University of Illinois
at Urbana-Champaign

Laser Safety Manual

<u>Emergency reference numbers:</u>

Police, Fire, or Ambulance……………………..9-911 from campus phone

Radiation Safety……………………………217-333-2755

Laser Safety Officer…………………………217-244-7605

Revision 3
May 2014

Laser Safety Manual

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Laser Safety Manual revision history

Revision 1, October 2010. Added requirement for annual laser safety training and definitions of laser Classes 2M and 3R. Added information on cleaning, storing, and inspection of laser safety eyewear. Added notification and reporting requirements, laser eyewear inspection form, Authorized Laser Operators forms, laser safety operation procedure preparation guide, and sample Laser Safety Operation Procedure.

1.0 Introduction

This manual describes the laser safety program for the University of Illinois at Urbana-Champaign. The purpose of this program is to protect U of I personnel, guests, and property from the hazards associated with lasers and laser systems. This manual provides: a reference source for laser users and basic laser safety information and establishes an awareness of the rules, regulations, and procedures governing the safe use of lasers.

The requirements in this manual apply to lasers in classes 3b and 4 only. The hazards from lasers in classes 1, 2, and 3a are less significant than the higher-powered lasers in classes 3b and 4. All lasers, regardless of class, can cause injury if misused.

2.0 Registration of Laser Systems

The Illinois Emergency Management Administration (IEMA) requires that all Class 3b or 4 laser systems be registered with the state. The Division of Research Safety (DRS) can assist with this registration process.

To register a laser, obtain a copy of the Laser Registration from Appendix A of this manual. Provide full and complete responses to the application and submit it to the DRS. DRS will ensure that the laser system is registered with IEMA.

3.0 Laser Safety Training Requirements

Each principal investigator (PI) is responsible for providing laser safety training to employees using lasers or entering controlled areas under his or her supervision. Other individuals may provide the training under the supervision of the PI. DRS can provide general training to personnel upon request.

The nature of the initial laser safety training shall include instructions for the safe operation of each laser.

Annual laser safety training is required. This training can be given as in-service training covering laboratory-specific laser safety techniques and information. Suggested topics: operation and emergency procedures, use of protective devices (including selection and use of eyewear), precautions to avoid exposure greater than the maximum permissible exposure (MPE) of a given laser, review of laser safety terminology.

4.0 Responsibilities

4.1 PRINCIPAL INVESTIGATORS

The PI has is responsible for ensuring the safe use of laser. Specifically, PIs are responsible for ensuring that:

- Only authorized individuals operate lasers or have access to controlled areas during laser operations;
- Individuals authorized to use lasers have received adequate training;
- Appropriate personal protective equipment (PPE) is available and worn when necessary;
- Laser operating procedures are provided and include adequate safety measures;
- Lasers manufactured or modified are properly classified, labeled and registered.
- All class 3b and 4 lasers have been registered with Radiation Safety.
- Details of any accidents/incidents involving lasers are provide to DRS in accordance with section 8.0 of this manual.

4.2 OPERATORS

Persons operating lasers are expected to:

- Follow proper operating and safety procedures,
- Perform only those operations authorized by the PI,
- Restrict access to controlled areas during operations.

4.3 LASER SAFETY OFFICER

An individual designated as the campus laser safety officer (LSO) has the authority and responsibility to monitor and enforce the control of laser hazards and to effect the knowledgeable evaluation and control of laser hazards. The LSO is responsible for issuing laser incident/accident notifications and reports to the IEMA in accordance with section 8.0 of this manual.

4.4 DIVISION OF RESEARCH SAFETY PERSONNEL

DRS personnel are available to provide support in all aspects of laser safety, including:

- Providing general laser safety training and/or training materials to PIs and laser operators,
- Providing appropriate warning signs and labels,
- Reviewing operating and safety procedures.

4.5 LASER SAFETY COMMITTEE

The Laser Safety Committee, also referred to as the Radiation and Laser Safety Committee, advises the Vice Chancellor for Research (VCR) and DRS on matters related to the campus Radiation Safety Program. The committee includes faculty members representing various areas of research and teaching and representatives of the campus administration including the Campus Radiation Safety Officer (Assistant Director, DRS).

The chancellor delegates the authority to oversee the use of lasers throughout the campus to the Radiation and Laser Safety Committee, giving it the authority to permit, deny, or revoke authorization for individuals to obtain and use lasers on the U of I campus.

The responsibilities of the Radiation and Laser Safety Committee include the following:

- Review proposals for unusually hazardous uses of lasers, and establish criteria for equipment and procedures to ensure employee, student and public safety;
- Review cases that involve repeated infractions of the rules and regulations for laser safety;
- Review accidents that may involve injury or serious economic loss and other cases for which reports to outside regulatory authorities are required;
- Review appeals from laser users to modify rules or DRS decisions;
- Meet formally as often as necessary to review campus laser safety with DRS;
- Make recommendations concerning the establishment or modification of campus laser safety policies.

5.0 Laser and Laser System Hazards

EYE
Laser light can damage different structures of the eye depending on the wavelength. Retinal burns resulting in partial or complete blindness can occur in the visible (400-700 nm) and near-infrared (700-1400 nm) regions. At these wavelengths, the eye will focus the beam or a specular reflection on a tiny spot on the retina. This focusing increases the irradiance of the beam by a factor of about 100,000.

Laser emissions in the ultraviolet (<400 nm) and infrared to far-infrared (>1400 nm) regions are primarily absorbed by and cause damage to the cornea. In the near-ultraviolet range (315-400 nm), some of the radiation reaches the lens of the eye.

SKIN
Skin damage can occur from exposure to infrared or ultraviolet light. For infrared exposure, the results can be thermal burns or excessively dry skin depending on the intensity of the radiation. In the 230-380 nm range of ultraviolet light, erythema (sunburn), skin cancer, or accelerated skin aging are possible. The most damaging region of ultraviolet is 280-315 nm, also known as UV-B.

ELECTRICAL
Many lasers contain high-voltage components, which can present a potentially lethal hazard. Proper lockout procedures should be followed when working on high-voltage components.

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

HAZARDOUS MATERIALS
Laser laboratories contain many of the same hazards found in chemical laboratories; therefore, the same precautions should be taken. In addition, most laser dyes are considered to be hazardous materials and should be handled accordingly. Laser interactions with certain materials may produce toxic fumes, which must be properly vented.

6.0 Laser Classifications

Lasers and laser systems are classified by potential hazard according to a system described in the American National Standards Institute (ANSI) standard Z136.1 and in 21 CFR part 1040. A laser's classification is based on several factors, including its wavelength, power output, accessible emission level, and emission duration. The level of hazard associated with each class of lasers is listed below.

Regulations in the United States define 5 laser classifications: Class 1, 2, 3A, 3B, and 4. These classifications currently dictate laser hazard standards in the US. International regulations define two additional classifications: Class 2M and 3R. Definitions provided for these classifications are for information only.

CLASS 1
Lasers in this class cannot cause eye damage. These lasers are exempt from labeling requirements.

