department after hours. The supervisor should immediately notify VEHS of any laser exposure incidents, and complete the Tennessee First Report of Work Injury for the injured employee.

Written Procedures

The LSO or responsible faculty member shall prepare written standard operating procedures (SOP) and service and maintenance procedures for each Class 4 laser; it is also recommended that such procedures be prepared for Class 3b lasers. A template SOP is available from the VEHS web site (<http://www.safety.vanderbilt.edu/>) under "Chemical and Laboratory Safety." Written alignment procedures are to be posted in the area or kept with the equipment. 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 "owners manual" should be available to operators.

Appropriate design standards for laser systems are as follows:

- Lasers should be equipped with a protective housing, an aperture that is clearly identified, and a clearly marked switch to deactivate the laser or reduce its output to less than maximum permissible exposure (MPE). If this is not possible, VEHS should be consulted to assess the hazards and to ensure that appropriate controls are in place. Such controls may include, but not be limited to the following:
 - Access restriction
 - Eye protection
 - Area controls
 - Barriers, shrouds, beam stops, etc.
 - Administrative and/or procedural controls
 - Education and training
- Protective housings should be interlocked for Class 3a, 3b and 4 lasers. Commercially manufactured lasers come equipped with such interlocks.
- A keyed master switch should be provided for Class 3b or 4 lasers. Lasers should be stored or disabled by removing the key when the laser is not in use for prolonged periods.
- Viewing ports and collecting optics shall provide adequate protection to reduce exposure at viewing position to, at, or below the MPE level. (Classes 2, 3a, 3b, or 4).
- 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.
- If the beam is totally enclosed, the laser will meet the standard of a Class 1 laser (all areas below MPE), and no further restrictions are required.
- Commercially manufactured Class 3b and Class 4 lasers must come equipped with a jack for external interlocks.
- Lasers should be stopped in a suitable "beam stopper." Most laser heads come equipped with a permanently attached stopper or attenuator, which will lower the beam power to MPE at the aperture from the housing. Additional beam stoppers may be needed in the beam path to keep the useful beam confined to the experimental area.

It is strongly recommended that lasers should **not be modified to defeat the engineering safeguards** without notifying VEHS.

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.

Control of Laser Areas

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. Contact VEHS to review the alternative methods to be employed.

Lasers should not be transferred to different areas, unless the lasers are brought up to Federal certification standards. Copies of Federal standards are available online through the VEHS web site.

In many campus research areas the requirements for controlled laser areas have been interpreted to mean that the doors must be locked, or interlocked, and a proper warning indication provided at the entrance to the area when the laser is operating. Also proper protective eyewear must be available at or immediately **outside** of the entrance.

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

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

- Keep the exposure at the entryway below MPE by use of a barrier inside of the door. Don't direct the laser beam toward the entry.
- Use shields and barriers around the laser work area so that the beam, reflections, and scatter are contained on the optical table. Try to keep the unenclosed beam path out of the normal eye-level zone. (The normal eye-level range is from 4 - 6 feet from the floor).
- Ensure that only diffuse reflective materials are in or near the beam path to minimize the chance of specular reflections.
- Ensure that locks or interlocks do not obstruct rapid egress from the door or the admittance to the room in the event of an emergency situation.
- Have lighted, warning signs (preferably flashing) and/or audible signals to indicate when a Class 4 laser is energized and operating. Signage must clearly explain the meaning of the lights.

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

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

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. Below is a checklist of protective measures according to ANSI classes 3 and 4.

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.

Laser Safety Measures for High-powered (class 3b and 4) Lasers

R=REQUIRED o=RECOMMENDED

CONTROL MEASURE	CLASS 3B	CLASS 4
Protective Housing	R	R
Interlocks on Protective Housing	R	R
Key Switch Master	o	R
Remote Interlock Connector	o	R
Service Access Panel	R	R
Assessment of Nominal Hazard Zone (open beam path)	R	R
Beam Stopper or Attenuator on Laser	o	R
Beam Stopper or Attenuator on Bench	o	R
Warning System for Activation/ Operation	o	R
Controlled Area	R	R
Labels	R	R
Area Posting	R	R
Operating Procedures (written)	o	R
Alignment Procedures (written)	R	R
Education and Training (including laser, electrical and ancillary hazards)	R	R
Access Controls (Authorized Personnel)	R	R
Access Controls (Spectators)	o	R
Eye Protection	o	R
Pre-placement eye exams	o	o
Inventory	R	R
Meet Federal Standards for Transfer or Disposal	R	R

Posting and Warning Systems for Laser Controlled Areas

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 should be covered or restricted to reduce transmitted laser levels below MPE. **VEHS provides assistance to laser users in obtaining appropriate signs for posting and advice on controlling laser areas.**

The term "proper warning indication" generally means that an illuminated warning sign is outside of the area. Preferably the light should 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).

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

The faculty member or LSO is responsible for posting signs and informing personnel of potential hazards.

Ancillary Hazards

X rays

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 should 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 VEHS upon installation to ensure adequate shielding is included.

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

Plasma radiation

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.

Fires

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 VEHS for assistance.

Laser Generated Air Contaminants (LGAC)

Air contaminants, produced by the interaction of the laser beam with the target material, can result in the production of hazardous materials.

During surgical procedures, biohazardous aerosols containing bloodborne pathogens are created. The OSHA web site provides information on biohazardous air contaminants produced during surgery. Look for the link to "Laser/Electrosurgery Plume" from the VEHS web site's "Laser Safety Links" under "OSHA Guidance" documents on the VEHS web site.

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

Chemicals

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 VEHS web site (<http://www.safety.vanderbilt.edu/>). If the MSDS cannot be located, call VEHS.

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

Gas cylinders, dyes and solvents must be properly disposed of through the VEHS Chemical Waste Collection program. Consult the VEHS web site for instructions.

Hazardous Gases and Cryogenic Materials

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.

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

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.

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

Electrical Safety

Most laser systems involve high potential, high current power supplies. The most serious accidents with lasers have been electrocutions. There have 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 should 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 should have a separate circuit and local cut-off switch (breaker) for the circuit.

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.

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 on-line at <http://www.vandysafe.com>. Contact VEHS for additional information on electrical safety.

UV Lasers

Since UV radiation scatters easily from many surfaces, and exposure to UV radiation can cause cancer and 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 VEHS for assistance on ozone concerns and UV radiation hazards.

Purchases and Acquisitions

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 LSO or 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."

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

Registration

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

- Manufacturer:
- Model (laser head):
- Serial No.:
- Type: (Argon-ion, Nd:YAG, etc.)
- Classification:
- Wavelength:
- Beam diameter:
- Beam Divergence:
- Mode:
- Location: (Building, room)
- Responsible faculty member and laser operators:

Disposal

Sale or disposal of lasers off-campus require that certain precautionary measures be taken involving the notification of the potential hazards of the equipment. Before the laser is released, contact the Office of General Counsel for direction on this matter.

Please contact VEHS if you have additional questions regarding laser safety or related safety concerns.