CLASS 2
Lasers in this class emit visible light only. They are capable of producing eye damage only if the beam is stared at directly for longer than the normal human aversion response time to bright light (0.25 second). This means a person would naturally turn away from the beam before any damage is done.

CLASS 2M
A Class 2M laser is safe if not viewed through optical instruments; the blink reflex provides protection. This applies to laser beams with a large diameter or large divergence for which the amount of light passing through the pupil cannot exceed the limits for class 2.

CLASS 3A
Class 3a lasers are those that normally would not produce injury if viewed only momentarily with the unaided eye. They may present a hazard if viewed using collecting optics, e.g., telescopes, microscopes, or binoculars.

CLASS 3R
These laser products are marginally unsafe for intrabeam viewing (current Class 3A lasers that have beam diameters of less than 7 mm). A Class 3R laser is considered safe if handled carefully with restricted beam viewing, and the MPE can be exceeded with a low risk of injury. Visible continuous lasers in Class 3R are limited to 5mW. For other wavelengths and for pulsed lasers, other limits apply.

CLASS 3B

Viewing of the direct or specularly-reflected beam from Class 3B lasers can cause eye damage. Diffuse reflections from these lasers are generally not hazardous except due to intentional staring at distances close to the diffuser.

CLASS 4

Lasers in this class are high powered. Short-duration exposure to the direct, specularly reflected, or diffusely reflected beam can cause severe eye and skin damage. Flammable or combustible materials may ignite if exposed to the direct beam.

EMBEDDED LASERS

A laser system of one class may contain a laser of a higher class. For example, a class 3A system might contain a class 4 laser in an interlocked protective housing that incorporates design features to limit the accessible emission level to the class 3A level.

If a laser or laser system has been manufactured by or modified at the U of I, the PI is responsible for determining the laser's proper classification. This classification may be accomplished using one of the following tables (taken from ANSI Z136.1 -- 2000), depending on whether the laser is pulsed or continuous.

Classification Table for Continuous Wave (CW) Small-Source Lasers

Wavelength (μm)	Laser type	Wavelength (μm)	Class 1* (W)	Class 2* (W)	Class 3** (W)	Class 4* (W)
Ultraviolet 0.180 to 0.280	Nd:YAG (Quadrupled)	0.266	$\leq 9.6 \times 10^{-9}$ for 8 hours	None	>Class 1 but ≤ 0.5	>0.5
	Argon	0.275				
Ultraviolet 0.315 to 0.400	He-Cd	0.325	$\leq 3.2 \times 10^{-6}$	None	>Class 1 but ≤ 0.5	>0.5
	Argon	0.351, 0.363				
	Krypton	0.3507, 0.3564				
Visible 0.400 to 0.700	He-Cd	0.4416 only	$\leq 4 \times 10^{-5}$	> Class 1 but $\leq 1 \times 10^{-3}$	> Class 2 but ≤ 0.5	>0.5
	Argon (visible)	0.457	$\leq 5 \times 10^{-5}$			
		0.476	$\leq 1 \times 10^{-4}$			
		0.488	$\leq 2 \times 10^{-4}$			
		0.514	$\leq 4 \times 10^{-4}$			
	Krypton	0.530				
	Nd:YAG (doubled)	0.532				
	He-Ne	0.543				
	Dye	0.400 - 0.500	$\leq 0.4C_B \times 10^{-4}$			
	He-Se	0.460 - 0.500				
	Dye	0.550 - 0.700	$\leq 4 \times 10^{-4}$			
	He-Ne	0.632				
	InGaAlP	0.670				
	Ti:Sapphire					
	Krypton	0.6471, 0.6764				
Near Infrared 0.700 to 1.400	GaAlAs	0.780	$\leq 5.6 \times 10^{-4}$	None	> Class 1 but ≤ 0.5	>0.5
	GaAlAs	0.850	$\leq 7.7 \times 10^{-4}$			
	GaAs	0.905	$\leq 9.9 \times 10^{-4}$			
	Nd:YAG	1.064	$\leq 1.9 \times 10^{-3}$			
	He-Ne	1.080	$\leq 1.9 \times 10^{-3}$			
		1.152	$\leq 2.1 \times 10^{-3}$			
	InGaAsP	1.310	$\leq 1.5 \times 10^{-2}$			
Far Infrared 1.400 to 1000	InGaAsP	1.550	$\leq 9.6 \times 10^{-3}$			
	Holmium	2.100				
	Erbium	2.940				
	Hydrogen Fluoride	2.600 - 3.00				
	He-Ne	3.390 only				
	Carbon Monoxide	5.000 - 5.500				
	Carbon Dioxide	10.6				
	Water Vapor	118	$\leq 9.5 \times 10^{-2}$			
	Hydrogen Cyanide	337				

* Assumes no mechanical or electrical design incorporated into laser system to prevent exposures from lasting to T_{max} = 8 hours (one work day); otherwise the Class AEL could be larger than tabulated.

** Class 3a lasers and laser systems include lasers and laser systems that have an accessible output between one and five times the Class 1 AEL for wavelengths shorter than 0.4um or longer than 0.7 um, or less than five times the Class 2 AEL for wavelengths between 0.4 and 0.7 um.

Classification Table for Single Pulse Small-Source Lasers

Wavelength (µm)	Laser type	Wavelength (µm)	Pulse Duration (s)	Class 1 (J)	Class 3b (J)	Class 4 (J)
Ultraviolet 0.180 to 0.400	Excimer (ArF)	0.193	20 x 10^{-9}	≤2.4 x 10^{-5}	> Class 1 but ≤0.125	> 0.125
	Excimer (KrF)	0.248	20 x 10^{-9}	≤2.4 x 10^{-5}		
	Nd:YAG Q-switched (quadrupled)	0.266	20 x 10^{-9}	≤2.4 x 10^{-5}		
	Excimer (XeCl)	0.308	20 x 10^{-9}	≤5.3 x 10^{-5}		
	Nitrogen	0.337	20 x 10^{-9}	≤5.3 x 10^{-5}		
	Excimer (XeF)	0.351	20 x 10^{-9}	≤5.3 x 10^{-5}		
Visible 0.400 to 0.700	Rhodamine 6G (Dye laser)	0.450 - 0.650	1 x 10^{-6}	≤1.9 x 10^{-7}	> Class 1 but ≤0.03	> 0.03
	Copper vapor	0.510, 0.578	2.5 x 10^{-9}			
	Nd:YAG (doubled) (Q-switched)	0.532	20 x 10^{-9}			
	Ruby (Q-switched)	0.6943	20 x 10^{-9}			
	Ruby (Long pulse)	0.6943	1 x 10^{-3}	≤3.9 x 10^{-6}		
Near Infrared 0.700 to 1.400	Ti:Sapphire	0.700 - 1.000	6 x 10^{-6}	≤1.9 x 10^{-7}		
	Alexandrite	0.720 - 0.800	1 x 10^{-4}	≤7.6 x 10^{-7}	> Class 1 but ≤0.033	> 0.033**
	Nd:YAG (Q-switched)	1.064	20 x 10^{-9}	≤1.9 x 10^{-6}	> Class 1 but ≤0.125	>0.125
Far Infrared 1.400 to 1000	Erbium:Glass	1.54	10 x 10^{-9}	≤7.9 x 10^{-3}	> Class 1 but ≤0.125	> 0.125
	Co:Mg-Fl	1.8 - 2.5	80 x 10^{-6}	≤7.9 x 10^{-4}		
	Holmium	2.1	250 x 10^{-6}	≤7.9 x 10^{-4}		
	Hydrogen Fluoride	2.600 - 3.000	0.4 x 10^{-6}	≤1.1 x 10^{-4}		
	Erbium:Glass	2.94	250 x 10^{-6}	≤5.6 x 10^{-4}		
	Carbon Dioxide	10.6	100 x 10^{-9}	≤7.9 x 10^{-5}		
	Carbon Dioxide	10.6	1 x 10^{-3}	≤7.9 x 10^{-4}		

* Assuming that both eye and skin may be exposed, i.e., 1.0 mm beam (area of limiting aperture = 7.9 x 10^{-3} cm^2)

** Class 3b AEL varies from 0.033 to 0.480 J corresponding to wavelengths that carry between 0.720 and 0.800 um.

7.0 Control Measures

This section describes administrative, procedural, and engineering measures that can reduce the chance of a laser-related incident. These measures should be considered when evaluating a class 3B or 4 laser facility. Although some items are appropriate for all facilities (e.g., posting proper warning signs), others may not be practical for some operations. Primary control measures are *italicized* for emphasis. In most cases, implementing these measures will provide effective hazard control.

BEAM CONTROL

Enclosure of the laser equipment or beam path to isolate or minimize the hazard is the preferred method of control. As a minimum, beam stops must be used to ensure no direct or specularly reflected laser light leaves the experiment area.

Laser beam height should be maintained at a level other than the normal position of the eye of a person who is standing or seated. Securely fasten the laser and all optics on a level, firm, and stable surface.

REFLECTIONS

Remove unnecessary reflective items from the vicinity of the beam path. Do not wear reflective jewelry such as rings or watches while working near the beam path.

Be aware that lenses and other optical devices may reflect a portion of the beam from their front or rear surfaces.

Avoid placing the unprotected eye along or near the beam axis. The likelihood of a hazardous specular reflection is greatest in this area.

POWER LEVEL

Use the minimum laser radiation required for the application. Operate a laser at the minimum power necessary for any operation. Beam shutters and filters can be used to reduce the beam power. Use a lower power laser when possible, *especially* during alignment procedures.

WARNING SIGNS

The entrance to a class 3B or 4 laser facility must be posted with the appropriate warning sign. Warning signs show the classification of the laser, identify the wavelength(s), power output, or provide protective action instructions. Signs can be obtained through DRS.

LABELS

Each laser must be labeled as required by 21 CFR part 1040. These labels show the classification of the laser and identify the aperture(s) where the laser beam is emitted. The laser manufacturer usually provides this label.

WARNING DEVICES

Class 4 laser facilities where the beam is not fully enclosed should have a visible warning device (e.g., a flashing red light) at the outside of the entrance that indicates when a laser is in operation.

CONTROL OF AREA

Except for fully enclosed and interlocked systems, an authorized user must be present or the room kept locked during laser operations.

INTERLOCKS

Many laser systems have interlocked protective housings that prevent access to high-voltage components or laser radiation levels higher than those accessible through the aperture. These interlocks should not be bypassed without the specific authorization of the PI. Additional control measures should be taken to prevent exposure to the higher radiation levels or high voltage while the interlock is bypassed.

PERSONAL PROTECTIVE EQUIPMENT

Eye protection designed for the specific wavelength of laser light should be available and worn when there is a chance that the beam or a hazardous reflection could reach the eye. The manufacturer should mark protective eyewear with the wavelength range over which protection is afforded and the minimum optical density within that range. Eyewear should be examined prior to each use and discarded if there is damage that could reduce its effectiveness.

Protective eyewear generally will not provide adequate protection when viewing the direct beam of a high-powered laser. Wearing protective eyewear should not be used as an excuse for performing an unsafe procedure.

Eyewear is a laser safety necessity and must be maintained properly. Proper care of laser safety eyewear will prolong its life and help ensure that personnel are protected. Use a lens cleaning solution and cloth that are safe to use with the filters to remove dirt, oil, and dust without scratching, delaminating, or damaging dielectric coatings. Store eyewear in a hard or soft case and place in a secure area. These simple steps will keep protective equipment functioning properly for a long time.

Each lab shall inspect laser safety eyewear a**t least every six months** to ensure that there are no scratches, holes, cracks, pits, discolorations, or other damage that would reduce the intended safety level. Eyewear found to be unacceptable shall be removed from service. Results of this inspection shall be documented.

TRAINING

All operators must be trained by the PI, or person designated by the PI, in the safe and proper use of lasers before being allowed to operate a laser. Annual laser safety training is also required. All training should be documented.

OPERATING PROCEDURES

Written operating and specific alignment procedures that describe applicable safety measures should be available.

MAINTENANCE/SERVICE

Only a knowledgeable person who has been specifically authorized by the PI to perform such work should perform maintenance, servicing, or repair of a laser. Whenever such work involves accessing an embedded laser of a higher class, the controls appropriate to the higher class must be applied.

Any laser that is significantly modified must be re-evaluated to determine its classification.

The following table provides general laser safety guidelines for all classes of lasers.

LASER SAFETY GUIDELINES

CLASS	USER PRECAUTIONS
General Safety for All Classes	• Ensure that personnel have had safety training appropriate to the level of expected hazard. • Do not aim the laser beam at people or at objects not involved in the research. • Protect against non-beam hazards. • Use the minimum energy required for the experiment. • Develop standard procedures (e.g., operating, alignment).
1	• No user rules necessary in normal usage.
2	• Do not stare into the laser beam.
3A	• Permit only properly trained personnel to operate the laser. • Do not view the beam or its specular reflection with collecting optics.
3B	• Establish a Nominal Hazard Zone (NHZ) for the laser. • Post appropriate laser hazard signs. • Permit only properly trained personnel to enter the NHZ and operate the laser. • Do not view the laser beam or its specular reflection. • Enclose as much of the beam path as possible. • Use beam stops to terminate beams at the end of useful beam paths. • Ensure that the beam path is above or below the eye level of sitting and standing personnel. • Mount the laser, its associated optics, and other equipment firmly to a stable surface to ensure that the beam travels along its intended path. • Wear appropriate laser eyewear within the NHZ. • Practice good laboratory hygiene. Remove unnecessary reflective surfaces from the vicinity of the beam path.
4	• Establish a Nominal Hazard Zone (NHZ) for the laser. • Post appropriate laser hazard signs. • Permit only properly trained personnel to enter the NHZ and operate the laser. • Do not view the laser beam, its specular reflection, or in some cases, its diffuse reflection. • Enclose as much of the beam path as possible. • Use non-flammable beam stops to terminate beams at the end of useful beam paths. • Ensure that the beam path is above or below the eye level of sitting and standing personnel. • Mount the laser, its associated optics, and other equipment firmly to a stable surface to ensure that the beam travels along its intended path. • Wear appropriate laser eyewear within the NHZ. • Practice good laboratory hygiene. Remove unnecessary reflective surfaces from the vicinity of the beam path. • Install appropriate shielding to protect personnel from the beam. • Operate the laser in a room with door interlocks if possible. • Use remote firing and/or remote monitoring systems if possible.

8.0 Emergencies and Incident Procedures

EMERGENCIES
For any emergency requiring police or fire or ambulance assistance, call 911 from any university or personal telephone.

EMERGENCIES OR INCIDENTS INVOLVING LASERS

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

- Ensure that the laser shutter is CLOSED or de-energized completely.
- Provide for the safety of personnel (first aid, evacuation) as needed.

  Note–If a laser eye injury is suspected, have the injured person keep their head upright and motionless to restrict bleeding in the eye. A physician should evaluate laser eye injuries as soon as possible.
- Obtain medical assistance for anyone who may be injured.

  Dial 911 from any university or personal telephone for ambulance (urgent medical care) or fire department.
- If there is a fire, leave the area, pull the fire alarm, and contact the fire department by calling 911. Do not fight the fire unless it is very small and you have been trained in fire-fighting techniques.

  If after normal working hours, contact the U of I Police Department (Non-emergency: 217-333-1216; emergency: 911 from campus phone), which can contact the above using their emergency call list.
- Inform the PI, the group safety officer, and the building manager as soon as possible. If there is an injury, the PI needs to submit a report of injury to Risk Management. Provide as many details as possible.
- Inform the DRS at 217-333-2755 as soon as practical. Provide as many details as possible.

Non-Life-Threatening Injury

Employees should seek treatment at the Occupational Medicine Departments identified by the Workers' Compensation program. Currently, there are two facilities:

- Carle Occupational Medicine, 810 W. Anthony Drive, Urbana. Normal hours are 8 a.m. to 5 p.m. weekdays. Phone: 217-383-3077. Employees can go to the Carle Emergency Department at 602 W. University Ave, Urbana. After normal hours, on weekends, and on holidays, phone 217-383-3313.

- **SAFEWORKS OF ILLINOIS,** Weekdays 8 a.m. to 5 p.m., 1806 N. Market Street; Champaign, 217-356-6150. *After hours and weekends:* **Provena Covenant Hospital Emergency Department,** 1400 W. Park Street; Urbana, 217-337-2131

When seeking treatment, bring a either a note from your supervisor verifying that the injury took place during work OR the name and number of your supervisor (who will be called the following day to verify that the injury occurred during work) and a Material Safety Data Sheet (MSDS) if a chemical was involved in the injury (if an MSDS cannot be found, do not delay seeking medical attention).

Non-employees should seek treatment at the emergency room of either Carle Foundation Hospital or Provena Covenant Medical Center. Students may seek basic medical care at the McKinley Health Center or with their personal physician. Costs associated with most injuries incurred during unpaid activities are the responsibility of the individual and their health insurance.

NOTIFICATIONS AND REPORTS

Under most circumstances, DRS will make formal notifications and reports to the Illinois Emergency Management Agency (IEMA). Completion of these reports may require additional consultation with laboratory personnel. The PI should provide the details of the incident (who/when/how) to the DRS for preparation of this reporting process within the time frames specified below. Notifications and reports include:

Immediate notification

Illinois state regulations require the immediate notification to the IEMA of any incident involving exposure to laser radiation that has or may have caused accidental injury to an individual in the course of use, handling, operation, manufacture, or discharge of a laser system including:

- An exposure to an individual of greater than 100 times the MPE,
- An exposure to an individual that involves the partial or total loss of sight in either eye,
- An exposure to an individual that involves perforation of the skin or other serious injury exclusive of the eye.

24-hour notification

Notification to IEMA within 24 hours is required for any incident involving exposure to laser radiation that has or may have caused:

- An individual's exposure of greater than five times the MPE,
- An exposure that involves second- or third-degree burns to the skin.

Reports

A written report shall be made to the IEMA within 30 days for any of the exposures described in the preceding paragraphs. Each report shall include the full name of each individual exposed to laser radiation, including estimates of each individual's exposure, levels of laser radiation involved, the cause of the exposure, a description of the injuries, and corrective steps taken or planned to be taken to prevent a recurrence. The report shall also be sent to the individual(s) exposed to laser radiation. The report to the individual shall be transmitted at a time not later than the date of transmittal to IEMA.

Reports are normally prepared and transmitted by the DRS.

WORKERS COMPENSATION:

For information concerning workers compensation go to:
http://www.obfs.uillinois.edu/risk/workers_compensation

Appendix A: Recommended Laser Forms

University of Illinois
LASER REGISTRATION FORM
Required for all class 3B or 4 lasers

Complete this form and return to:
Radiation Safety Section
Division of Research Safety, MC-225

GENERAL INFORMATION – Please print legibly

Principal Investigator____

Department____

Office_______________________ Phone_________________________

Email_________________________ Mail Code___________________

LASER SYSTEM DESCRIPTION

Location of laser (room & building)_______________________________

Manufacturer_______________________ Model___________________

Serial number________________________ Class__________________

UIUC Property #____

Status of unit: ___Operable ___Inoperable ___Stored

Date placed in service:___________________

Laser type (CW, pulsed)____

Description (He-Ne, Nd-YAG, CO_2, etc)_________________________

Wavelength(s)____

Maximum power (Watts) or energy (Joules)______________________

Pulse duration (if applicable)____________, Frequency_____________

Emerging beam divergence______________________________________

Beam diameter____

Has laser been modified from the original? ___Yes ___No

Description of changes made______________________________

____

S:\RSS\lasers\Laser Registration Form.doc

Laser Eyewear Inspection Record

Laser eyewear shall be inspected to ensure there are no scratches, holes, cracks, discolorations or other damage that would decrease the intended safety level at intervals **not to exceed 6 months**. Eyewear found to be unacceptable shall be removed from service.

Location:______________________________ PI:_______________________________________

Date	Inspector's name	Type of eyewear units inspected	# of this type of eyewear	Status

Laser Safety Training Record

(for single laser labs)

Location:______________________________ PI:_______________________________________

Laser:____

The PI shall provide **initial** and **annual** in-service training on laser safety for laser users. The training shall cover: operating and emergency procedures; use of protective devices, including selection and use of eyewear; warnings and precautions to avoid possible exposure to laser radiation in excess of the MPE; and safety regulations.

Operator Name	Date of Laser Safety Training

Laser Safety Training Record

(for multiple-laser labs)

Location:______________________________ PI:_______________________________________

Attach list of laser systems for this location.

The PI shall provide **initial** and **annual** in-service training on laser safety for laser users. The training shall cover: operating and emergency procedures; use of protective devices, including selection and use of eyewear; warnings and precautions to avoid possible exposure to laser radiation in excess of the MPE; and safety regulations.

Authorized Users	Systems Authorized to Use	Date of Training

Appendix B: SOP PREPARATION GUIDE

This outline can be used as basis for preparing laser standard operating procedures (SOPs). The SOP should include all lasers in a given laser system, including alignment and pumping lasers. The SOP should be reviewed every two years and revised as needed.

I. Introduction
   A. Location of laser/laser system (building, room)
   B. Map of area
   C. Description of each laser:
      1. Classification
         a. Class 1, 2, 3A, 3B, or 4
         b. Continuous wave, pulsed, Q-switched
      2. Lasing medium
      3. Beam characteristics (as applicable):
         a. Divergence
         b. Aperture diameter
         c. Pulse length
         d. Pulse frequency
         e. Maximum energy output
   D. Purpose/application of laser(s)

II. Hazards
   A. Identify hazards present:
      1. Laser beam(s)
      2. Electrical
      3. Chemical
      4. Fire/explosion
      5. UV light
   B. Hazard analysis

III. Controls
   A. Engineering controls, e.g., interlocks, beam stops.
   B. Administrative controls, e.g., signs, LSOP, etc.
   C. Personnel Protective Equipment, e.g., laser eye protection, gloves.

IV. Operating Procedures
   A. Equipment preparation
   B. Personnel Protective Equipment preparation
   C. Step-by-step protocol for laser system operation
   D. Shutdown procedures
   E. Special procedures:
      1. Alignment
      2. Safety checks
      3. Maintenance

V. Emergency procedures

A. Immediate actions
B. Medical assistance
C. Contact information

VI. User Training
A. Initial orientation/basic laser safety principles
B. Annual/in-service training
C. Laser safety during operations
D. Maintenance and repair training, if applicable
E. Documentation of training

VII. Responsibility
A. Supervisor (include emergency contact)
B. Users and auxiliary personnel

VIII. Miscellaneous
A. Rules for visitors
B. Rules for building service workers
C. Other

Appendix C: SAMPLE LASER SOPs

Sample Laser Safety Operating Procedure (LSOP)

Standard Operating Procedures for the High Watt Laser

1. Introduction:

This Standard Operating Procedure (SOP) dictates the requirements for an authorized user of the High Watt lasers in room 123 Laser Research Laboratory and describes the normal operation of the lasers and hazards that may be encountered during normal operation. The SOP provides techniques to minimize hazards and instructions on how to respond to emergency situations. The High Watt is a Class IV KrF excimer laser that can produce a 20 nanosecond 800 mJ/pulse at a wavelength of 248 nm and a repetition rate of 1–50 Hz during normal operation. The emerging beam divergence is 1 mrad, and the beam diameter is 1 mm. Safety glasses marked with the appropriate wavelength and optical density (OD) are provided and must be worn during normal laser operation. The High Watt laser is used in atomic and molecular spectroscopy.

2. Hazards:

Laser Hazards
Severe damage to skin and eye tissue can occur from direct exposure to any Class IV laser; specular or diffuse reflections can cause eye damage. The High Watt laser produces (invisible) ultraviolet light that is harmful to the skin.

Electrical Hazards
Electrical shock or electrocution could result from contact with the high voltage (HV) power supply used to excite the gas mixture. Also, large currents are used in the heaters of the vacuum chambers adjacent to the laser.

Chemical Hazards
The gas mixture used as the lasing medium contains fluorine, krypton, and neon. Fluorine is a toxic gas, and a lethal dose can be received if proper safety procedures are not followed.

Pressure Hazards
The lasing gas mixture and He purge gas are in compressed form and represent possible explosion hazards if proper safety procedures are not followed. Also, the lasing cavity is kept at a nominal pressure of 3600 mbar, which is significantly above atmospheric pressure.

3. Hazard Controls

Lasers

- Access to the laser facility is controlled; only authorized users have key access.
- Lasers shall be operated only by authorized personnel.
- A warning sign outside the door to the lab shall be lit whenever the laser system is operating.
- The shield curtain should be fully closed when the laser is running to separate the laser and non-laser areas.
- During operation of the laser system, unauthorized personnel shall be allowed entry to the laser area (inside the curtain) only under the supervision of an authorized user.
- Protection from high voltages produced in the laser power supply is provided by the grounded metal enclosure of the power supply. The outer casing of the laser is also interlocked, and the laser will not energize the cavity if a panel is taken off of the outer housing. The metal casing shall not be opened until the high-voltage capacitors are completely discharged and the main cable has been disconnected.
- The 10 mW HeNe laser shall be used for assisting with beam alignments of the High Watt laser. Be aware that although this is a Class II device, you may not safely stare into the beam and should treat this device with the same care and respect as you would the High Watt laser.
- Laser glasses for protection against 248 nm must be available and are located near the entrance of the laser area in room 123 Laser Research Laboratory. Laser glasses must always be worn when the laser is firing, whether or not the shutter is open.
- Specular and diffuse reflections shall be controlled using apertures, beam housings and enclosures, and various optical components. The housings covering the beam path at various points (exiting the laser, entering the chambers, or going through optics) must be in place during normal operation. Access ports for making adjustments are to be used only when using the HeNe laser for alignment or when the laser shutter is closed.
- To locate an invisible beam, thermal-sensitive paper may be used. Use only by securing it in place over an optic, then closing all access ports and making sure all enclosures are secure before opening the shutter and activating the laser.
- Laser alignment must be performed only by following the steps outlined in the alignment supplement, and energy measurements must be performed directly in front of the focusing lenses with the beam enclosures in place.
- If the beam path must be changed significantly (i.e., not in the normal course of adjusting the mirrors) by relocating mirrors or other optics, all users of the laser must be notified of the change.
- The same precautions that are taken in safe operation of the laser and optics must also be followed when changing vacuum chamber optics and adjusting the focusing lenses to line up incident onto the chamber targets with a specific spot size.

- Any stray or unused beams are terminated by using beam stops or dumps.
- The beam is enclosed as much as practical; the shutter is closed as much as practical during coarse adjustments; optics/optical mounts are secured to the table as much as practical; beam stops are secured to the table or optics mounts.

Electrical

The High Watt laser uses high voltage to excite the lasing gas mixture, so all maintenance to the internal components of the High Watt laser may be performed only by authorized repair technicians, and there must be more than one authorized user present for any maintenance operation that requires access to the internal components of the laser.

Chemical

- Corrosive and toxic gases are used as the lasing medium of the High Watt laser. Even in small concentrations, fluorine gas can be hazardous. In addition, ozone and nitrogenous gases may be created by high-power UV pulses. Ensure that the room ventilation is working properly before operating the laser.
- The smell of fluorine (a sharp, pungent odor) indicates that the laser cavity or Swagelok tubing is leaking, provided the exhaust is within normal parameters. If fluorine is detected, the gas cylinder could be leaking.
- Nitrile gloves shall be used when changing optics or using polishing powder on the laser windows. Be aware that some of the laser windows are coated on one side. Wear nitrile gloves when changing the halogen filter.
- A new fill may be performed only by authorized users or qualified laser repair technicians.

Pressure

- All large compressed gas cylinders shall be securely fastened to the wall with Unistrut and chains or similarly approved assemblies. Small cylinders used for experiments shall also be securely fastened.
- Do not adjust the laser cavity windows unless following the guidelines laid out in the alignment supplement. The laser cavity can be alternately pressurized or under vacuum and thus represents both an explosion and an implosion hazard.
- The use of compressed gases shall be performed only through a regulator.
- The laser cavity pressure shall not exceed 4000 mbar, and lasing will not be efficient under 3100 mbar.

4. Normal Operation

Laser Startup

- Remove all jewelry from fingers and arms (e.g., rings, watch, bracelet). If wearing a necklace, either remove it or ensure that it is secured between your shirt and body.
- Wear appropriate clothing to protect hands and arms from excessive laser radiation.

- Remove all unnecessary equipment, tools, and combustible materials from near the beam path to minimize the possibility of stray reflections and non-beam accidents.
- Ensure that all personnel inside the Nominal Hazard Zone are wearing appropriate laser safety glasses.
  - Verify that the wavelength is suitable for the laser in use.
  - Verify that the optical density (OD), as indicated by inscriptions on the lenses or frame of the glasses, is adequate.
  - Ensure that the glasses are in good condition (i.e., no deep scratches or cracks in lenses, good frame integrity).
- Check for exposed wiring or electrical components. Be aware that high voltage capacitors have electrical potential long after they have been de-energized and unplugged.
- Do not open the laser cover except under instructions from a knowledgeable person. Besides exposing high voltage electrical sources, removing the cover may expose users to secondary wavelengths that may be invisible and that fall outside the protection range of the selected eyewear.
- Avoid having eyes (including when wearing safety eyewear) in the same optical plane as the beam. Generally, personnel should remaining standing while the laser is in operation. If personnel must be seated, provide tall stools that will keep the eyes above the plane of the optical table.
- Assure that the chiller is turned on and cooling water is flowing to the laser.
- Verify that the High Watt laser back panel indicates the laser is on.
- Confirm that the beam path is set up by using the HeNe alignment laser so that a focused spot will land onto the exposed target in the chamber.
- Confirm that the HeNe alignment laser is out of beam path.
- Confirm that all beam enclosures are in place before the High Watt laser shutter is opened.
- **Warn all personnel near the NHZ by saying "Firing" before starting to 1) fire the laser or 2) open the laser shutter.**
- If necessary, use an energy meter to check the laser energy.
- Close the laser shutter and take the energy meter out of the beam path.
- Record the laser status in the laser logbook. When ready to begin the run, open the shutter and ensure that all safety enclosures, beam stops, and shields are in place.
- During the run, ensure that the laser beam is striking the target by indirectly noting the plasma glow of the plume**. *Do not stare directly at where the focused spot hits the target*.**
- Record any anomalous behavior in the laser logbook, and alert other users.
- If there are warnings from the laser computer application, refer to the laser manual for

troubleshooting.

Laser shutdown

- When the run is finished, close the laser shutter and stop the laser computer from triggering.
- After the last user of the day, disconnect the power from the laser.
- Record pertinent details for the laser usage in the log book.
- Allow the chiller to run for at least a few minutes following laser usage. Before leaving the lab, turn off the chiller.
- Ensure that the beam enclosures are left in place. This ensures that the laser will be ready to go in a short time period for the next user and protects the next laser user and other personnel in the area from potential stray beam reflections.
- Place dust covers over optics as necessary.

Alignments

Beam alignment requires work with an open beam and involves directing the beam toward a series of reflective or partially reflective surfaces, such as mirrors or lenses, so that it follows a predetermined path. Laser alignments may be internal or external.

Internal alignments take place within the laser cavity or head and often place the work at increased risk of electrical accidents as well as primary beam exposure and ancillary wavelength exposure. The need for internal alignments usually arises because of problems associated with beam mode or power.

External alignments are those that occur from the laser's end window to a terminal target. A number of optical components (optics) arrayed in more or less complex configurations may be between these two locations. The need for external alignments occurs because of reconfiguration of the optical setup or replacement of components either within the laser head or in the open beam path.

Perform alignments with a colleague. Review alignment operating procedures with your colleague and communicate at all times. Identify equipment and materials necessary such as safety eyewear, tools, power meter/detector, and beam stops prior to performing alignment.

View beams indirectly. Use thermal paper to view the excimer laser beam and paper business cards to view the HeNe laser alignment beam.

- **Internal Alignment** (with laser windows cleaning/replacement)
  - Place dielectric pieces (with holes through the middle) on the front and back in front of the windows.

- Position the HeNe laser on a stand and direct it at the hole in the front piece. Adjust the tilt to get the laser beam through both holes at once to make the beam parallel. Do not look at the beam directly; use a business card to view the spot.
- Adjust the back laser mirror to position the reflection in the center of the front piece. Then remove the dielectric pieces.

- **External Alignment**
  - Using thermal paper, look at the excimer laser spot at the front shutter. A uniform plateau-like laser spot is ideal. Adjust the front window to produce a uniform rectangular shape.
  - Check that the beam is centered on the first aperture.
  - Tape thermal paper to the aperture, and trigger the laser to create a spot.
  - Use the HeNe laser and direct it to the center of the spot created by the excimer pulse. Remove the paper.
  - Repeat this process until the laser spot is roughly in the center of the excimer laser spot at all points of interest throughout the optics setup.
  - Open up the sample deposition chamber. Check the spot at the deposition target. Adjust the spot position on the target with the last mirror. Adjust the aperture to produce a small circular spot.
  - Save the thermal paper of the final spot at the target for comparison with previous and future alignments.
  - Normal laser hazard controls shall be restored when the alignment is completed. This includes replacing all enclosures, covers, beam blocks/barriers and checking affected interlocks for proper operation.

Maintenance procedures
Maintenance not described in this procedure shall be performed only by a qualified technician, normally a factory representative. Any deviations from this protocol shall be approved in writing by the PI.

For optics cleaning or replacing the halogen filter, please consult the laser manual.

5. Emergency Procedures

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

- Ensure that the High Watt laser shutter is CLOSED and that the laser is not pulsing or that it is in an otherwise safe condition.

- Provide for the safety of personnel (first aid, evacuation) as needed. **Note**: If a laser eye injury is suspected, have the injured person keep his/her head upright and motionless to reduce bleeding in the eye. A physician should evaluate laser eye injuries as soon as possible.

- Obtain medical assistance for anyone who may be injured. ***Dial 911 from any university or personal telephone for an ambulance (urgent medical care) or the fire department.***

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

After normal working hours, contact the U of I Police Department (non-emergency: 217-333-1216; emergency: 911 from campus phone), which can contact the above using their emergency call list.

- Inform the PI, the group safety officer, and the building manager as soon as possible. If there is an injury, the PI needs to submit a report of injury to Risk Management.
- Inform the DRS at 217-333-2755 as soon as possible.

Non-Life-Threatening Injury

Employees should seek treatment at one of the two Occupational Medicine Departments identified by the Workers' Compensation program:

SAFEWORKS OF ILLINOIS, Weekdays 8 a.m. to 5 p.m., 1806 N. Market Street; Champaign, 217-356-6150. *After hours and weekends:* **Provena Covenant Hospital Emergency Department;** 1400 W. Park Street; Urbana; 217-337-2131.

Carle Occupational Medicine, Weekdays 8 a.m. to 5 p.m., 810 W. Anthony Drive; Urbana, IL 61801; (217) 383-3077; *After hours and weekends:* **Carle Hospital Emergency Department,** 602 W. University Avenue, Urbana, 217-383-3313.

When seeking treatment, bring either a note from your supervisor verifying that the injury took place during work OR the name and number of your supervisor (who will be called the following day to verify that the injury occurred during work) and a Material Safety Data Sheet (MSDS) if a chemical was involved in the injury (if an MSDS cannot be found, do not delay seeking medical attention).

Non-employees should seek treatment at the emergency room of either Carle Foundation Hospital or Provena Covenant Medical Center. Students may seek basic medical care at the McKinley Health Center or with their personal physician. Costs associated with most injuries incurred during unpaid activities are the responsibility of the individual and their health insurance.

6. Personnel training:

The High Watt laser may be operated only by authorized personnel who are fully cognizant of all safety issues involved in operation of such a device. These personnel are to ensure that the laser is operated in accordance with the instructions in this document. To become an authorized user, one must:

- Complete DRS training;
- Pass the DRS laser safety quiz;
- Read and fully understand this SOP;
- Receive training on the High Watt laser by the primary user;

- Receive and document annual laser safety training;
- Sign the authorized user sheet to affirm that the above steps have been completed.

No unauthorized personnel may enter the laser area during laser operation unless accompanied by an authorized user. All visitors should be briefed on proper safety protocol and should wear appropriate laser safety goggles located near the entrance.

The following was taken from the Illinois Administrative Code, Title 32: Energy, Chapter II: Division of Nuclear Safety, Subchapter b: Radiation Protection, Part 315 "Standards for Protection against Laser Radiation", Appendix A.

Standard Operating Procedures (SOPs) are governed by institutional policy and are developed, modified and maintained in accordance with the needs of individual facilities. Information relative to safety incorporated into these SOPs is gathered from a wide range of resources, including, but not limited to, the laser system manufacturer or distributor. This appendix contains examples of SOPs for issues associated with the use of laser systems. It is recognized that the safety needs of installations with multiple laser systems may be different from those facilities with a single laser system. The samples that follow cannot cover all situations or procedures; they are only intended as models that should be used to accommodate specific requirements.

It is reasonable to expect that the manufacturer of the laser system shall supply safety information that can serve as the cornerstone for the generation of the SOPs. It is incumbent upon the operator to demand the information from the manufacturer. The availability of safety related information is facilitated by the FDA requirement that the manufacturer of laser products provide the user with adequate instructions for the safe operation and maintenance of all laser products.

SAMPLE 1: Controlled Access to the Laser Room

Purpose: To define the area in which control measures shall be applied and to describe the control measures necessary in order to maintain a safe environment for use of the laser system.

Policy: Class 3b and Class 4 lasers shall be operated in areas where traffic flow and compliance with all safety procedures can be monitored.

Procedure:

1) Appropriate warning signs shall be posted at eye level on all doors that access a room where a laser is to be operated. These signs shall state all required information and shall be removed when the laser is not in use.

2) Safety goggles labeled with the appropriate wavelength and optical density shall be available at the entry where each door sign is posted.

3) Glass windows shall be covered with shades or filters of appropriate optical density whenever a fiberoptic laser system is operational.

4) All safety procedures shall be followed during service, maintenance and demonstrations.

5) No one shall be allowed into a laser room unless properly authorized and protected.

6) The laser shall not be activated when it is necessary to open the door, if the controlled area extends to the doorway.

7) Laser keys shall be kept in a secured area and signed out only by those authorized to do so.

SAMPLE 2: Ocular Safety

Purpose: To prevent ocular injuries to personnel working with Class 3b and Class 4 lasers.

Policy: Within the controlled area, all personnel shall adhere to appropriate eye protection procedures during all laser applications.

NOTE: Under some conditions, the controlled area may include the entire room in which the laser procedure is performed. Under those conditions, the ocular safety procedures listed in this Sample 2 apply to the entire room. In health care facilities, ocular safety procedures shall also apply to the patient receiving laser treatment.

All personnel involved in maintenance and demonstrations of laser systems shall follow all ocular safety procedures whenever a laser is in operation in the facility.

Procedure:

1) Appropriate eyewear shall be worn by everyone in the controlled area while the laser is in operation. Appropriate eyewear consists of glasses or goggles of sufficient optical density to prevent ocular damage at the laser wavelength in use. Exception to this is the operator looking through an attached microscope with a lens that has the appropriate optical density for the laser in use.

2) Prior to use, the operator and ancillary personnel shall be responsible for selecting and examining eyewear for comfort, proper fit, and presence of labels describing both wavelength and proper optical density.

3) If eyewear is damaged, it shall not be worn and a report shall be made to the laser safety officer.

4) Contact lenses are not acceptable as protective eyewear. Prescription lens wearers shall use appropriate laser safety eyewear.

5) All goggles shall have side shields to protect from peripheral injury and impact.

6) Any articulated arm that is not shuttered shall be capped when not connected to the hand piece or the operating microscope.

7) The laser system shall be placed in standby mode when delivery optics are moved away from the target.

8) In health care facilities, patients shall be fitted with appropriately labeled eyewear, or have their eyes covered with wet cloth pads or towels. Metal or dry materials shall be placed on the patient's face or eyes only when indicated.

SAMPLE 3: Handling of Laser Fiber Delivery Systems in Health Care Facilities

Purpose: To promote safe and proper handling of laser fiber delivery systems and to limit the potential for fiber breakage, damage and reduced efficiency during clinical laser procedures.

Policy: Personnel handling laser fibers shall assure compliance with all safety procedures and shall consider the fiber an extension of the laser system, governed by applicable standards and regulations.

Procedure:

1) Appropriate eye safety filters shall be used with endo/microscopes.

2) Laser room windows shall be covered completely with appropriate filters, if necessary.

3) Fibers and associated equipment shall be positioned to allow for safe traffic patterns in the room.

4) The fiber shall be examined for breaks or damage of the distal tip, the proximal connector and the catheter sheath. Fiber shall be calibrated in accordance with manufacturer's directions. If deficiencies or damage are noted, another fiber shall be obtained.

5) Do not use clamps or other instruments to secure fiber in the operative site.

6) Always use coaxial cooling that is appropriate to the procedure. Never use gas to purge a fiber in the intrauterine cavity.

7) Never operate the laser unless the aiming beam (if used) and the tip of the fiber beyond the end of the endoscope are both visible.

8) Monitor the fiber for distortion of the beam, decreased power transmission and accumulation of debris on the tip.

9) Never reuse a disposable fiber without manufacturer's directions.

10) Always put the laser in standby when not aimed at a target.

SAMPLE 4: Non-Beam Hazards in Health Care Facilities

Purpose: To recognize and effectively deal with a variety of potential non-beam hazards that may be present during laser procedures.

Policy: Non-beam hazards are the purview of safety and industrial hygiene personnel, who will affect the appropriate hazard evaluation and control.

Procedure:

I. Fire

1) Never use alcohol in the operative field. Fibers may be rinsed in hydrogen peroxide or saline intraoperatively.

2) Never place a hot fiber directly on paper drapes. Wait until tip is cool before contact is made with flammable material.

3) Use fire-retardant drapes, damp packs or pads. Fill pelvic cavity with Ringer's, saline or other appropriate solution during surgery.

4) Put laser system in standby mode when procedure is interrupted or terminated.

5) Avoid high levels of oxygen in the operative field.

6) Avoid laser beam exposure of the sheaths of flexible fiber endoscopes, since many of the sheaths are flammable.

II. Plume Management

1) Remove laser generated airborne contaminants from the laser target area to reduce the transmission of potentially hazardous particles.

2) Position smoke evacuator in the operating room whenever a plume is anticipated.

3) Check operation of the plume management system prior to the beginning of a procedure.

4) Check the plume filter monitor and, if needed, install a clean filter.

5) In-line filters with minimum 0.3 micrometers filtration shall be placed between wall suction and the fluid canister for:

    a) Suction line not connected to evacuator

    b) Procedures producing minimal plume

    c) Failure of evacuator before or during operation

6) Distal collection port shall be no more than 2 cm from impact site when practical.

7) All tubing, connectors, adaptors and wands will be changed between patients and disposed of according to biohazard procedures.

III. Electrical Shock

1) During service or maintenance, precautions shall be taken against electrical shock that may be fatal.

2) Medical lasers shall be installed and operated in conformity with the National Electrical Code.

SAMPLE 5: Work Practices for Optical Fiber Communications Systems (OFCS)

Purpose: To recognize and effectively deal with a variety of potential hazards that may be present when working on an OFCS.

Policy: Engineering controls shall not take the place of good work practices. Good work practices are essential to operating, servicing and maintaining OFCS, especially with higher power systems that utilize Class 3b and Class 4 lasers.

Procedure: The following presents some basic guidelines when working on any OFCS.

1) Trained Personnel. Only authorized, trained personnel shall be permitted to install or perform service on OFCS containing Class 3b or Class 4 lasers.

2) Unterminated Fibers

    a) Do not view the end of a fiber with unprotected eye. Fiber should only be viewed with an indirect image converter or with a filtered optical instrument or optical density (OD) sufficient to reduce the exposure to levels below the appropriate MPE.

b) Always cover the ends of unterminated fibers with a splice protector, tape or end caps.

3) Splicing. Splicing on ribbon cables, fixed array cables or OFCS containing Class 3b or Class 4 lasers shall be de-energized or viewing systems incorporating personal protection shall be employed.
4) Installation and Testing. The laser source shall be first to be disconnected and last to be connected when installing and/or testing an OFCS.

5) Modifications. No modifications shall be made to the OFCS or associated equipment without management or supervision authorizations. Such modifications may alter the service group classification of the OFCS.

6) Labels. Any damaged or missing optical safety labels shall be reported immediately to the supervisor.

7) Other Hazards

a) Use of protective guards or shields shall be used during splicing and cleaving operation to prevent direct injury from small lengths or particles of fiber. Proper disposal of fiber pieces avoids subsequent embedding in clothing or skin.

b) Optical photocuring may present a UV or light source hazard. Protective filter lenses of the appropriate optical density shall be worn if viewing of the light source is probable.

Appendix D: Glossary

Accessible Emission Level (AEL)
The magnitude of laser radiation to which human access is possible. Usually measured in watts for continuous wave lasers and in joules for pulsed lasers.

Accessible Emission Limit
The maximum accessible emission level permitted within a particular class.

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

Aversion Response
Movement of the eyelid or the head to avoid exposure to a bright light. For laser light, this response is assumed to occur within 0.25 second.

Continuous Wave (CW) Laser
A laser that has a continuous output for greater than or equal to 0.25 second.

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

Diffuse Reflection
A reflection where different parts of the beam are reflected over a wide range of angles, such as when hitting a matted surface.

Divergence (φ)
Divergence is the plane angle projection of the cone that includes 1-1/e (i.e., 63.2%) of the total radiant energy or power. The value of divergence is expressed in radians or milliradians.

Embedded Laser
A laser with an assigned class number higher than the classification of the laser system in which it is incorporated, where the system's lower classification is appropriate because of the engineering features limiting accessible emission.

Enclosed Laser System
Any laser or laser system located within an enclosure that does not permit hazardous optical radiation emission from the enclosure.

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

Fiber Optics
A system of flexible quartz or glass fibers with internal reflective surfaces that pass light through thousands of glancing (total internal) reflections.

Fluorescence
The emission of light of a particular wavelength resulting from absorption of energy, typically from light of shorter wavelengths.

Infrared Radiation (IR)
Invisible electromagnetic radiation with wavelengths that lie within the range of 0.70 to 1000 micrometers.

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

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

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

Maximum Permissible Exposure (MPE)
The level of laser radiation to which a person may be exposed without hazardous effect of adverse biological changes in the eye or skin. The criteria for MPE for the eye and skin can be found in ANSI Z136.1 – 2000.

Nominal Hazard Zone (NHZ)
The space within which the level of 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.

Optical Density (OD)
A logarithmic expression for the attenuation produced by an attenuating medium, such as an eye protection filter. $OD=\log10 (I_i/I_t)$ where I_i is the incident irradiance and I_t is the transmitted irradiance.

Protective Housing
A device designed to prevent access to radiant power or energy.

Pulsed Laser
A laser that delivers its energy in the form of a single pulse or a train of pulses, with a pulse duration of less than 0.25 s.

Scanning Laser
A laser having a time-varying direction, origin, or pattern of propagation with respect to a stationary frame of reference.

Specular Reflection
A mirror-like reflection. The exact definition of a specular surface is one in which the surface roughness is smaller than the wavelengths of the incident light.

Tunable Laser
A laser system that can be "tuned" to emit laser light over a continuous range of wavelengths or frequencies.

Ultraviolet (UV) Radiation
Electromagnetic radiation with wavelengths between soft X-rays and visible violet light, often broken down into UV-A (315-400 nm), UV-B (280-315 nm), and UV-C (100-280 nm).

Visible Radiation (light)
Electromagnetic radiation that can be detected by the human eye. It is commonly used to describe wavelengths that lie in the range between 400 nm and 700 nm.

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

Appendix E: References

American National Standards Institute for Safe Use of Lasers, ANSI Z136.1 -- 2000.

Code of Federal Regulations, Title 21, Part 1040, Performance Standards for Light-emitting Products.

Illinois Administrative Code, Title 32 Energy, Part 315 Standards for Protection Against Laser Radiation

Laser Institute of America, Orlando, Florida, www.laserinstitute.org

Rockwell Laser Industries, Inc., Cincinnati, Ohio, www.rli.com

University of Illinois at Urbana-Champaign, Division of Research Safety, http://www.drs.illinois.edu/rss/lasers/index.aspx?tbID=lsr